The neural correlates of personal semantics

Annick Tanguay

A thesis submitted in partial fulfillment of the requirements for the Doctorate in Philosophy degree in Experimental psychology

School of Psychology
Faculty of Social Sciences
University of Ottawa

Acknowledgements

Most sincere thanks to **Dr. Patrick S. R. Davidson**, who has advised and mentored for 7 years (B.A. included). I loved our discussions where we left no stones unturned. I always felt encouraged and supported to follow the best scientific practices, no matter the cost. I am thankful that I could follow my passion and at times, test some crazy ideas. After 7 years, I don't think that I got to the bottom of the fount of wisdom. Thank you for this and so much more.

I was lucky to have several great mentors. **Dr. Louis Renoult** was my host supervisor at the University of East Anglia, and mentor. The "personal semantics" theme of this thesis originates from Louis' ideas or our discussions. I appreciate the mental discipline and creativity, and hands-on approach to teaching me good research practices and a lot of what I know about EEG.

I thank **Dr. Daniela J. Palombo** for teaching me so much about fMRI from data collection to data analyses, and more. "With great power, comes great responsibility" (from biblical inspiration) often came to mind when I was conducting fMRI research. Daniela has done so much to encourage cutting-edge and impactful research. Daniela – like Patrick and Louis – inspires excellence, is incredibly generous, and it is a joy to collaborate with her.

I thank **Dr. Kenneth Campbell** and **Dr. Vanessa Taler** for their kind support and good advice throughout the years.

I thank **Dr. Simon G. Beaudry**, a true expert of motivation, who helped me to be enthusiastic from day 1 (in 2012) to day 2200 (or so, in 2018). INSPIRE has been part of my training as a researcher and incredibly fun. The INSPIRE team –including, Maxime Dorville, Misha Voloaca, Leanne Kane, Stéphanie Jolin- helped me to complete this thesis through their kindness and generosity.

Thanks to **Dr. Isabel Lindner** for the stimulating conversations, for the gentleness, and for the beauty that imbues everything she does.

Several contributed to research in this PhD thesis or to related studies in one way or another (in no particular order): **Dr. Cristina Atance, Myriam Beaudry, Dr. Paniz Tavakoli, Sheida Rabipour, Dr. Ioanna Markostamou, Rachel Lambert, Galit Karpov, Lauren Benton, Lorenza Romio, Dr. Carolin Sievers, Kylee Ack Baraly, Abdo Elnakouri, Alix Hill, Kerri D. Adams, Anndee Hoover, Eléa Knobloch, Imaan Handulle, Marie Huc, Talia Chin, Petar Vidjen, Sara Trincao-Batra, Laurence Boutin. Dr. Andra Smith, Dr. Stuart Fogel, Dr. Joshua Rutt, the team at the Brain Imaging Centre of the Royal Ottawa.**

After all these thanks (that don't quite make justice to the contribution of anyone), I transition to thanking my family and friends. Last but not least.

Il devrait y avoir plus d'un nom sur le diplôme et beaucoup de personnes qui le reçoivent avec moi. En ordre d'ancienneté : (papa) Raynald Tanguay, (maman) Francine Touchette, Jérôme Lévesque, Karine Tanguay, Julie Tanguay, Gabrielle, Thomas, Alexis. Qu'avez-vous fait? Sans nommer de noms : Réparer un ordinateur pour les analyses IRMf; me reconduire pour mon examen de synthèse; me donner des ordinateurs; rescaper mes fichiers; lire et réviser un nombre incalculable de textes; aider avec une démonstration EEG ou participer à du pilotage/testing;

aider avec des remue-méninges pour des idées de recherche ou l'interprétation des données; démontrer une grande patience et un absence de jugement face à mes absences; m'offrir des cafés délicieux sur demande; m'encourager à travailler quand la motivation n'était pas au rendez-vous; venir m'apporter du bonheur pendant des moments de solitude à l'étranger ou à Gatineau, me concocter des kits de survie pour la dernière phase de la thèse, me dire être fiers de moi (etc.). Vous avez tant fait. Azure (un chat) serait co-auteure s'il s'agissait de « regarder » la thèse. J'ai vu une image (de PhD comics) qui comparait terminer sa thèse à l'arrivée au sommet d'une montagne. Selon ce dessin humoristique, à ce moment-là, soit le point de vue change ou soit on manque d'oxygène. C'est grâce à vous que j'ai eu assez d'oxygène, des bons souliers, la nourriture, et bien plus.

Thank you, **Angeline Tsui.** I could turn to you for advice, encouragements, consolation, celebrations, and at times input on texts. You are an inspiration and a great friend.

A million thanks.

Abstract

The long-term memory system for what is conscious and can be verbalized – declarative memory- is often separated into memory for general facts and memory for personal events (Squire, 2009; Tulving, 2002). Personal semantics share elements of both semantic memory (i.e., they are facts that can be known) and episodic memory (i.e., they are self-related and idiosyncratic; Renoult, Davidson, Palombo, Moscovitch, & Levine, 2012). According to the taxonomy of personal semantics (Renoult et al., 2012), they vary in proximity to either semantic or episodic memory. Towards one end of the continuum, memory for autobiographical facts such as jobs and names of friends were hypothesized to be closer to general facts. Towards the other end of the continuum, repeated events are summaries of the core elements of similar events that happened more than once (e.g., getting coffee at a coffee shop), and they were hypothesized to be closer to episodic memory (i.e., the recollection of a unique event). Self-knowledge involves self-reflection about one's own personality traits and preferences; it was thought to be the most distinct from semantic and episodic memory. However, little research had compared personal semantics to both semantic and episodic memory, or to one another, and these proposals needed to be tested experimentally.

In this thesis, I compared the neural correlates of three types of personal semantics to semantic memory (study 1, 2, 3) and episodic memory (study 1, 2), and to one another (study 1) using functional magnetic resonance imaging (fMRI; study 1) and event related potentials (ERPs; study 2, 3). Moreover, I examined whether temporal orientation modified the personal semantics' relationship to the typically atemporal semantic memory (study 2, 3) and to the typically past-oriented episodic memory (study 2).

In study 1, general facts, autobiographical facts, repeated events, and unique events were compared using fMRI, in a follow-up to an ERP study (Renoult et al., 2016). In our analyses of

the hippocampus (HPC) and posterior medial network (Ritchey, Libby, & Ranganath, 2015), general semantics and autobiographical facts were often not significantly different from one another (except for the left posterior HPC), and repeated events and unique events did not differ from one another in any comparison. I observed a small graded increase of brain activity from general facts to autobiographical facts to repeated events and unique events (with a significant linear trend) in the left posterior HPC. In contrast, no memory type differed in the anterior temporal network (Ritchey et al., 2015).

In study 2 and 3, self-knowledge was operationalized as the knowledge of one's own traits, and could concern past (study 2), present (study 2, 3) and future selves (study 2, 3). A neural correlate of recollection, the Late Positive Component (LPC), had a larger mean amplitude for thinking about the self than others (study 2, 3), and thinking about a past and/or future self than the present self (on average for study 2, and significant for study 3). The amplitude of the LPC for thinking about the past and future selves did not differ from an episodic recognition memory task (or present self-knowledge; study 2). Further, the temporal orientation effect was smaller and not significant when we compared thinking about the present and the future traits of others (study 3). The operationalization of the "other" as a close friend or a group of people did not modify this result (study 3).

Together, in addition to Renoult et al. (2016), these findings suggest that: the neural correlates of autobiographical facts, repeated events, and self-knowledge do not overlap perfectly with semantic or episodic memory. Moreover, the temporal orientation of the knowledge is one factor that can influence the proximity of the neural correlates of personal semantics to either semantic or episodic memory.

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CHAPTER I. INTRODUCTION

If I asked you "who are you?" anything you would answer would come from declarative memory; that is, from a memory system for facts and events that can be consciously retrieved, hence communicated (L. R. Squire, 2009). In an effort for brevity, you could describe a sort of "skeletal CV" (Renoult et al., 2016; Warrington & McCarthy, 1988): e.g., my name is George, I have one daughter, I live in Sydney, I am a Professor, and I am a vegetarian. In the language of the taxonomy of personal semantics, these are autobiographical facts (Renoult et al., 2012). To retrieve these facts, you would not need to re-experience personal events. In other words, you do not need to *recollect* the day you moved to Sydney to *know* that you currently live in Sydney. You could also convey who you are through your perceptions on your personality traits and your preferences: e.g., I am curious, I like simplicity. In that case, you would recruit self-knowledge (Renoult et al., 2012). Time permitting, you might also describe some life events in forms of summaries: every Thursday evening, I play hockey with friends. Those are named "repeated events" (Renoult et al., 2012). Autobiographical facts, self-knowledge, and repeated events are collectively called personal semantics, and they share an intermediate status. That is, they resemble facts like semantic memory, which concerns knowledge that is culturally shared (e.g., I know that a city is a large agglomeration of houses and people). However, they are also personal and idiosyncratic like episodic memory, which refers to the re-experiencing (and sometimes pre-experiencing) of an event and its spatial and temporal details (e.g., I can re-live the moment I received an award; Tulving, 2002). To this day, personal semantics have been rarely compared to both semantic and episodic memory, and to one another.

In this thesis, I compare the neural correlates of some types of personal semantics to semantic and episodic memory, and to one another. Although this is a fundamental research program, the interest in such distinctions in declarative memory stems from clinical observations

(Grilli, Bercel, Wank, & Rapcsak, 2018; Grilli & Verfaellie, 2014, 2015, 2016; Renoult et al., 2012). People with a semantic memory or episodic memory impairment can have intact personal semantics (e.g., Klein & Lax, 2010). In the first part of this literature review, I provide an overview of some models that contrasted semantic and episodic aspects of declarative memory. After this background, I describe the taxonomy of personal semantics, as well as the methods to investigate personal semantics and the main findings they produced recently.

1.1 Models of declarative memory

1.1.2 Endel Tulving (1972, 1984, 1999)

Tulving evolved within a scientific community that considered memory to be a unitary construct (1999, 2002). However, his neuropsychological, neuroimaging, and experimental findings suggested that two long-term memory systems co-existed (Tulving, 1999). In particular, the memory function of people with amnesia (like HM and KC) was best characterized as an impaired ability to recollect past events from their personal past, but preserved knowledge about the world (Tulving, 2002). Additionally, neuroimaging studies suggested that personal events and general facts were associated with differences in brain activity, for example in the lateralization of brain activity (Tulving, 2002). The two long-term memory systems were named semantic and episodic memory (Tulving, 2002). Tulving (2002) defined episodic memory as the ability to travel in time mentally in order to re-experience past events. Episodic memory requires autonoetic awareness, that is, an awareness of the self through time (Tulving, 2002). In contrast, semantic memory refers to knowledge about the world and vocabulary that is culturally shared. Semantic memory requires noetic awareness (i.e., facts are *known*). Noetic awareness does not require an awareness of self or a sense of time (Tulving, 2001). More recently, know (or familiar) responses were described as automatic and rapid, whereas recollection was depicted as more demanding (Rugg & Curran, 2007). Only recollection requires the retrieval of context (Rugg & Curran, 2007). Episodic memory is described as interacting with or requiring semantic memory, but involving more processes (e.g., autonoetic awareness, retrieval of context; Tulving, 1999, 2002).

1.1.2 Larry R. Squire (2004)

The memory system can be divided into declarative and non-declarative memory. The first, declarative memory, pertains to consciously recalled facts and events, and can be dissociated into semantic and episodic memory (as defined above). Squire's diagram shows semantic and episodic memory as linked owing to their common activation in the medial temporal lobe (MTL); thus, Squire moderately supports their distinction (if at all). The non-declarative portion of memory includes various forms of memory that demonstrate learning in the absence of a conscious retrieval, e.g., procedural memory, priming, simple classical conditioning, etc. These divisions are often shown as a tree that conveys the discreteness of the memory types (e.g., memory is declarative *or* non-declarative, etc.). These memory types "(…) operate independently and in parallel (…)" (Larry R. Squire, 2004). The model draws from neuropsychological and neuroimaging data that suggest each of these memory types are associated with distinct neural correlates. For example, an "emotional response" is associated with the amygdala, whereas declarative memory is linked to the medial temporal lobe. Hence, the justification for proposing distinct memory systems– somewhat like Tulving – relies primarily on lesion studies and neuroimaging data.

1.1.3 Morris Moscovitch (Cabeza & Moscovitch, 2013; Moscovitch, 1992)

As neuroimaging data accumulated, it became apparent that data deviate from a discrete approach to memory systems, because of the notable variability within and between tasks. The hippocampus – traditionally associated with episodic memory- is engaged in a variety of tasks, including non-episodic memory (Maguire & Mummery, 1999) and generalization (Zeithamova, Dominick, & Preston, 2012). The component process view proposes that we develop "theories" about the process(es) associated with a brain region. For example, we could formulate the theory that the hippocampus is responsible for relational processing (as described in Cabeza & Moscovitch, 2013). The "theory" can inform predictions about the brain regions that should be involved in a memory task (or any task). There are several possible component processes, and this perspective does not constrain their number. Brain regions can form a temporary "process-specific alliance" (PSA) to execute a process. In the personal semantics taxonomy, some examples of component processes that could dissociate memory types are: visual imagery, perspective taking, emotional valence, spatial and temporal details, and self-reflection (Renoult et al., 2012). The differences in the recruitment of component processes predict brain activity. Despite a careful experimental design, the various memory types may not match in all ways, for example in effort and valence, thus, imposing limits in their direct comparison. From the perspective of component processes, such differences may not be problematic as long as they are reflective of the memory type.

1.1.4. Lawrence W. Barsalou (1988)

Computational models of memory and data from behavioural experiments inspired and shaped this theory of autobiographical memory. Autobiographical memory is hierarchical, meaning that the higher levels of the hierarchy encompass and facilitate access to the lower levels. Unique events (e.g., I celebrated my wedding anniversary at Los Flores this year) are nested under repeated events (e.g., my wedding anniversaries), which in turn are organized within an extended period of time (e.g., after the kids left home). When events happen more than once, they become associated with the prior similar event(s) that contain similar concepts. The repeated events form summaries, and it is their commonalities that are recalled. Barsalou (1988) found that repeated events accounted for the largest proportion of a narration, even when the instructions emphasized the recall of unique events. According to the theory, repeated events can be more easily accessed than unique events. Higher up in the hierarchy, the extended events last longer than a day, and although pertaining to unifying theme, they are not continuous in time like a unique event would be. The concept of extended events is similar (if not identical) to lifetime periods or life chapters (Thomsen, 2015). In the hierarchy, extended events are organized chronologically, such that people would typically narrate that they moved out of home, started their degree, and continued with a Master, etc. in that order. Further, the theory postulates that there can be multiple extended events occurring at once, like completing a Ph.D. and taking care of one's family. Personal goals link events within the hierarchy. For instance, "repainting the wall" could become associated with the wedding anniversary if it was a gift for the significant other. Barsalou (1988, p. 204) also referred to a continuum from semantic to episodic memory, with cultural scripts closer to semantic memory, and repeated events closer to episodic memory.

1.1.5 Martin Conway (2009)

Conway's influential model of autobiographical is also hierarchical, and compatible with Barsalou overall, but more exhaustive. In this case, the "conceptual self" is at the top of the hierarchy, and encompasses self-images (including beliefs and attitudes). Apart from this addition, the hierarchy resonates with the model of Barsalou. From top to bottom, we find: self-images, lifetime periods, general events (not necessarily repeated), episodic events and their details. Personal goals modulate memory encoding and retrieval at all levels of the hierarchy. Frames constitute another important addition. These are usually associated with the episodic details, and provide the semantic structure or context for the event. A frame without the episodic details can be observed in overgeneral autobiographical memory, as can be seen in aging or psychiatric disorders (e.g., I know that I went to casino years ago, but I am unable to provide details on the event; Wilson & Gregory, 2018). Conversely, episodic details without a frame could intrude in irrelevant contexts (e.g., in PTSD; Brewin, 2014). The model does not correspond necessarily to a continuum perspective from semantic to episodic memory because visual imagery can be evoked at the highest level (self image), which is typically associated with processing events, but the lower lifetime period is described as semantic. Conway's model draws from a vast literature including his own research, Barsalou's research, neuropsychological research, etc. (Conway, & Pleydell-Pearce, 2000).

1.2. Personal semantics

1.2.1 Overview of the taxonomy of personal semantics (Renoult et al., 2012)

In neuroimaging research of autobiographical memory, the vivid recollection of a specific event (i.e., episodic memory) is commonly contrasted to a general semantic task [or a control task, or the now disfavoured resting state (because it is not a null state and rather engages the same core network); Buckner, Andrews-Hanna, & Schacter, 2008; Svoboda, McKinnon, & Levine, 2006)]. Intermediate memory types (like self-concepts/self-knowledge, general events/repeated events) are named personal semantics or sometimes, semantic autobiographical memory. Most often, they have been studied in isolation of semantic and episodic memory, or in relation to only one of those, and in the abstraction of a model of declarative memory (at least at the time of the taxonomy). Some people with amnesia were reported to have intact knowledge of personal facts (Cermak & O'Connor, 1983; Tulving, Schacter, McLachlan, & Moscovitch, 1988; Warrington & McCarthy, 1988), but such findings were usually discussed in a tangential manner. As a further complication, the operationalization of the memory types have been mixed at times, and different terms were used to describe the same construct at other times. For example, for Klein & Lax (2010, p . 1) self-knowledge is "semantic summary information about one's personal dispositions (i.e., one's trait characteristics)", similar to this taxonomy's definition. For D'Argembeau (2015), self-knowledge includes any representations of the self, even of the "self" re/pre-experiencing events (i.e., episodic memory). Martinelli, Sperduti, & Piolino (2013) performed a meta-analysis of PET/fMRI studies on self-concepts (e.g., like Klein's self-knowledge) and semantic autobiographical memory. This last category included repeated and extended events, autobiographical facts, and self-relevant stimuli. This state of affairs possibly dissimulates similarities and differences between memory types, and renders comparisons across studies (and models) difficult. Therefore, a merit of the taxonomy of personal semantics, in my opinion, is to provide clear definitions about four types of personal semantics: self-knowledge, autobiographical facts, repeated events, and autobiographically significant concepts (see Figure 1, p 34 and p 111). These memory types were identified on the basis of neuropsychological and neuroimaging studies that presented a relatively distinct profile for each. The taxonomy does not argue for creating new or additional memory systems *per se*, even if the memory types can be used to better characterize patterns of memory impairments and preservation (e.g., Strikwerda-Brown, Mothakunnel, Hodges, Piguet, & Irish, 2018). Instead, it offers a terminology to investigate interrelationships between semantic and episodic memory. Additionally, Renoult et al. (2012) specified hypotheses about the relationship of the memory types to one another (relative to semantic and episodic memory). Renoult et al. (2012) proposed several perspectives to summarize the relationships of memory types within declarative memory: 1) personal semantics could be a subcategory of semantic memory (a bit like objects and people), 2) they could be organized from the experience near to the experience far, and 3) the component process view (described above). A goal of my thesis was to test some of the hypotheses described in Renoult et al. (2012).

In principle, it is difficult (if not impossible) to compare four personal semantics at once to semantic and episodic memory within a single neuroimaging study. That is the case partly because the experiment would prohibitively long, partly because we must match the stimuli both in cognitive demand and content. In this thesis, I focused on three types of personal semantics: repeated events, autobiographical facts, and self-knowledge. In what follows, I review some of the tasks to investigate these types of personal semantics and their findings, with an emphasis on recent studies. Many of these studies are discussed in the articles of this thesis. Hence, I synthesized the literature with an emphasis on the different methods to facilitate the critical assessment of the contributions of my studies. Moreover, the synthesis could prove useful in the evaluation of future directions (both for myself, and for other personal semantics researchers).

1.2.2 Sentence verification.

In a set of studies, (Maguire, 2003; Maguire & Mummery, 1999; Maguire, Vargha-Khadem, & Mishkin, 2001) crossed self-relevance (relevant, irrelevant) and temporal specificity (specific, general). This produced four conditions: personal event (self-relevant, specific temporally), autobiographical fact (self-relevant, non-specific temporally), public event (self-irrelevant, specific temporally, and general fact (self-irrelevant, non-specific temporally). The authors personalized the stimuli based on a questionnaire and an interview completed weeks prior to the neuroimaging session. During the recording of brain activity, participants listened the statements, and verified whether they were true. The PET data showed that all memory types activated the MTL (parahippocampal gyrus, hippocampus), the mPFC, temporal pole, posterior cingulate cortex (PCC), and the temporoparietal junction. (MRI data was consistent; Maguire & Mummery, 1999; Maguire et al., 2001.) Increased self-relevance and specificity (together) modulated the left hippocampus, medial frontal cortex, and temporal pole by increasing their activity (Maguire & Mummery, 1999).

Nearly a decade later, Foster, Dastjerdi, and Parvizi (2012) also adopted a sentence verification task to contrast the activity of unique events, autobiographical facts, self-knowledge, rest, and mathematical problems within the posterior medial cortex (that includes the PCC and retrosplenial cortex, among others). Examples of stimuli (with a reformulation of the experimental condition's name) are: "I wore white socks yesterday" (unique events); "I usually wear white socks" (autobiographical facts), and "I am a patient person" (self-knowledge; Foster et al., 2012). Like in Maguire's studies, the task involved indicating whether the statements were true. Whereas the stimuli were well matched for unique events and autobiographical facts, the other conditions (e.g., self-knowledge, rest, mathematical problems) differed in many ways (e.g., valence). The intracranial electrodes indicated that the activity of the posterior medial cortex gradually decreased from unique events to autobiographical facts to self-knowledge (and rest and mathematical problems).

We adapted Foster et al. (2012) for electroencephalography (EEG) to compare unique events, repeated events, autobiographical facts, and general facts (Renoult et al., 2016). In our ERP study (Renoult et al., 2016), participants verified 67 sentences in each of these four memory conditions that covered broad topics relevant to everyone (e.g., food, clothes, activities). An advantage of the task is to circumvent the need for a pre-experimental questionnaire or an interview prior to the neuroimaging session. We first presented one of the cues that specified the way in which the sentence should be processed (e.g., general facts: some people, everyone; autobiographical facts: usually, often, rarely; repeated events: when at school, when on the bus; unique event: today, yesterday). Next, we showed the sentence (e.g., general facts: wear white socks; autobiographical facts: I wear white socks; repeated events: I have worn white socks; unique events: I wore white socks). The sentences varied in verb tense to agree with the temporal orientation and specificity of the memory condition (past for unique events, present perfect for repeated events, and present for general facts and autobiographical facts). Instructions at the beginning of each memory block further detailed how these sentences should be verified. For general facts, people decided whether the statements were true for most people in this country. For autobiographical facts, participants thought about what is usually true of themselves. For repeated events, participants thought about what happened to them repeatedly during the last year, and for unique events, about what happened to them (once) during the last week. Two event-related potentials (ERPS) were of particular interest: The N400 amplitude is sensitive to the processing of meaning (Kutas & Federmeier, 2011), and the amplitude of the Late Positive

Component responds to recollection (Rugg & Curran, 2007; Wilding & Ranganath, 2012, see Section 1.3 for more details on ERPs). We performed the ERP analysis time-locked to the onset of the last word of true statements. In brief, ERP analyses showed that the mean amplitude of the N400 was maximal for general semantics and minimal for unique events, and the opposite happened for the LPC amplitude. The N400 amplitude and the LPC amplitude of autobiographical facts and repeated events were intermediate between these two extremes (*nb*. before correction for multiple comparisons). Autobiographical facts and repeated events did not differ significantly from one another, although there were some other differences (e.g., in scalp distribution). In **study 1** of this thesis, I follow up on this EEG study using a similar design, but adapted for fMRI.

In another ERP study, Coronel & Federmeier (2016) developed statements about preferences that were coherent or incoherent with a participant's preferences, as verified with a pre-experimental task. Knowledge of personal preferences is part of self-knowledge. Coronel & Federmeier (2016) added a general semantics condition pertaining to people's preferences in general. Coronel & Federmeier (2016) found a larger N400 amplitude for inconsistent vs. consistent preferences both for self and others. The amplitude of the LPC was larger for personal preferences than other people's preferences (Coronel & Federmeier, 2016).

1.2.3 Me/not me, and personality questionnaires

Self-knowledge has been most often studied in relation to personality traits. The task, sometimes called "me/not me" (Markus, 1977), entails indicating whether a trait (e.g., kind, generous, impatient) reflect one's personality. In **study 2 of this thesis**, I designed a task with Drs. Louis Renoult and Patrick S. R. Davidson to compare self-knowledge to general semantics and episodic memory (Tanguay et al., 2018). Participants decided whether traits reflected their own personality 5 years ago, currently, and 5 years from now, for the self-knowledge conditions, and whether they reflected the personality of most people holding an occupation (e.g., funny, priest) for the general semantics condition. The study ended with an episodic recognition memory task to obtain a neural correlate representative of recollection. I adapted the design for a follow-up **in study 3**. Because these studies are part of the thesis, I will not describe them further. An alternative is to ask participants to rate the traits according to how well they correspond to them on a 4-point scale (Grilli et al., 2018; Marquine et al., 2016). This task is performed more than once, and corroboration from an acquaintance is obtained when possible, to get an indication of the reliability and accuracy of the judgments (Grilli et al., 2018; Marquine et al., 2016). This has shown that judgments about an acquaintance's personality can be accurate, whereas judgments about the self can be impaired after a lesion to the mPFC (Marquine et al., 2016). Moreover, a lesion to the left anterior temporal lobe impaired autobiographical facts, but not self-knowledge (Grilli et al., 2018).

1.2.4 Interviews.

Three interviews have been used to investigate personal semantics. The first is an adaptation of the "I am" task (Grilli & Verfaellie, 2015, 2016; Rathbone, Moulin, & Conway, 2009). The participants complete eight statements starting with "I am". Next, they select the top four that are most self-defining, and explain why they are self-defining for up to four minutes. Finally, participants describe six specific events that illustrate the "I am" statement. The coding scheme dissociates various episodic (unique, repeated, hypothetical) and semantic (autobiographical facts, thoughts/beliefs, traits/roles) types of memory (Grilli & Verfaellie, 2015). An update distinguished experience-far autobiographical facts (without spatial or temporal context; e.g., I have a rabbit) and experience-near autobiographical facts (e.g., I take the bus down the hill every morning; Grilli & Verfaellie, 2016). This last category was further divided into those associated with a lifetime period, repeated events, or unique events. Notably, the "I am" task showed that patients with a lesion to the MTL justified their "I am" statement mostly through personal semantics (like controls). However, the number of personal semantics was reduced compared to controls, especially when the "I am" referred to a trait (rather than a role). In addition, people with a MTL lesion used experience-far autobiographical facts similarly than controls, but resorted less to those that were experience-near. Patients with lesions extending to the anterior lateral temporal lobe showed an additional reduction of experience-far autobiographical facts. An MTL lesion produces amnesia, that is, an impairment of episodic memory. The studies demonstrate that the lesion could affect some types of personal semantics.

Another common way to assess personal semantics is the Autobiographical Memory Interview (AMI; Kopelman, Wilson, & Baddeley, 1989). The AMI includes questions about the names of people and places, and other autobiographical facts, from three life periods (Kopelman et al., 1989). This assessment was used, for example, to compare autobiographical facts and self-knowledge in Grilli et al. (2018), as described above.

Recently, the Autobiographical Interview (AI; Levine, Svoboda, Hay, Winocur, & Moscovitch, 2002) was adapted to code personal semantics (Strikwerda-Brown et al., 2018). The AI starts with inviting participants to describe a specific event in details from a few life periods. General probes are used to invite the recall of a specific event or further elaboration. After all events are narrated, a structured interview aims to elicit more details about the event through specific questions (e.g., about the weather, the location, sensations). The events are coded into elements that are either internal or external to the event. Internal details refer to perceptual, sensory, emotional, temporal details (etc.) of a unique/central event. Therefore, an event with a lot of internal details should convey an impression of re-living the experience [like Tulving's (2002) definition of episodic memory]. External details refer to details about other events, meta-narration, repetitions, semantic facts, etc. The semantic category reflects a mix of memory types, such as personal semantics.

Hodgetts et al. (2017) used the traditional coding scheme of the AI to show that the semantics details (which they labelled “semantic autobiographical memory”) related to diffusion tensor imaging (DTI) measures of the inferior longitudinal fasciculus (a tract that goes from occipitotemporal regions to the anterior temporal lobe). Unfortunately, the semantic category includes a mix of general semantics, self-knowledge, and autobiographical facts (but not repeated/extended events). In contrast, DTI measures of the fornix (projecting to and from the hippocampus) related to internal details (labelled “episodic autobiographical memory”).

Strikwerda-Brown et al. (2018) refined the coding scheme of external details to clarify what this score reflects. In particular, Strikwerda-Brown et al. (2018) added extended events (lasting over 24 hours, or repeated), personal semantics (personal roles, personal traits, personal facts, personal thoughts and beliefs, autobiographically significant facts in relation to other people). The coding scheme stipulates that facts that are only indirectly related to the self or not experienced personally (e.g., an event a friend described to us) are grouped with general semantics. Patients with Alzheimer’s disease (AD) and Semantic dementia (SD) included more extended events and general semantics in their description of an event compared to controls. The events of AD patients included also more personal semantics compared to controls.

1.2.5 Cues

Memory can also be elicited through cues, for example words (Addis, Cheng, P. Roberts, & Schacter, 2011; Addis, Moscovitch, Crawley, & McAndrews, 2004; Holland, Addis, & Kensinger, 2011), and songs (Ford, Addis, & Giovanello, 2011). Ratings can be obtained after each trial to categorize them or to include those ratings in the analyses (e.g., vividness, valence, details). A pre-experimental interview can be used to obtain the cues (e.g., Addis et al., 2004), but it is not a prerequisite (Ford et al., 2011). In her studies, Donna R. Addis, used cues to investigate general events (extended or repeated) and/or lifetime periods, as well as unique events. Compared to general events, unique events was associated with greater activity in the precuneus, lateral temporal lobe, posterior cingulate cortex (Addis et al., 2004; Ford et al., 2011; Holland et al., 2011) hippocampus, parahippocampus gyrus, (Addis et al., 2004; Ford et al., 2011) dorsolateral prefrontal cortex, and medial PFC or frontal pole (Ford et al., 2011; Holland et al., 2011). General events were only associated with greater activity than unique events in a later phase, during elaboration (Holland et al., 2011).

1.2.6 Prospective method (Cabeza & St Jacques, 2007a)

The prospective method entails recording events –memories- as they occur or soon after, either through the use of a journal or through the automatic capture of pictures**.** The method could modify the encoding of events, in principle, but it negates the need for a prior recall as part of an interview and reduces effects of rehearsal (Cabeza & St Jacques, 2007b; Levine et al., 2004). In the case of (Levine et al., 2004), five participants recorded the details of unique events shortly after they happened. Moreover, participants recounted repeated events (e.g., similar to routines). The authors obtained “other events” via the use of other participants’ stories. Lastly, readings from a book about Toronto constituted the general semantics condition**.** After a mean of 5 months, participants listened to recordings in an MRI scanner. Importantly, the activity of the anterior region of the mPFC gradually decreased from unique events to repeated events to general semantics (Levine et al., 2004).

In a recent study, the participants of Brown, Rissman, Chow, Uncapher, & Wagner (2018) wore a camera for a period of two to three weeks, one to two weeks before an fMRI session. Some of the personal pictures were mixed with other people's pictures to create a recognition memory task. To each picture, the 22 participants could select one of five options: "remember, familiar, know, unsure, not yours". In this study, a "know" response (signifying that the event is not recollected and is not familiar) to a personal picture was likened to personal semantics, whereas a "remember" response reflected episodic recollection. The mPFC, dorsal angular gyrus, and precuneus decreased in activity across the responses options: from remember to familiar to know to correction rejections. Overall, the activity associated with a know response engaged a similar network than remember and familiar responses, but was more constrained. In analyses of the long axis of the hippocampus, the activity linked to remember responses was greater than know responses for the hippocampus head and body, but not the tail (but note that the interaction between memory type and regions of the hippocampus was not significant).

1.2.7 Fluency

Sheldon and Moscovitch (2012) administered a fluency task with four categories, which they named: autobiographical, spatial, nonepisodic, and phonemic. Each of these categories had 15 variations, e.g., for autobiographical: "books you've read", "name of family members", "sports that you've played" (see Table 1; Sheldon & Moscovitch, 2012). Thus, the "autobiographical" category corresponds well to the operationalization of autobiographical facts overall. For each of these, participants had to generate covertly as many relevant instances as possible within 36 seconds during an fMRI session. Participants pressed a button for each instance they generated. Compared to baseline, the left hippocampus was significantly more active for the autobiographical and spatial categories (e.g., "things on a desk", also significant for the right hippocampus), but not the nonepisodic category (e.g., "famous people", except at liberal threshold) and the phonemic category (Sheldon & Moscovitch, 2012). Other brain regions showed differences, as well. In brief, autobiographical and spatial (together) had greater activity in the MTL, posterior parietal, media frontal, and temporal regions compared to nonepisodic and phonemic (together; Sheldon & Moscovitch, 2012).

1.2.8 Other

For the sake of completeness, I should note that novel methods of studying personal semantics have been published recently (such as Brown et al., 2018). In particular, in an ERP study, some researchers showed a picture of oneself and another person superimposed on a congruent (neutral) and incongruent (negative) situation (Schöne, Köster, & Gruber, 2018). The judgments about the self were considered to rely on personal semantics. In the discussion of this thesis, I assess briefly the contribution of these designs to the field of personal semantics.

1.3 Using ERPs to investigate declarative memory

1.3.1 N400

Kutas & Hillyard (1980) discovered the ERP component named "N400" using sentences that ended with a congruent word, or an unexpected word, or an incongruent word. For example, “I watched a movie on a television” ends with a congruent word, and “I watched a movie on a sock” ends with an incongruent word. Kutas & Hillyard (1980), and many others since (reviewed in Kutas & Federmeier, 2011), found that incongruent words elicited a negative deflection that peaked between 250–500 ms (around 400 ms); this deflection had a larger amplitude for incongruent than congruent words. The N400 is maximal over centro-parietal sites (Renoult, 2016). Although the N400 effect was initially found when manipulating the congruency of words, it has since been found to respond to several manipulations of meaning, and various tasks and stimuli (Kutas & Federmeier, 2011; Renoult, 2016). In addition, each word of a sentence produces a N400 amplitude, and single words can be used as stimuli (Van Petten & Kutas, 1990; Renoult, 2016). Words that violate world knowledge also produce a larger N400 amplitude (e.g., the Canadian flag is red and *green*; Hagoort, Hald, Bastiaansen, & Petersson, 2004). As a recent relevant study (for study 2 & 3), Kiang et al. (2017) used a design reminiscent of priming. The prime was “I am” and a trait was shown on a separate screen (Kiang et al., 2017). Negative traits elicited a smaller N400 amplitude for people with Major Depressive Disorder (MDD) compared to healthy controls (Kiang et al., 2017). Kiang et al. (2017) interpreted their finding as negative traits being more consistent with the self-concept of people with MDD compared to healthy controls. Zhou et al. (2010) used a similar design evoking priming. Like study 2 and 3, Kotlewska and Nowicka (2016), Luo, Huang, Chen, Jackson, and Wei (2010), and Nowicka, Wójcik, Kotlewska, Bola, and Nowicka (2018) showed a single word (i.e., a trait) on the screen. Additional relevant studies are described in study 2 and 3 of this thesis (e.g., Coronel & Federmeier, 2016; Renoult et al., 2015).

1.3.2 LPC

Coincidentally, the origin of the LPC can also be traced back to 1980 in a publication of Sanquist, Rohrbaugh, Syndulko, and Lindsley. This ERP component is equally labelled the left parietal old-new effect in part because of its posterior parietal scalp distribution, and in part because it is observed in old/new contrasts (described below; Rugg, & Curran, 2007; Wilding, & Ranganath, 2012). In addition to its scalp distribution, the LPC is recognizable as a positive deflection that peaks between 500 and 800 ms (Rugg, & Curran, 2007; Wilding, & Ranganath, 2012). In a typical task, researchers present stimuli (e.g., words, pictures) during the encoding phase, and subsequently ask participants to recognize whether the item was presented previously or to identify contextual details associated with the item (Rugg, & Curran, 2007; Wilding, & Ranganath, 2012). Moreover, the participants could be asked to qualify subjective aspects of the recognition. The LPC is widely regarded as correlate of *recollection* specifically, which signifies that participants are thought to retrieve both item and context (Rugg, & Curran, 2007). A number of characteristics support this assertion. The LPC amplitude is larger for correctly recognized words compared to misses, false alarms, and correct rejections (Rugg, & Curran, 2007; Wilding, & Ranganath, 2012). The amplitude of the LPC is sensitive to the number of (accurate) contextual details retrieved (Vilberg, & Rugg, 2009; Wilding, 2000). Depth of encoding also influences the LPC amplitude (Rugg, Mark, Wall, Schloerscheidt, Birch, & Allan, 1998). In contrast, items that feel familiar but do not produce a sense of recollection are associated with the "mid-frontal old-new effect" (Rugg, & Curran, 2007). As described previously, a larger LPC amplitude was also found for personal semantics and personal events compared to general semantics (Coronel, & Federmeier, 2016; Renoult et al., 2015; Renoult et al., 2016).

1.3.3 Using ERPs to investigate personal semantics

In the previous sections, the N400 is presented as a correlate of semantic processing, and the LPC as a correlate of episodic processing. What are the neural correlates of personal semantics? The personal semantics are conceptualized as intermediate types of declarative memory that share component processes with both semantic and episodic memory. Hence, personal semantics should rely on both semantic and episodic processing, but to a varying degree.

1.4 The goal of this thesis

The overarching goal of this thesis was to investigate the neural correlates of personal semantics in relation to semantic and episodic memory. Are personal semantics a homogeneous group of memory types? Are the neural correlates of personal semantics closer to semantic or episodic memory? To provide answers to these questions, personal semantics must be compared to semantic and episodic memory within the same study. Moreover, different kinds of personal semantics must be compared to one another. As discussed above, personal semantics have rarely been compared to both semantic and episodic memory. Additionally, personal semantics have rarely been compared to one another using recordings of brain activity. In my thesis, I aimed to address these limitations. The specific goals of my studies were:

Study 1) As a follow-up to Renoult et al. (2016), I compared the neural correlates of general facts, autobiographical facts, repeated events, and unique events using fMRI instead of ERPs. The comparison centered on the long axis of the hippocampus (Poppenk & Moscovitch, 2011; Sekeres, Winocur, & Moscovitch, 2018), as well as the posterior medial and anterior temporal networks (Reagh & Ranganath, 2018).

Brief overview of the main hypotheses: In accordance with Renoult et al. (2012), and the literature reviewed in this thesis, hippocampal activation was expected to follow a gradation from general facts to personal semantics to unique events. Further, past neuropsychological and neuroimaging research suggested that autobiographical facts appeared closer to general facts, and repeated events appeared closer to unique events (Renoult et al., 2012).

Study 2) I compared self-knowledge (of traits) to semantic and episodic memory using ERPs. I also considered whether the temporal orientation of self-knowledge (past, present, future) modulated the proximity of the neural correlates of self-knowledge to semantic and episodic memory.

Brief overview of the hypotheses: According to Renoult et al. (2012) self-knowledge demarcates itself the most from semantic and episodic memory from the four types of personal semantics. For example, self-knowledge can be preserved when semantic or episodic memory is impaired (Klein & Lax, 2010). Two perspectives support distinct hypotheses regarding the temporal orientation effect on self-knowledge. First, according to Construal Level Theory, thinking about distant times increases the reliance on abstract thinking (Trope & Liberman, 2010). Thus, thinking about past and future traits could be closer to semantic memory compared to thinking about present traits. From another perspective, thinking about past and future traits may require to ground that knowledge in self-defining events. Moreover, a sense of time and orienting to a distant moment in time are shared component processes with episodic memory. This second perspective predicts that past and future self-knowledge should be closer to episodic memory compared to present self-knowledge.

Study 3) In this follow-up of study 2, I aimed to dissociate effects of self-relevance and temporal orientation on the LPC amplitude. Further, I examined whether the operationalization of the "other" modified the effects.

Brief overview of the hypotheses: In this study, we expected to replicate our finding that future self-knowledge elicits a larger LPC amplitude than present self-knowledge (study 2). Further, we expected that thinking about the self would be associated with a larger LPC amplitude compared to thinking about others (irrespective of temporal orientation). Thinking about the future should be associated with a larger LPC amplitude than thinking about the present (irrespective of self-relevance). Moreover, we considered that the temporal orientation effect might be smaller for others than the self, because orienting to a distant moment in time may instead reflect a semantic knowledge of time rather than autonoetic awareness. Lastly, we hypothesized that thinking about close friends might increase the self-relevance of the "other" and might increase the recollection of events compared to thinking about a group of people. Thus, the difference in LPC amplitude between self and others could be reduced when thinking about a close friend compared to a group of people or a generic person.

The contribution of these studies:

1) (Study 1, 2, 3) I exploited novel designs that bridge the gap between general semantics, personal semantics, and episodic memory.

2) (Study 1, 2, 3) I used both ERPs and fMRI to elucidate the neural correlates of personal semantics. The difference in design and stimuli curtailed the ability to contrast the results found with both techniques [e.g., study 1 relative Renoult et al. (2016)]. Notwithstanding this caveat, my studies highlight some benefits of using ERPs and fMRI to investigate declarative memory.

For example, the apparent interrelationship between the P200 and N400, and the differences in the LPC time-window in study 2 –all within 800 ms of stimulus onset- would be impossible to detect with fMRI. In contrast, the excellent spatial resolution and brain coverage of fMRI allowed us to examine the relationship of personal semantics to the hippocampus. Several studies found a relationship between hippocampal activity or integrity and personal semantics (as discussed in study 1), but current models like the updated Trace Transformation Theory (Sekeres et al., 2018) cannot explain this relationship.

3) (Study 2, 3) I examined one component process that could influence the relationship of personal semantics to semantic or episodic memory, that is, temporal orientation. The knowledge about the self is not solely atemporal or anchored in the present, but can also concern the past (e.g., I was an impulsive teenager) and the future (e.g., in the new year, I will be disciplined and organized).

4) (Study 3) Personal semantics is both knowledge about oneself, and knowledge that is not culturally-shared. Therefore, what is knowledge about close friends, significant others, and family members? General semantics or personal semantics? We could predict that knowledge of close others will be more closely related to personal semantics or episodic memory compared to general semantics (e.g., because of valence, episodic memories, self-relevance, as discussed in study 3). This research question can help to further characterize personal semantics, and to develop a comprehensive model of declarative memory.

5) (Study 3) Lastly, little is known about how self-relevance and temporal orientation interact to modulate the LPC amplitude (and their interaction in general).

CHAPITRE II. ARTICLES

An fMRI investigation of the continuum perspective on personal semantics

Annick N. Tanguay[a], Daniela J. Palombo[b], Louis Renoult[c], Patrick S. R. Davidson[a]

[a] School of Psychology, University of Ottawa, Ottawa, Canada.

[b] Department of Psychology, University of British Colombia, Ottawa, Canada.

[c] School of Psychology, University of East Anglia, Norwich, UK

Abstract

Personal semantics are at the intersection of memory for culturally-shared facts (i.e., semantic memory) and memory for a personal event (i.e., episodic memory; Renoult, Davidson, Palombo, Moscovitch, & Levine, 2012). That is, personal semantics resemble facts, but they are idiosyncratic and pertain to the self. Personal semantics are thought to vary in proximity to either semantic or episodic memory (Renoult et al., 2012). We investigated whether the neural correlates of autobiographical facts (AF; i.e., relatively objective facts about oneself, such as jobs, names, owned objects) were closer to general semantics (GF), and whether repeated events (RE; i.e., a summary of recurrent events) were closer to unique events (UE). Similar to Renoult et al. (2016), we matched stimuli across the four memory conditions, but changed the cues and verb tense to signal temporal orientation (atemporal, past), and specificity (general, specific). General facts and autobiographical facts were both atemporal and general, but only autobiographical facts referred to the self. Similarly, repeated events and unique events were self-relevant, but they also involved the retrieval of past events varying in temporal specificity (low specificity for repeated events, and high specificity for unique events). Twenty-eight participants took part in this functional magnetic resonance imaging (fMRI) study on personal semantics. Our analyses focused on the long axis of the hippocampus (HPC): The anterior HPC is thought to be associated with memory for gist, whereas the posterior HPC is related to memory for vivid perceptual details (Sekeres, Winocur, & Moscovitch, 2018). In addition, we compared the anterior temporal and posterior medial networks, which relate to semantic and episodic memory, respectively (Reagh & Ranganath, 2018; Ritchey, Libby, & Ranganath, 2015). In our analyses of the HPC and posterior medial network, GF and AF were often not significantly different from one another (except for the posterior HPC), and RE and UE did not

differ from one another in any comparison. We observed a small graded increase of brain activity from GF to AF to RE and UE (with a significant linear trend) in the left posterior HPC. In contrast, no memory type differed in the anterior temporal network. Thus, memory for "facts" (whether personal or not) shared greater similarity with one another, and "events" (whether unique or not) likewise (Renoult et al., 2012). Overall, the data is suggestive of a continuum perspective on personal semantics, but requires replication.

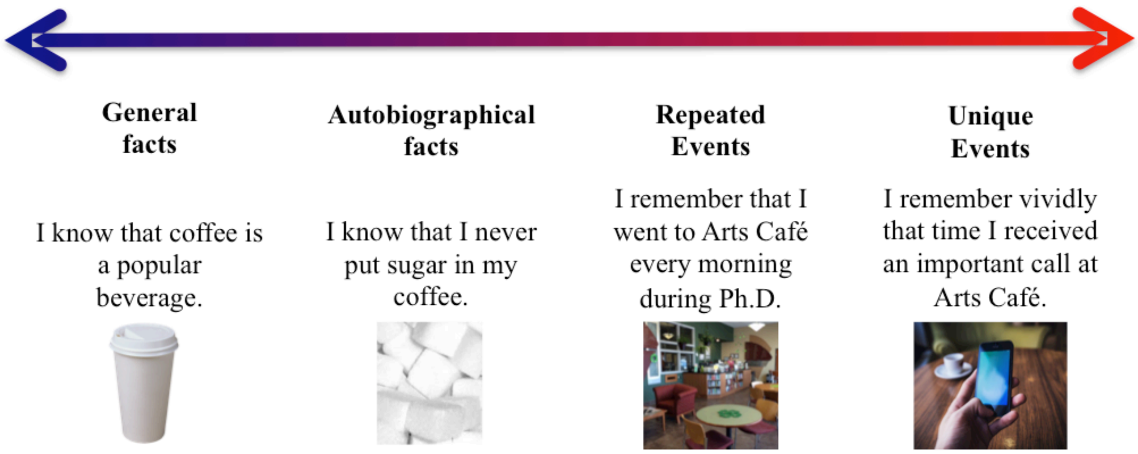
Keywords: Personal semantics, autobiographical facts, repeated events, unique events, general semantics, semantic memory, episodic memory, declarative memory, functional magnetic resonance imaging, hippocampus, PMAT framework

The brain and mind can transport us back to distant times, allowing us to reconstruct events in detail as if we were truly back in those moments (Tulving, 1972, 1983). This "mental time travel" has been named "episodic memory", and has often been contrasted to knowing facts about the world, or "semantic memory" (Tulving, 1972, 1983). These two kinds of memory are generally viewed as sub-systems of declarative memory, i.e., a system for the conscious memory of facts and events (Squire, 2004, 2009). However, there are some aspects of declarative memory that may not fit so neatly under the episodic or semantic label. These have been termed Personal semantics (Cermak & O'Connor, 1983; Grilli & Verfaellie, 2014; Renoult et al., 2012; Tulving, Schacter, McLachlan, & Moscovitch, 1988; Warrington & McCarthy, 1988) and arguably come in at least four types: *Repeated events* summarize the commonalities of several similar events from one's personal past (e.g., the cleaning routine at a job; Renoult et al., 2012). A*utobiographical facts* are personal facts that are relatively devoid of their context of acquisition (e.g., I was born in Toronto; I obtained my Ph.D. at the University of East Anglia; (Grilli & Verfaellie, 2016; Renoult et al., 2012). *Self-knowledge* entails a component of self-reflection, in particular about one's own personality traits and preferences (e.g., I am passionate; Renoult et al., 2012). Lastly, *autobiographically significant concepts* are concepts (e.g., Justin Trudeau) that are attached to a personal event (e.g., I joined the Liberal party because of his election; Renoult et al., 2012).

Personal semantics is now being explored using cognitive neuroscience methods (Ford, Addis, & Giovanello, 2011; Grilli, Bercel, Wank, & Rapcsak, 2018; Grilli & Verfaellie, 2016; Renoult et al., 2016; Tanguay et al., 2018). For example, in a recent electroencephalography (EEG) study (Renoult et al., 2016), we closely matched conditions and compared event-related potentials (ERPs) for general facts (which would be strongly reflective of semantic memory) against two kinds of personal semantics -- autobiographical facts and repeated events -- and unique events (which would be strongly reflective of episodic memory). Both types of personal semantics produced intermediate mean amplitudes for the N400, an index of semantic processing (Kutas & Federmeier, 2011), and for the LPC, an index of episodic processing (Rugg & Curran, 2007), compared to general facts and unique events (Renoult et al., 2016). Qualitatively (although not always quantitatively), the data were compatible with a continuum perspective or a component process view on personal semantics (see Figure 1 for a depiction of these accounts; (Renoult et al., 2012, 2016). We could hypothesize about the brain regions associated with these two kinds of personal semantics—that is, autobiographical facts and repeated events—on the basis of the N400 and LPC results from Renoult et al. (2016). Several regions contribute to classical N400 (e.g., left temporal and left inferior parietal cortex; Kutas & Federmeier, 2011) and LPC effects (e.g., retrosplenial cortex, right hippocampus, posterior parahippocampal gyrus, left orbitofrontal cortex, bilateral temporal cortex, right dorsolateral prefrontal cortex, from Hoppstädter, Baeuchl, Diener, Flor, & Meyer, 2015). A bilateral hippocampal lesion diminishes the amplitude of the LPC (Addante, Ranganath, Olichney, & Yonelinas, 2012; Düzel, Vargha-Khadem, Heinze, & Mishkin, 2001; Olichney et al., 2000), whereas a left temporal-parietal lesion decreases the N400 amplitude (Friederici, Hahne, & von Cramon, 1998; Hagoort, Brown, & Swaab, 1996; Swaab, Brown, & Hagoort, 1997). EEG is praised for its excellent temporal resolution, relative minimal cost per participant, and appropriateness for many participants (and other reasons; Wilding & Ranganath, 2012). However, scalp EEG captures the electrical signal emitted from a large population of neurons (i.e., larger than functional magnetic resonance imaging; fMRI; Huettel, Song, & McCarthy, 2014; Luck, 2014). In this follow-up study, we aimed to benefit from the whole brain coverage - including deep structures – and from the excellent spatial resolution of fMRI.

In the present study, we adapted the same sentence verification task for fMRI to investigate the neural substrates of these four memory types (i.e., general facts, autobiographical facts, repeated events, and unique events). Previous functional neuroimaging work using the sentence verification paradigm or cues to probe personal semantics has found decreased hippocampal activity from unique events to personal semantics (and decreased ventral/dorsal/anterior medial prefrontal cortex activity; mPFC; (Ford et al., 2011; Holland, Addis, & Kensinger, 2011; Maguire, 2003; Maguire & Mummery, 1999; Maguire, Vargha-Khadem, & Mishkin, 2001). Hippocampal activity was associated with personal semantics, but not general semantics in a fluency task (Sheldon & Moscovitch, 2012). Further, a graded decrease from unique event to personal semantics *to general semantics* (as well) has been found for the mPFC and retrosplenial cortex [(Levine et al., 2004; Maguire, 2003; Maguire & Mummery, 1999; Maguire et al., 2001); for a retrosplenial gradation, see also Foster, Dastjerdi, and Parvizi (2012)]. Here, we took two approaches: First, we focused on the long axis of the hippocampus (HPC), which shows a relationship with the vividness of episodic memory (Poppenk, Evensmoen, Moscovitch, & Nadel, 2013; Sekeres et al., 2018), but has been little examined for personal semantics. Second, we broadened our focus to explore whether our different trial types might engage the posterior medial (PM) and anterior temporal (AT) networks differentially; these networks have been associated with episodic memory and with semantic memory, respectively (Reagh & Ranganath, 2018; Ritchey, Libby, et al., 2015). The focus on these regions of interest (ROI; or networks) minimized the multiple comparison problem. For completeness, we also followed up with whole brain contrasts of memory types that are hypothesized to be closer to one another on the continuum (GF and AF, AF and RE, RE and UE), and each memory type relative to the baseline task.

A)



B)

Episodic details	-	++	+++	++++
Visual imagery	+	++	+++	++++
Emotional valence	+	++	+ +	+++
Self-reflection	-	++	++	+++
Person perspective	N/A	First person, third person, or none	First person	First person
Type of retrieval	Noetic/Knowing	Noetic/Knowing	Autonoetic/ Recollection	Autonoetic/ Recollection

C)

Example of stimuli	Many people drink coffee	Every day I drink coffee	When shopping I have drunk coffee	This morning I drank coffee.

Figure 1. a) Two kinds of personal semantics (i.e., autobiographical facts and memory for repeated events) could be conceptualized as an intermediate type of declarative memory, between semantic (i.e., general facts) and episodic (i.e., unique events) memory. This continuum

perspective suggests that the memory types could be characterized by a gradation in brain activity rather than activity in different brain regions. b) Alternatively, the memory types could be associated with a different weighting of component processes; this predicts differences in brain regions. The weightings in this figure illustrate the possible overlap between the two perspectives, that is, they could support similar hypotheses. A minus suggests the component process is not engaged, whereas pluses suggest a graded increase in the involvement of a component process along the continuum. Based on (Renoult et al., 2012). c) Examples of stimuli used in this experiment.

A Continuum Perspective on Personal Semantics

According to the continuum perspective on personal semantics, memory types can be organized on a continuum (or within an hierarchy) from the most abstract, general and experience-far to the most concrete and experience-near (Renoult et al., 2012). Accordingly, in their review, Renoult et al. (2012) proposed that the neural correlates of repeated events appear closer to unique events, whereas those of autobiographical facts appear closer to general facts. Repeated events retain components of episodic memory: a first-person perspective, self-relevance, and some temporal and spatial context, visual imagery and emotional valence (Addis, Moscovitch, Crawley, & McAndrews, 2004; Ford et al., 2011; Levine et al., 2004; Renoult et al., 2012), but the key elements of repeated events are “summarized” and trimmed of the individual events’ details (Barsalou, 1988). Accordingly, although the HPC activity of repeated and unique events is sometimes greater for unique events than repeated events (Ford et al., 2011; Holland et al., 2011), other times it is not significantly different (Addis et al., 2004; Levine et al., 2004). Next on the continuum, autobiographical facts refer to knowing facts about oneself (e.g., jobs held, names of friends, the model of one’s first car). They are further detached from events, and do not involve recollection. Autobiographical facts are associated with HPC activity, although not to the same degree as unique events (Maguire, 2003; Maguire & Mummery, 1999, p. 199; Maguire et al., 2001). In lesion work, experience-far autobiographical facts (e.g., I have two cats) appear resilient to medial temporal lobe (MTL) damage, but not to a lesion extending to the anterior temporal lobe (Grilli & Verfaellie, 2016). In contrast, some experience-near autobiographical facts might elicit some episodic processes through their association with events or through their spatial and temporal context (e.g., I often drink coffee at work; Grilli & Verfaellie, 2016). Indeed, patients with a MTL lesion produced fewer experience-near autobiographical facts than controls (Grilli & Verfaellie, 2016). Therefore, even if personal semantics are "semanticized", they may relate to HPC activity. Little is known on whether they are differentiated on the long axis of the HPC (Poppenk et al., 2013) and how they compare to one another.

Tight Focus: The Longitudinal Axis of the Hippocampus

To orient our work on possible longitudinal axis effects in the hippocampus for personal semantics, we used the recent update of Trace Transformation Theory (TTT; Sekeres et al., 2018). The TTT summarizes the scientific literature on the neural correlates of declarative memory, and can serve as a foundation for postulation on those of personal semantics, even if it was not developed specifically for that purpose. TTT proposes that the neural activity associated with a memory depends on its "nature" (i.e., phenomenological characteristics) rather than simply its age (Sekeres et al., 2018). Some key features are thought to dictate whether the regions of the hippocampus (HPC) or the medial prefrontal cortex (mPFC) will be recruited: 1) perceptually rich memories should engage the posterior HPC (pHPC); 2) general or imprecise memories (i.e., memory for gist) should recruit the anterior HPC (aHPC); and 3) schemas (i.e., representations of multiple events' commonalities, abstracted from their episodic details; Ghosh & Gilboa, 2014) should relate to mPFC activity (Sekeres et al., 2018). Sekeres et al. (2018) explicitly link the recollection of a detailed *unique event* (e.g., I remember the perceptions and sensations from holding my nephew for the first time) to the pHPC, whereas the gist of a *unique event* should produce aHPC activity (e.g., I remember the main elements of my visit to a coffee shop last week), and a schema should relate to mPFC activity (e.g., I know the sequence of events for teaching a class). Even though schemas and repeated events (i.e., the type of personal semantics) both involve extracting commonalities from across multiple events, these two constructs might not be entirely overlapping. In particular, we operationalized repeated events as personal events that had happened repeatedly (i.e., a few times) during the last year, and these could have retained episodic-like qualities similar to a "gist" (e.g., I remember the (many) times I got ice cream at Rideau Centre and walked in front of Parliament Hill; Renoult et al., 2016). In contrast, Sekeres et al. (2018; p. 2) delineates the difference like so: "…a gist representation may not be richly detailed but, nevertheless, be specific to a *single* episode (e.g., the recent birthday party), whereas a schema is a representation based on *multiple* episodes or memory (e.g., what happens at birthday parties in general)." Hence, our operationalization of "repeated events" is a hybrid of schemas and gist, which would suggest mPFC and/or aHPC activity. The authors acknowledge HPC's association with self-relevance (Sekeres et al., 2018, p. 2); that is, personal semantics relate to HPC activity (Addis et al., 2004; Maguire, 2003; Maguire & Mummery, 1999; Maguire et al., 2001). Nevertheless, it is not evident why personal semantics should relate to HPC based on the updated TTT (apart from self-relevance). If we consider the letter of TTT's law rather than its spirit, neither autobiographical facts nor repeated events should recruit the HPC, because neither depends on the retrieval of a unique event (detailed or not), by definition.

But if we consider the spirit of TTT's law, personal semantics could differentially engage the anterior and posterior HPC depending on whether they approximate memory for gist or whether they are associated with personal events.

To our knowledge, only a single fMRI study has compared the activity of personal semantics to episodic memory across the long axis of the HPC: Brown, Rissman, Chow, Uncapher, and Wagner (2018) showed participants pictures from a portable camera that they had worn for the previous few weeks. The researchers equated a Know/noetic response to personal semantics, and a Remember/autonoetic response to episodic memory. Speculatively, a "know" response could stem in part from knowing where key events take place and with whom (e.g., "my home", "my work place", thus autobiographical facts in a way) or from a memory for gist like repeated events. The activity associated with remember responses was greater in the head (aHPC) and body (part of the pHPC) of the HPC bilaterally than know responses, but they did not differ in the tail (Brown et al., 2018). Brown et al.'s (2018) study argues against a simple dissociation such as: personal semantics engage the aHPC, and episodic memory recruits the pHPC. These researchers used pictures (rather than sentences) and a subjective rating (rather than pre-categorized stimuli), thus it will be important to assess whether their results generalize to other stimuli and apply to specific categories of personal semantics.

Briefly, we consider the structure and function of the hippocampus to apply and extend the ideas of the TTT to personal semantics (even though what follows is speculative in part, because little research has been conducted on personal semantics specifically). HPC's subfields vary within the long axis, with more of the dentate gyrus (DG), CA2/CA3 in the pHPC than in the aPHC, and more of the CA1 in the aHPC than pHPC (Zeidman & Maguire, 2016). DG/CA3 contributes to pattern separation, that is, the differentiation between similar representations (e.g., Leal & Yassa, 2018). In contrast, CA1 and CA3 take a pattern completion (or integrative) role, using existing representations to supplement those that are partial (Dimsdale-Zucker, Ritchey, Ekstrom, Yonelinas, & Ranganath, 2018; Duncan & Schlichting, 2018; Leal & Yassa, 2018; Yassa & Stark, 2011). In parallel, the aHPC is sometimes ascribed the role of pattern completion, and the pHPC that of pattern separation (Duncan & Schlichting, 2018). Pattern separation and completion (and differentiation) could subserve autobiographical memory function (Collin, Milivojevic, & Doeller, 2017; Duncan & Schlichting, 2018; Palombo et al., 2018). Pattern completion/separation possibly aids us to navigate the hierarchy in autobiographical memory. Some views of autobiographical memory highlight its hierarchical structure, with details of unique events at the lowest level under their associated repeated and extended events, and self-concepts (Barsalou, 1988; Conway & Pleydell-Pearce, 2000; Grilli, 2017). By way of illustration, repeated events could provide the missing elements of a unique event through pattern completion. Further, the retrieval of a general event or personal fact could be the first stage to retrieving a distinct event (Conway & Pleydell-Pearce, 2000).

Additionally, the "place fields" and "time fields" decrease in size from the anterior to the posterior HPC (Brunec et al., 2018; Collin et al., 2017; Kraus, Robinson, White, Eichenbaum, & Hasselmo, 2013; Miller, Frankland, & Josselyn, 2018). In agreement with this, the aHPC represents the broader "resolution" for elements of a narrative, whereas the pHPC represents more similarly the smaller and contiguous elements (Collin, Milivojevic, & Doeller, 2015). The spatial distance and temporal duration that the left aHPC tracks might be considerable, on the order of kilometres and weeks (or more; Nielson, Smith, Sreekumar, Dennis, & Sederberg, 2015). Moreover, the neurons of the hippocampus follow a temporal drift over days with a subset with greater activity at certain times (Miller et al., 2018). Repeated events could be associated with a more diffuse activity than unique events; the latter might be associated with a restricted neuronal population that code for an instance (Ranganath, 2018).

All this considered, personal semantics might be associated with HPC activity, because: 1) of its involvement in the integrative process linking new memories to the larger autobiographical memory network; 2) retrieving specific memories requires us to distinguish them from similar memories; 3) the coarsest representations of the aHPC might in fact be personal semantics; and/or 4) some personal semantics might be associated with a personal event (e.g., experience-near autobiographical facts or autobiographically significant concepts; Grilli & Verfaellie, 2016; Renoult et al., 2012, 2016). In the spirit of the TTT (Sekeres et al., 2018), we hypothesize that unique events should be associated with maximal pHPC activity, and that the activity of repeated events should be somewhat reduced and possibly shifted towards the aHPC. However, the research of Brown et al. (2018) suggests that unique events could be associated with greater activity than other memory types in both the aHPC and pHPC. In contrast, autobiographical facts might relate to greater aHPC than pHPC activity. General semantic tasks are sometimes associated with HPC activity or anatomical integrity (Blumenthal et al., 2017; Klooster & Duff, 2015; Maguire & Mummery, 1999), but we expected that general facts would display the least aHPC or pHPC activity.

Broader Focus: The Posterior Medial and Anterior Temporal (PMAT) Networks model

Declarative memory also recruits networks that extends beyond the HPC. To provide a framework for an analysis with a broader perspective, we used the Posterior Medial and Anterior Temporal (PMAT) framework, which divides the MTL and cortex based on anatomical and functional connectivity (Inhoff & Ranganath, 2017; Ranganath & Ritchey, 2012; Reagh & Ranganath, 2018; Ritchey, Libby, et al., 2015). The posterior medial (PM) network includes the parahippocampal gyrus, the retrosplenial cortex, the posterior cingulate, the precuneus, the angular gyrus, the anterior thalamus, the presubiculum, the mamillary bodies, and the mPFC (Ritchey, Libby, et al., 2015). The anterior temporal (AT) network includes perirhinal cortex, ventral anterior temporal cortex, lateral orbitofrontal cortex, and the amygdala (Ritchey, Libby, et al., 2015). The ventral mPFC and the HPC incorporate the information from both the PM and AT networks, and modulate them (Inhoff & Ranganath, 2017; Ritchey, Libby, et al., 2015). Within the HPC, the pHPC connects more strongly to the posterior network, and the aHPC more strongly to the anterior network (Poppenk et al., 2013; Sekeres et al., 2018). Neuroimaging and neurophysiological data indicate that the PM network is more strongly associated with recollection and autobiographical memory (and contextual processing/ "situational models", among other functions), whereas the AT network is more strongly linked with semantic memory overall (and memory for items/ "entities", among other functions; Inhoff & Ranganath, 2017; Reagh & Ranganath, 2018). On the basis of the framework, we could hypothesize that personal semantics could shift from the PM network to the AT network (Reagh & Ranganath, 2018). Research on autobiographical facts supports this perspective in part, particularly in the case of experience-far autobiographical facts (Grilli et al., 2018; Grilli & Verfaellie, 2016). Nevertheless, autobiographical facts and repeated events are associated with regions of both networks (reviewed in Table 1). Personal semantics may depend on the construction of "situational models", albeit to a lesser extent than unique events. Although the study focuses on the HPC, we include analyses with the PM and AT networks to generate hypotheses about their relationship to personal semantics relative to general facts and unique events.

Table 1. Brief review of brain regions included in the PMAT and their relationship with personal semantics.

Network	Region	Associated with activity of personal semantics (as suggested by common activity across memory types, greater activity for personal semantics compared to general semantics, or greater activity for personal semantics compared to unique events)?
PM	parahippocampal gyrus	Repeated/general events, autobiographical facts (Ford et al., 2011; Holland et al., 2011; Maguire, 2003)
	retrosplenial cortex	Autobiographical facts (Maguire, 2003)
	posterior cingulate	Repeated/general events (Ford et al., 2011)
	Precuneus	Repeated/general events (Holland et al., 2011)
	angular gyrus	
	presubiculum	
	anterior thalamus, mamillary bodies	
	medial prefrontal cortex	Autobiographical facts, repeated events (Ford et al., 2011; Levine et al., 2004; Maguire, 2003; Maguire & Mummery, 1999)
AT	Perirhinal cortex	
	Ventral anterior temporal cortex	Possible (lateral temporal) Autobiographical facts, repeated events (Ford et al., 2011; Grilli et al., 2018; Holland et al., 2011; Maguire, 2003; Maguire & Mummery, 1999)

Lateral orbitofrontal cortex	Possible (lateral frontal) Repeated events (Levine et al., 2004), autobiographical facts (Maguire, 2003)
Amygdala	

In the current study, we adapted the sentence verification task of (Renoult et al., 2016) for fMRI. The design offers advantages: 1) a pre-scan interview is not necessary, thus avoiding the retrieval of the previous recollection at the interview (rather than or in addition to the fact/event) and guaranteeing identical stimuli for all participants; 2) the stimuli in the four memory conditions are closely matched and differ only in verb tense, temporal specificity, and self-relevance; and 3) we also matched the memory conditions in task demand (e.g., other studies suggest that semantic memory can be processes faster than episodic memory). Despite similarities across memory types, we could detect distinctions between general semantics, personal semantics, and episodic memory with ERPs (Renoult et al., 2016). Thus, we expected the personal semantics to also differ from general semantics and episodic memory with fMRI, and possibly from another, as described above.

Methods

Participants

Thirty-three participants took part in the study. These 13 women and 20 men were 26 years old on average (*SE* = .76), and finished a mean of 16.76 years of education (*SE* = .41). The participants responded to advertisements displayed at the University of Ottawa or Carleton University, and to brief messages distributed on social media. Each interested enquirer was screened for eligibility: They had to be right-handed, native English speakers, free of any contraindications for MRI research (i.e., metal, back pain, claustrophobia, pregnancy), and from a neurological or psychiatric disorder. Participants also had to be between 20 and 35 years old, and have normal or normal-to-corrected vision. We excluded three participants because of a phase encoding switch, another because of an incidental finding, and one did not meet the eligibility criteria fully. Consequently, we included the data of 28 participants in the analyses. Scanner time ranged from 90 to 120 minutes, some participants asking for a break outside of the scanner. For the other steps, starting with consent and ending with debriefing, the study required an additional 60 minutes approximately. The participants were offered $30 (CAD) to offset transportation costs and for their time. The study received REB approval at the University of Ottawa (H08-16-32), and the Royal Ottawa Mental Health Centre (ROH; 2016023).

Task and procedure

The sentence verification task described in Renoult et al. (2016) was optimized for fMRI. In brief, the task involved verifying the accuracy of statements about oneself (autobiographical facts, repeated events, and unique events) or other people (general facts). Participants thought about whether events happened repeatedly in the last year for "repeated events" (RE), and at a specific time within the last week for unique events (UE). The autobiographical facts (AF) condition entailed thinking about what is usually true for oneself, and for general facts (GF), about what is true of most people in this country. The four memory conditions consisted of similar sentences that varied in temporal specificity and verb tense, e.g., No one washes the dishes (GF;) Every day, I wash the dishes (AF); When at work, I have washed dishes (RE); Yesterday, I washed dishes (UE; stimuli in Appendix A). The participants pressed one of two buttons to give a “yes” or “no” response. Participants practiced with a short version of the task outside and inside the scanner. Brief instructions were displayed before each memory condition as reminders. An odd-even task was included during the ITI interval as a baseline condition.

We programmed the task with E-Prime 2.0 (Psychology Software Tools, Inc, 2012). We opted for a mixed design (i.e., block design and event-related), because the statements might not be sufficient to generate a certain memory processing, and to reduce cognitive costs associated with switching between tasks. Each of the seven runs included the four memory conditions, and the sentences were presented in a block. The full set of 70 sentences (per condition) was divided in a low, medium, or high frequency of yes responses based on an item analysis of Renoult et al. (2016) and pilot data. A total of ten sentences from these three subsets were randomly assigned to a run (yielding a total of 7 runs). This randomization was performed once, thus, the attribution of sentences to a run was identical for all participants. This aimed to increase the likelihood of a “yes” response for all memory conditions within each run. We randomized the order of the memory conditions within a run once for all participants (i.e., all participants received the same orders). Each participant received a different order of the sentences within memory blocks. Our epoch of interest started with the cue onset (e.g., Last weekend) and ended with the sentence offset (e.g., I went to the pharmacy). Participants responded after each statement during a “response screen”. During the jittered ITI lasting from 0 to 12 seconds, participants indicated whether a single digit or a series of single digits were even using the same response options and buttons as the main task (adapted from Madore, Szpunar, Addis, & Schacter, 2016). Each number was shown for 2 seconds. Thus, the participants performed the odd-even task for one to size numbers showed consecutively during the jittered ISI. The duration was obtained with some adaptations from Optseq2 (e.g., pretending the TR = 2 sec instead of 1.2 sec). Figure 2 depicts the run and trial structure, and the duration of events. In a post-scan interview, the researcher invited the participants to describe what they were thinking about during a few trials (see Appendix B for the procedure).

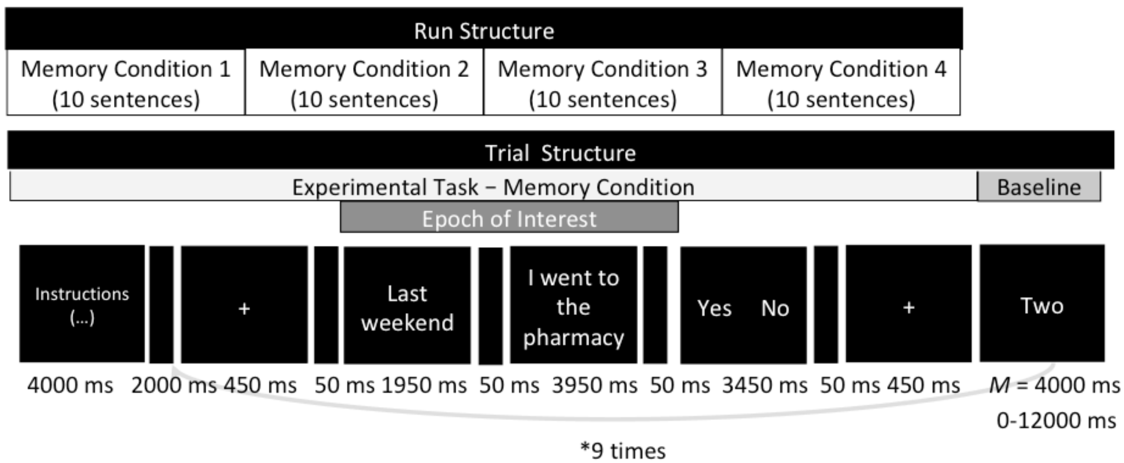


Figure 2. Task structure and durations. The four memory conditions were included in each run. The memory block started with instructions, which were followed with the ten sentences starting with a fixation cross. The cue lasted for 1950 ms, and the sentence 3950 ms. Next, the response screen was shown for 3450, during which participant could respond yes or no. An odd even task (range 0 to 12000 ms, M = 4000 ms, 1 number per 2000 ms) was presented during the interstimulus interval.

The fMRI version of the task differed from the EEG version in these ways: 1) the number of stimuli (70 instead of 67); 2) we added a response screen; 3) we added an odd-even task as a baseline; 4) the memory conditions were interleaved in each run, rather than presented as a single block of 67 sentences; 5) the stimuli were displayed on a black screen instead of a white screen, with a different font (arial 30 bold in this study); 6) we changed some of the cues to improve the relevance of the sentences for any age group; 7) we added practice trials outside and inside the scanner, 8) each word of the sentence (after the cue) was shown on different screens for the EEG version, and instead the whole sentence was shown on a single screen for the fMRI version; 9) the analyses were time-locked to the last word, thus exploiting EEG's excellent temporal resolution, whereas our epoch on interest started at cue onset and finished at sentence offset for the fMRI version. We implemented nearly all those changes with respect to the distinctions between EEG and fMRI, including testing conditions.

Image acquisition

We acquired the images on a Siemens Biograph mMR (Delso et al., 2011) with a 32-channel head coil at the Brain Imaging Centre (BIC) of the ROH. We collected the functional data with a multiband accelerated EPI sequence from CMRR that is sensitive to BOLD [(Moeller et al., 2010; Xu et al., 2013) aligned to anterior and posterior commissure, TR = 1200 ms, TE = 33, flip angle = 65 degrees, FOV = 200 mm, voxel size = 2.5 mm^3, slice thickness = 2.5 mm, volumes 530, multiband factor = 6]. The phase encoding alternated between anterior to posterior (for the 1^{st}, 3^{rd}, 5^{th}, 7^{th} run) and posterior to anterior (for the 2^{nd}, 4^{th}, 6^{th} run).

Unwittingly, the TE was 40 ms instead of 33 ms for the second, fourth, and sixth run of all participants. For this reason, we opted the field map-free method for distortion correction that is implemented in FMRIPREP (Esteban, Markiewicz, et al., 2018), described below, instead of correcting with the reverse phase encoding measurements. TE differences cannot explain difference between conditions. The task was divided in 7 runs, and their order was randomized across all participants. Moreover, we calculated the contrasts for each run, and combined them in higher-level analyses.

We registered the participants' functional to their individual anatomical scan. The T1-weighted pulse sequence (MPRAGE) had the following parameters: sagittal orientation, TR =

2530 ms, TE = 3.36 ms, TI = 1100 ms, flip angle = 7 degrees, slice thickness = 1 mm, matrix = 256, FOV = 256 mm, voxel size = 1 mm^3, with an acceleration factor of 2 using GRAPPA).

Behavioral analyses

The percentage of yes responses was entered in repeated measures ANOVA with memory (GF, AF, RE, UE) as a factor. Unlike (Renoult et al., 2016), the responses were recorded *after* readings the sentences, hence response times do not reflect the same cognitive construct. Nevertheless, we tested whether responses times differed between memory conditions (GF, AF, RE, UE) using a repeated measures ANOVA, with response type (yes, no) as an additional factor. In these, and all analyses, we applied the Greenhouse-Geisser correction when the sphericity assumption was violated (Greenhouse & Geisser, 1959).

fMRI analyses

FMRIPREP pipeline. The MRI data were preprocessed using FMRIPREP (Esteban, Blair, et al., 2018; Esteban, Markiewicz, et al., 2018). To describe the steps accurately and fully, we include the description found on http://fmriprep.readthedocs.io/en/latest/.

"Results included in this manuscript come from preprocessing performed using FMRIPREP version (1.0.6-2; Esteban, Blair, et al., 2018; Esteban, Markiewicz, et al., 2018), a *Nipype* (Gorgolewski et al., 2011, 2017) based tool. Each T1w (T1-weighted) volume was corrected for INU (intensity non-uniformity) using N4BiasFieldCorrection v2.1.0 (Tustison et al., 2010) and skull-stripped using antsBrainExtraction.sh v2.1.0 (using *the OASIS* template). Brain surfaces were reconstructed using recon-all from *FreeSurfer* v6.0.0 (Dale, Fischl, & Sereno, 1999), and the brain mask estimated previously was refined with a custom variation of the method to reconcile ANTs-derived and FreeSurfer-derived segmentations of the cortical gray-matter of *Mindboggle (Klein et al., 2017)*. Spatial normalization to the ICBM 152 Nonlinear Asymmetrical template version 2009c (Fonov, Evans, McKinstry, Almli, & Collins, 2009) was performed through nonlinear registration with the *antsRegistration* tool of ANTs v2.1.0 (Avants, Epstein, Grossman, & Gee, 2008), using brain-extracted versions of both T1w volume and template. Brain tissue segmentation of cerebrospinal fluid (CSF), white-matter (WM) and gray-matter (GM) was performed on the brain-extracted T1w using fast (Zhang, Brady, & Smith, 2001) (FSL v5.0.9).

Functional data were motion corrected using *mcflirt* (FSL v5.0.9; Jenkinson, Bannister, Brady, & Smith, 2002). "*Fieldmap*-less" distortion correction was performed by co-registering the functional image to the same-subject T1w image with intensity inverted (Huntenburg, 2014; Wang et al., 2017) constrained with an average *fieldmap* template (Treiber et al., 2016), implemented with *antsRegistration*(ANTs). This was followed by co-registration to the corresponding T1w using boundary-based registration (Greve & Fischl, 2009) with 9 degrees of freedom, using *bbregister* (*FreeSurfer* v6.0.0). Motion correcting *transformations, field* distortion correcting warp, BOLD-to-T1w transformation and T1w-to-template (MNI) warp were concatenated and applied in a single step using *antsApplyTransforms* (ANTs v2.1.0) using *Lanczos* interpolation.

ICA-based Automatic Removal Of Motion Artifacts (AROMA) was used to generate aggressive noise regressors as well as to create a variant of data that is non-aggressively denoised (Pruim et al., 2015). (…) Many internal operations of FMRIPREP use *Nilearn* (Abraham et al., 2014), principally within the BOLD-processing workflow. For more details of the pipeline see https://fmriprep.readthedocs.io/en/latest/workflows.html."

FMRIPREP extracts several noise regressors, but none were included in the model, and the non-aggressively denoised data were used instead. All the outputs of FMRIPREP were inspected.

FSL pipeline. The subsequent fMRI processing steps were executed in FSL 5.0.11 (Jenkinson, Beckmann, Behrens, Woolrich, & Smith, 2012; Smith et al., 2004; M. W. Woolrich et al., 2009). Using FEAT (FMRI Expert Analysis Tool) version 6.0, the brain was extracted with BET (Smith, 2002), and the entire 4D dataset was grand-mean normalized by a single multiplicative factor. Still in FEAT, the GLM model was built using FILM with local autocorrelation correction (Woolrich, Ripley, Brady, & Smith, 2001). The time-series model included six regressors in the model: one for the odd-even trials (modeled from the onset of the first number to the offset of last number), one for events of no interest (i.e., missing response during sentence verification, instruction screens, response screens, and no responses; from onset to offset), and a regressor for each memory condition (GF, AF, RE, UE). For this last set of regressors, the epoch started at the cue onset and ended at the offset of the sentence screen (see Figure 2). We only kept the trials followed with a yes response. All events were convolved to a double-gamma HRF. FSL expects registration files for higher-level analysis, thus a minimal registration to the MNI space was performed. We removed or replaced some files prior to higher-level analyses (as described in Mumford, 2017), thus preserving FMRIPREP's normalization. At the second level, we averaged the contrast estimates of a participant's runs using a fixed effects model, by forcing the random effects variance to zero in FLAME (FMRIB's Local Analysis of Mixed Effects; (Beckmann, Jenkinson, & Smith, 2003; M. W. Woolrich, Behrens, Beckmann, Jenkinson, & Smith, 2004). At the third level, the contrast estimates of all participants were combined using a FLAME stage 1 model (Beckmann et al., 2003; Woolrich, 2008; Woolrich et al., 2004).

ROI analysis.

aHPC vs pHPC. We segmented the Harvard-Oxford HPC anatomical mask at the uncal apex (i.e., Y = -21), which delineates the anterior and posterior sections (Poppenk et al., 2013; Zeidman & Maguire, 2016). Next, we computed the averaged parameter estimates (i.e., average of all voxels within a region) from the contrast of parameter estimate (COPE) images at the second level. More precisely, we extracted the averaged values with a region from each memory condition versus the baseline task (i.e., the odd-even task) for every participant. We compared the parameters estimates (PE) of the Memory types (GF, AF, RE, UE), with Hemisphere (left, right) and Region (anterior, posterior) as factors, using a (4 x 2 x 2) repeated measures ANOVA in SPSS. The cut-off for statistical significance was p = .05 .

PM vs AT. We obtained the PM by merging these Harvard-Oxford masks: the angular gyrus, the posterior cingulate gyrus, and the precuneus cortex. The parahippocampal gyrus, also part of the PM network, was retrieved from Neurovault (Gorgolewski et al., 2015; Ritchey, Montchal, Yonelinas, & Ranganath, 2015). The following regions were extracted from the Harvard-Oxford atlas for the AT network: frontal orbital cortex, inferior anterior temporal gyrus, temporal pole, and bilateral amygdala. The perirhinal cortex was also added, as found on

Neurovault (Gorgolewski et al., 2015; Ritchey, Montchal, et al., 2015). The PM network includes the mPFC; however, this approximate region (the frontal medial from the Harvard-Oxford) and the frontal pole were analyzed separately, because of their association with schemas and self-relevance (Denny, Kober, Wager, & Ochsner, 2012; Ghosh & Gilboa, 2014; Murray, Schaer, & Debbané, 2012). The Harvard-Oxford masks were thresholded (at 50) and binarized, and all masks were resampled to the resolution of the functional data. The averaged PE were compared in a repeated-measures ANOVA with Memory type (GF, AF, RE, UE) and ROI (PM, AT, mPFC, frontal pole) as factors. The cut-off for statistical significance was $p = .05$

Cluster and voxelwise. Each memory type was compared to the odd even task with Z (Gaussianised T/F) statistics images, thresholded non-parametrically using clusters determined by $Z > 3.1$ and a (corrected) cluster significance of $p = .05$ (Worsley, 2001). Additionally, we compared contiguous memory types on the continuum (i.e., GF and AF, AF and RE, RE and UE) with the same parameters. On the one hand, we targeted these contrasts because the ROI analyses might reveal small differences between these Memory types, which could mislead us into concluding that they are no (significant) differences. On the other hand, we aimed to limit the number of comparisons. Moreover, we performed contrasts of the Memory types to odd even for the voxels of the hippocampal mask only. For these, Z (Gaussianised T/F) statistic images were thresholded using GRF-theory-based maximum height thresholding with a (corrected) significance threshold of $p = .05$ (Worsley, 2001). Voxel correction can localize differences within a region, whereas inferences about location cannot be made with certainty when a cluster includes more than region (Roiser et al., 2016). All these analyses were conducted with automatic outlier detection (Woolrich, 2008).

Results

Behavioural

We entered the percentage of yes responses in a repeated measures ANOVA with Memory types as a factor (GF, AF, RE, UE). The percentage of "yes" responses differed between Memory types, $F(1.94, 52.42) = 28.87$, $p < .001$, $\eta^2_p = .52$. The percentage of "yes" was lower for UE ($M = 40.91$, $SE = 1.21$) than RE ($M = 49.36$, $SE = 2.86$, $\eta^2_p = .34$), AF ($M = 59.1$, $SE = 1.61$, $\eta^2_p = .81$), and GF ($M = 56.75$, $SE = 1.5$, $\eta^2_p = .83$), $p \leq .001$. This was expected, because UE features the greatest temporal specificity, and is similar to Renoult et al., (2016). The percentage of yes responses was also lower for RE compared to AF ($p = .002$, $\eta^2_p = .3$) and GF ($p = .01$, $\eta^2_p = .22$). GF and AF were not significantly different from one another, $p = .161$, $\eta^2_p = .07$. The mean number of "yes" responses ranged from 28.07 ($SE = .8$) to 40.61 ($SE = 1.2$) across memory conditions. The minimum number of "yes" responses was 18 for any condition and any participant. All runs included at least one yes response from each memory conditions, except RE for a single run of two participants. Four participants missed one complete run because of technological failure (e.g., power outage, lost data at BIC) or needing a break after the beginning of the run (insufficient data). All participants had a minimum of 6 runs.

Next, we conducted a repeated measures with the Memory types (GF, AF, RE, UE) and Response (yes, no) to compare the response time. The main effects of Memory types and Response were not significant, $p \geq .079$, $\eta^2_p \leq .09$, and these factors did not interact, $p = .985$, $\eta^2_p = .002$.

The participants achieved the accuracy of *M* = 96.71% (*SE* = .54) during the odd-even task across the runs. Indeed, this was significantly above chance (50%), as shown with a one sample t-test ($p < .001$), suggesting that the participants were alert throughout the session.

fMRI

Tight Focus: anterior vs posterior HPC.

The mean PE from each memory over each ROI is showed in Figure 3. The averaged PE were entered in a repeated-measures ANOVA with Region (anterior, posterior), Hemisphere (left, right) and Memory type (GF, AF, RE, UE). Memory conditions, Hemisphere, and Region interacted, $F(3, 81) = 3.27$, $p = .025$, $\eta^2_p = .11$. To decompose this effect, we conducted separate repeated-measures ANOVA for the aHPC and for the pHPC with the Memory types and Hemisphere as factors.

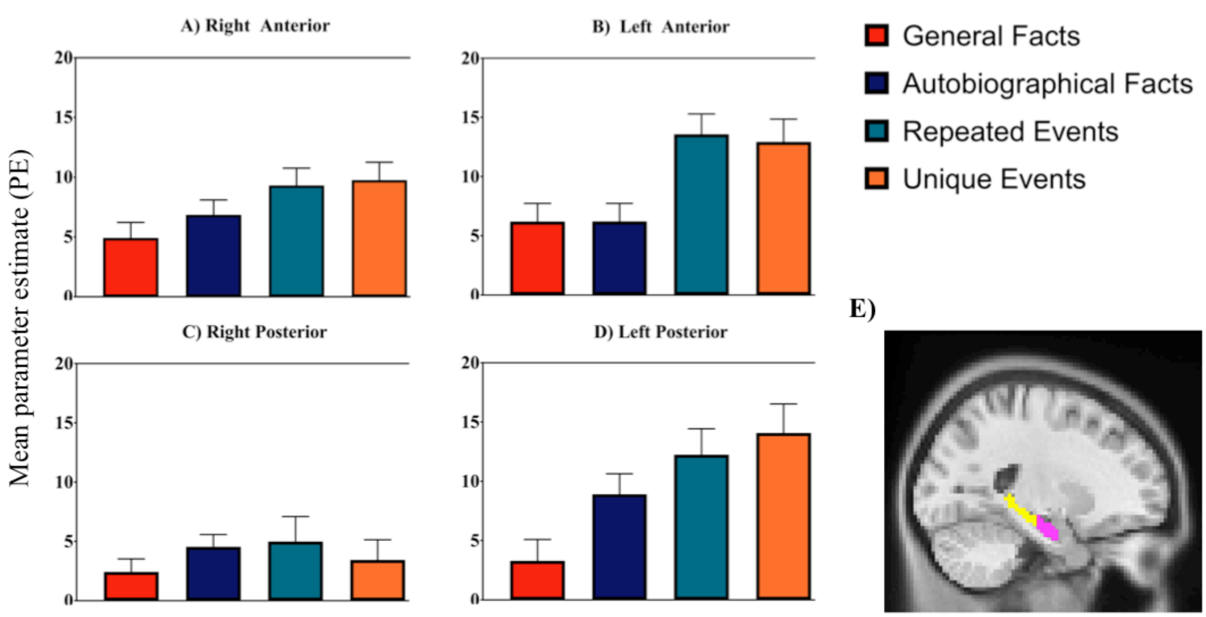


Figure 3. Panel A to D: The mean PEs of each memory condition for the left and right aHPC and pHPC. Errors bars ± 1 SE. E) A sagittal view of the aHPC (in pink) and the pHPC (in yellow).

Over the aHPC, the main effect of Memory type was significant, $F(3, 81) = 5.88$, $p = .001$, $\eta^2_p = .18$. GF and AF were not significantly different from one another ($p = .551$, $\eta^2_p = .01$), and both were less active than RE and UE ($ps \leq .027$, $\eta^2_p \geq .17$). RE and UE did not differ from another, $p = .961$, $\eta^2_p < .001$. The activity was greater over the left than the right hemisphere, $F(1,27) = 5.07$, $p = .033$, $\eta^2_p = .16$. The interaction between Memory and Hemisphere approached statistical significance, $F(3, 81) = 2.61$, $p = .057$, $\eta^2_p = .09$. All the effects of the main effect of Memory were replicated when including only the data of the left aHPC (see Table 2). Over the right aHPC, GF was less active than RE and UE, $p = .007$, $\eta^2_p = .24$, and these were the only significant differences (see Table 2).

Over the pHPC, Memory and Hemisphere interacted, $F(3,81) = 4.52$, $p = .006$, $\eta^2_p = .14$. Over the right pHPC, none of the memory conditions were significantly different from one another, $p \geq .210$, $\eta^2_p \leq .06$ Over the left pHPC, GF was significantly less active compared to all other conditions, $p \leq .012$, $\eta^2_p \geq .21$. No other differences emerged. As can be seen in Figure 1, activation increased incrementally from GF to AF to RE to UE. The significant linear trend supports this observation, $F(1,27) = 12.73$, $p = .001$, $\eta^2_p = .32$. Note that the linear was also significant over the right aHPC [$F(1,27) = 10.45$, $p = .004$, $\eta^2_p = .27$] and left aHPC [$F(1,27) = 14.69$, $p = .001$, $\eta^2_p = .35$], but not the right pHPC, [$F(1,27) = .28$, $p = .603$, $\eta^2_p = .01$]. See Table 2 for all pairwise comparisons.

Table 2. *All pairwise comparisons for Memory types per hemisphere and region.*

	df	***F***	***p***	η^2_p
		Right - aHPC		
GF vs AF	1,27	1.4	.248	.05
GF vs RE	1,27	8.59	.007*	.24

GF vs UE	1,27	8.5	.007*	.24
AF vs RE	1,27	1.38	.25	.05
AF vs UE	1,27	2.93	.099	.1
RE vs UE	1,27	.08	.785	.003
Right - pHPC				
GF vs AF	1,27	1.65	.21	.06
GF vs RE	1,27	1.41	.245	.05
GF vs UE	1,27	.23	.634	.01
AF vs RE	1,27	.03	.862	.001
AF vs UE	1,27	.38	.541	.01
RE vs UE	1,27	.41	.528	.02
Left - aHPC				
GF vs AF	1,27	0	.997	0
GF vs RE	1,27	14.75	.001*	.35
GF vs UE	1,27	6.98	.014*	.21
AF vs RE	1,27	8.76	.006*	.25
AF vs UE	1,27	10.9	.003*	.29
RE vs UE	1,27	.05	.824	.002
Left - pHPC				
GF vs AF	1,27	7.24	.012*	.21
GF vs RE	1,27	9.5	.005*	.26
GF vs UE	1,27	11.66	.002*	.3
AF vs RE	1,27	1.31	.263	.05
AF vs UE	1,27	4.1	.053	.13
RE vs UE	1,27	.34	.567	.01

An additional ANOVA was run to clarify whether each Memory type engaged differentially the anterior and posterior HPC. We conducted these comparisons with a factorial ANOVA (to obtain the η^2_p as a measure of effect size). For GF, there was greater activation in the aHPC than pHPC of the right hemisphere, [$F(1,27) = 6.46$, $p = .017$, $\eta^2_p = .19$], and this was a statistical trend over the left, [$F(1,27) = 3.67$, $p = .066$, $\eta^2_p = .12$]. The activity of the aHPC and pHPC did not differ significantly on the right [$F(1,27) = 2.97$, $p = .096$, $\eta^2_p = .1$] and left [$F(1,27) = 2.53$, $p = .123$, $\eta^2_p = .09$] hemisphere in the case of AF. On the right, both RE and UE had greater aHPC than pHPC activity, [RE: $F(1,27) = 7.37$, $p = .011$, $\eta^2_p = .21$; UE: $F(1,27) = 13.92$, $p = .001$, $\eta^2_p = .34$]. On the left, for RE and UE, the activity did not differ between aHPC and pHPC [RE: $F(1,27) = .53$, $p = .475$, $\eta^2_p = .02$; UE: $F(1,27) = .312$, $p = .581$, $\eta^2_p = .01$].

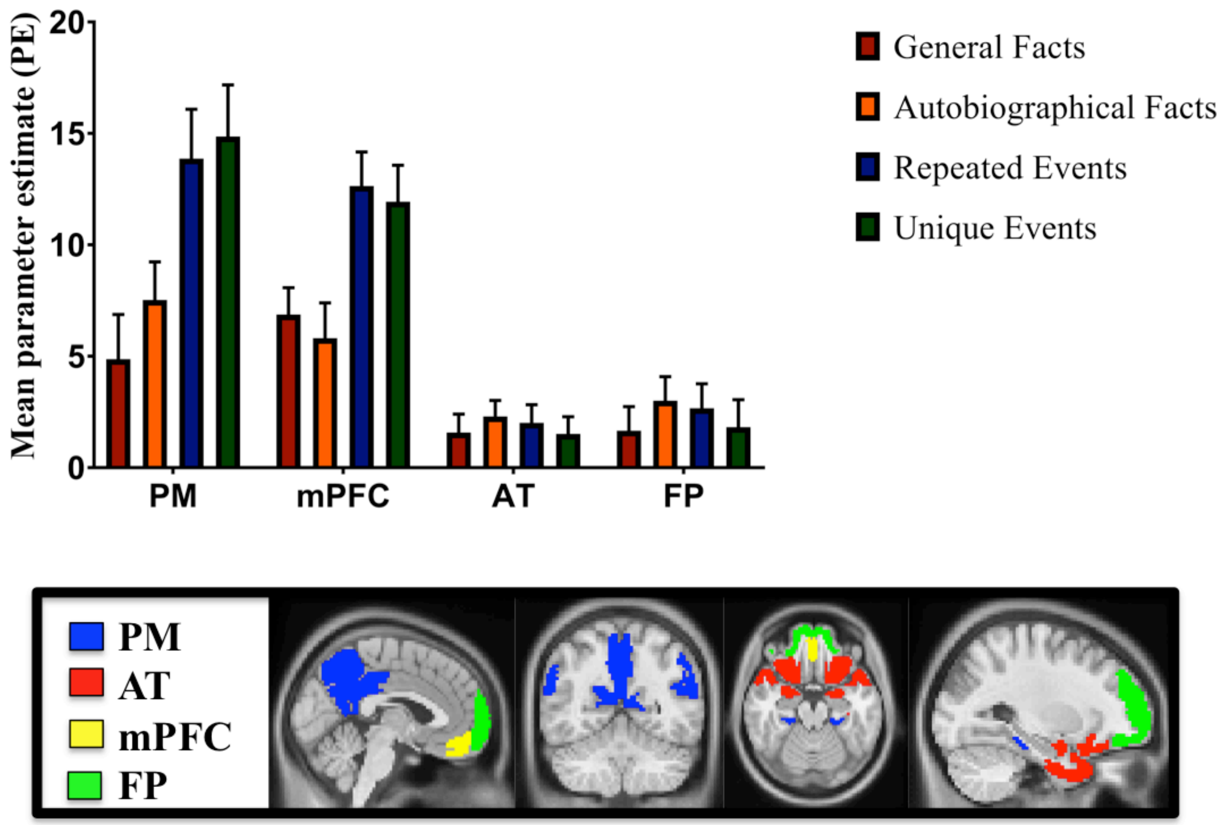


Figure 4. A) The averaged PEs of the four memory conditions are shown for each ROI of the PMAT framework. Errors bars ± 1 SE. B) The four ROIs displayed over a resampled MNI T1 that matches the spatial resolution of the functional. PM = posterior medial; AT = Anterior temporal; mPFC = medial prefrontal cortex; FP = frontal pole.

Broader focus: PM vs AT networks. The averaged PE were entered in a repeated-measures ANOVA with Memory type (GF, AF, RE, UE) and ROI (PM, AT, mPFC, Frontal Pole; see Figure 4). The effect of Memory and ROI interacted, $F(5.57, 150.29) = 12.93$, $p < .001$, $\eta^2_p = .32$. In the PM network, the activity of GF and AF was significantly lower than RE and UE, $p \leq .008$, $\eta^2_p \geq .23$. RE and UE were not significantly different, $p = .639$, $\eta^2_p = .01$. GF and AF did not differ as well, $p = .227$, $\eta^2_p = .05$. Similarly, over the mPFC, the activity of GF and AF were significantly lower than RE and UE, $p \leq .002$, $\eta^2_p \geq .25$. Neither RE and UE were significantly different, $p = .599$, $\eta^2_p = .01$, nor GF and AF differed, $p = .371$, $\eta^2_p = .03$. None of the memory conditions differed in the AT network or frontal pole ROI (see Table 3).

Table 3. Pairwise comparisons of the Memory types for the AT and frontal pole ROI.

	df	***F***	***p***	η^2_p
AT				
GF vs AF	1,27	.67	.422	.02
GF vs RE	1,27	.26	.616	.01
GF vs UE	1,27	.002	.961	< .001
AF vs RE	1,27	.103	.751	.004
AF vs UE	1,27	1.39	.248	.05
RE vs UE	1,27	.22	.641	.01
Frontal pole				
GF vs AF	1,27	1.3	.264	.05
GF vs RE	1,27	1.07	.31	.04
GF vs UE	1,27	.02	.884	.001
AF vs RE	1,27	.11	.746	.004
AF vs UE	1,27	1.14	.295	.04
RE vs UE	1,27	.56	.462	.02

Whole Brain Contrasts of Memory types. As final exploratory analysis, each memory type showed activity in contrast to the odd even task in some areas of the frontal lobes, lateral temporal lobes and cerebellum (the exact location depended on the memory type), as well as the precuneus, posterior cingulate cortex, occipital lobes, parahippocampal gyrus, In terms of the lateral temporal lobes: GF and AF were associated with left middle temporal gyrus activity only, whereas RE and UE were also associated with activity of the right middle temporal gyrus (none extending to the temporal poles). Although GF produced activation in several common areas than AF, RE, UE, activation was overall more restricted. Notably, only AF, RE, and UE were associated with hippocampal activity in these analyses (see Table 4 and Figure 5). However, clusters do not allow us to infer on specific regions of activation when a cluster includes more than one region (Roiser et al., 2016).Therefore, we also conducted a contrast of each memory type to odd even for voxels included in the hippocampal mask, and applied voxelwise correction (*p* = .05). As can be seen in Table 5, all memory types were associated with hippocampal activity. Notably, GF was associated with greater activity hippocampal activity (compared to odd-even) mostly over the bilateral aHPC, whereas all personal types of memory extended to the bilateral pHPC.

Next, we compared the contiguous memory types on the continuum. GF did not relate to greater activity than AF, and UE was also not associated with greater activity than RE. All other contrasts were associated with significant clusters. Compared to AF, RE was associated with greater activity in PM regions (parahippocampal gyrus, mPFC, precuneus, posterior cingulate cortex), and the left middle/superior frontal gyrus, and bilateral superior lateral occipital cortex. Compared to RE, AF was associated with greater activity in the right lateral frontal pole and inferior frontal gyrus, right angular gyrus, right and left supramarginal gyrus, and areas of the cerebellum (see Table 6, Figure 6 for the full list).

Table 4. Contrasts of memory conditions vs. the baseline (odd even), Cluster z > 3.1, cluster threshold significance of p ≤ .05.

General Facts vs Odd Even

	Label	Voxels	P	z max	z max x (mm)	z max y (mm)	z max z (mm)
Cluster 1	Right precentral gyrus	52	0.0388	3.92	39	-14.5	44.5
Cluster 2	Cerebellum - Right Crus II	209	1.37e-06	4.56	-58.5	-19.5	-18
Cluster 3	Left middle temporal gyrus (posterior, anterior)	352	1.17e-09	5.52	-6	55.5	-15.5
Cluster 4	Left inferior frontal gyrus (including orbital cortex, pars triangularis)	694	1.23e-15	4.89	-61	23	17
Cluster 5	Left superior frontal gyrus	1571	1.56e-27	5.88	-26	20.5	59.5
Cluster 6	Bilateral occipital pole, precuneus, posterior cingulate cortex, parahippocampal gyrus,	7678	0	7.88	-11	-92	-5.5

Autobiographical Facts vs Odd Even

	Label	Voxels	P	z max	z max x (mm)	z max y (mm)	z max z (mm)
Cluster 1	Right middle frontal gyrus	56	0.025	4.2	44	25.5	37
Cluster 2	Right (lateral) frontal pole	66	0.0109	4.83	34	38	-15.5
Cluster 3	Right superior parietal lobule	88	0.00201	5.24	39	-44.5	72
Cluster 4	Right precentral gyrus	95	0.00121	4.71	44	-17	69.5
Cluster 5	Cerebellum –	136	7.58e-05	5.39	4	-54.5	-53

	bilateral IX						
Cluster 6	Right superior lateral occipital cortex	262	5.96e-08	4.77	51.5	-67	37
Cluster 7	Right superior frontal gyrus	307	6.44e-09	4.52	24	43	52
Cluster 8	Left posterior middle temporal gyrus	482	2.5e-12	4.95	-66	-19.5	-13
Cluster 9	Mostly left lateralized medial prefrontal cortex (frontal pole)	641	4.46-e15	4.86	-6	65.5	22
Cluster 10	Left orbital frontal cortex	846	2.65e-18	5.42	-53.5	20.5	-5.5
Cluster 11	(Middle) Superior frontal gyrus	1359	2.1e-25	5.85	-1	33	44.5
Cluster 12	Bilateral occipital pole, precuneus, posterior cingulate cortex, parahippocampus, hippocampus	10712	0	7.7	-16	-89.5	-10.5

Repeated Events vs Odd Even

	Label	Voxels	P	z max	z max x (mm)	z max y (mm)	z max z (mm)
Cluster 1	Right middle temporal gyrus (anterior)	62	0.0166	3.96	59	-4.5	-20.5

Cluster 2	Right (lateral) frontal pole	68	0.0103	5.02	36.5	35.5	-18
Cluster 3	Cerebellum – Right Crus II	91	0.00183	4.72	49	-64.5	-43
Cluster 4	Cerebellum – Bilateral IX	152	3.36E-05	5.8	6.5	-52	-50.5
Cluster 5	Left middle temporal gyrus (posterior)	171	1.09E-05	4.54	-68.5	-42	2
Cluster 6	Right lateral occipital cortex (superior)	390	1.93E-10	6.04	49	-72	37
Cluster 7	Right superior frontal gyrus	464	8.08E-12	5.63	21.5	35.5	47
Cluster 8	Left middle temporal gyrus (anterior)	474	5.33E-12	5.78	-53.5	-14.5	-8
Cluster 9	Medial prefrontal cortex	3860	0	6.67	-6	55.5	-13
Cluster 10	Occipital pole, precuneus, posterior cingulate cortex, parahippocampal gyrus, hippocampus	10564	0	7.73	14	-84.5	-10.5

Unique events vs. Odd Even

	Label	Voxels	P	z max	z max x (mm)	z max y (mm)	z max z (mm)
Cluster 1	Right middle temporal gyrus (anterior)	87	0.00211	4.57	66.5	-4.5	-20.5
Cluster 2	Left middle	123	0.000171	4.46	-53.5	20.5	42

	frontal gyrus						
Cluster 3	Bilateral cerebellum IX	142	5.02E-05	5.01	1.5	-52	-50.5
Cluster 4	Right lateral occipital cortex (superior)	299	8.97E-09	5.96	49	-72	34.5
Cluster 5	Right superior frontal gyrus	356	5.90E-10	5.57	24	20.5	52
Cluster 6	Left middle temporal gyrus (anterior and posterior)	382	1.79E-10	5.51	-61	-12	-15.5
Cluster 7	Left frontal orbital cortex	413	4.48E-11	5.03	-41	28	-15.5
Cluster 8	Left superior frontal gyrus	734	1.26E-16	5.97	-28.5	33	52
Cluster 9	Medial prefrontal cortex	2208	1.61E-35	6.18	-8.5	50.5	-13
Cluster 10	Bilateral occipital cortex, posterior cingulate cortex, precuneus, parahippocampus, hippocampus	9081	0	7.81	-13.5	-89.5	-8

Table 5. Contrasts of memory conditions vs. the baseline (odd even) for the voxels included in the hippocampal mask only, voxel correction, p ≤ .05.

General facts vs. Odd Even

Cluster	Label	Voxels	Z max	Z-MAX X (mm)	Z-MAX Y (mm)	Z-MAX Z (mm)

1	Right anterior	3	3.86	26.5	-19.5	-15.5
2	Left, mostly anterior	20	4.6	-21	-19.5	-15.5
Autobiographical facts vs. Odd Even						
1	Left posterior	1	3.88	-13.5	-39.5	2
2	Left anterior	1	3.64	-33.5	-19.5	-18
3	Left posterior	2	3.5	-23.5	-29.5	-8
4	Left anterior	31	5.21	-21	-17	-20.5
5	Right anterior	48	4.58	29	-17	-18
Repeated events vs. Odd Even						
1	Right anterior, some posterior	81	6.42	21.5	-19.5	-20.5
2	Left anterior and posterior	159	6.51	-23.5	-19.5	-18
Unique events vs. Odd Even						
1	Left posterior	1	4.02	-13.5	-39.5	2
2	Right posterior	1	3.53	24	-27	-8
3	Left posterior	3	3.67	-26	-37	-3
4	Right anterior	88	5.5	21.5	-19.5	-18
5	Left anterior and posterior	120	5.61	-23.5	-19.5	-18

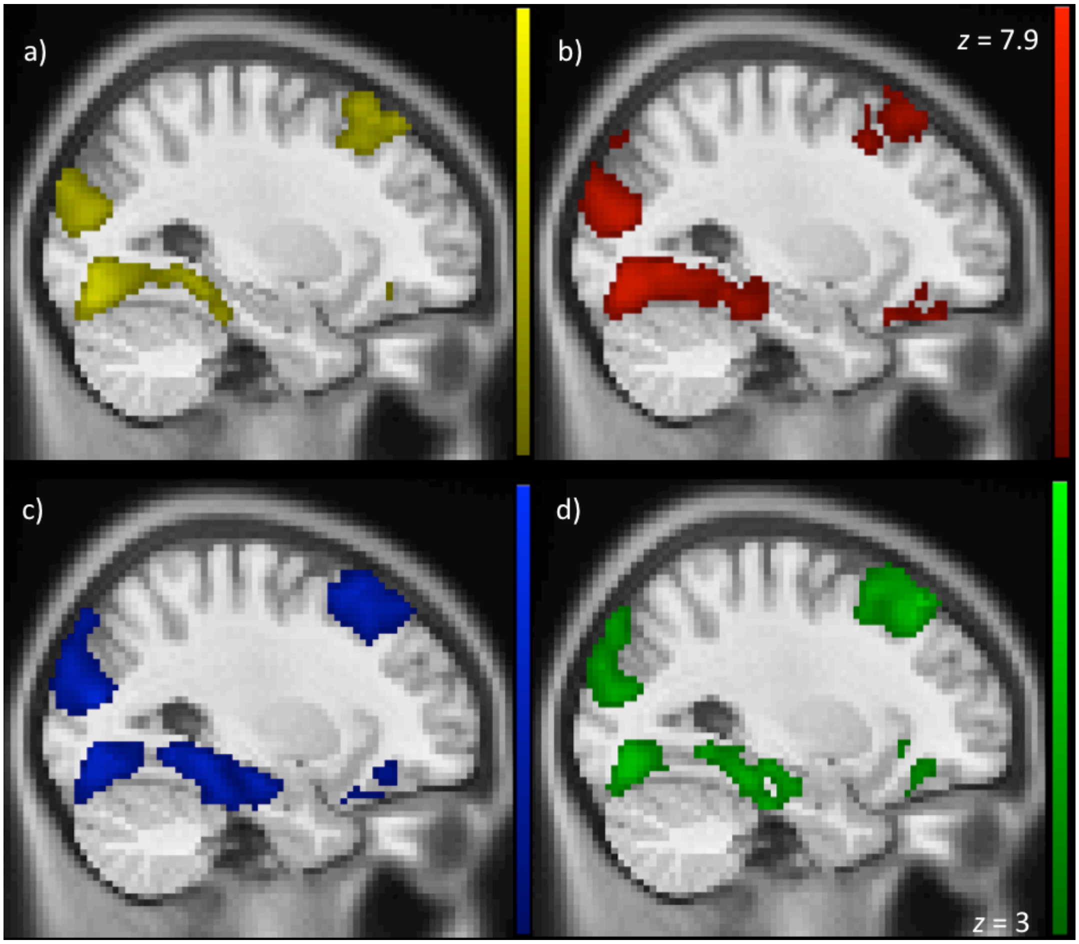


Figure 5. The following contrasts are shown (with cluster correction: $z > 3.1$, $p = .05$): a) GF vs Odd Even, b) AF vs Odd Even, c) RE vs Odd Even, d) UE vs Odd Even, overlayed on the MNI template that is resampled to match the resolution of the BOLD. The coordinate of the sagittal slice x = -28.56 (left hemisphere).

Table 6. Contrasts of contiguous memory types on the continuum using all the available voxels (whole brain). Cluster $z > 3.1$, cluster threshold significance of $p \leq .05$

General Facts vs. Autobiographical Facts

Not significant

Autobiographical Facts vs. General Facts

	Label	Voxel	P	Z max	z max x (mm)	z max y (mm)	z max z (mm)
Cluster 1	Right middle temporal gyrus (posterior)	44	0.0449	4.4	54	-19.5	-8
Cluster 2	Right frontal pole (lateral)	46	0.0368	4.59	26.5	58	32
Cluster 3	Right inferior lateral occipital cortex	48	0.0302	3.5	39	-89.5	-3
Cluster 4	Right occipital pole	66	0.00564	3.9	21.5	-94.5	-0.5
Cluster 5	Bilateral intracalcarine cortex	86	0.00103	4.04	6.5	-87	4.5
Autobiographical facts vs. Repeated Events							
Cluster 1	Left supramarginal gyrus, posterior division	52	0.0251	4.48	-68.5	-42	39.5
Cluster 2	Cerebellum – Right VIIb	55	0.0191	4.17	19	-72	-43
Cluster 3	Left inferior lateral occipital cortex	63	0.00937	3.98	-41	-69.5	7
Cluster 4	Cerebellum – Left Crus II	77	0.00287	4.17	-28.5	-77	-45.5
Cluster 5	Right inferior frontal gyrus – pars oparcularis	201	5.96e-07	4.5	54	15.5	12
Cluster 6	Right inferior lateral occipital	225	1.19e-07	4.04	54	-67	7

	cortex						
Cluster 7	Right (lateral) frontal pole	332	4.79e-10	5.17	44	43	22
Cluster 8	Right angular gyrus, supramarginal gyrus (posterior)	531	4.75e-14	5.55	56.5	-39.5	57
Repeated events vs. Autobiographical facts							
Cluster 1	Left posterior parahippocampal gyrus	45	0.0485	4.85	-33.5	-37	-10.5
Cluster 2	Left middle and superior frontal gyrus	67	0.00663	4.1	-21	20.5	62
Cluster 3	Right superior lateral occipital cortex	76	0.00312	4.16	46.5	-74.5	44.5
Cluster 4	Medial prefrontal cortex	244	5.96e-08	5.28	-3.5	55.5	-13
Cluster 5	Left superior lateral occipital cortex	327	6.16e-10	5.59	-41	-84.5	44.5
Cluster 6	Precuneous, posterior cingulate cortex	965	2.46e-21	6.12	-1	-59.5	17
Repeated events vs. Unique events							
Cluster 1	Left occipital pole	45	0.043	3.82	-13.5	-94.5	-8
Cluster 2	Left occipital cortex, inferior	53	0.0199	3.96	-46	-79.5	-13
Cluster 3	Right occipital pole	137	2.55e-05	4.91	14	-92	2
Unique events vs. Repeated events							

Not significant

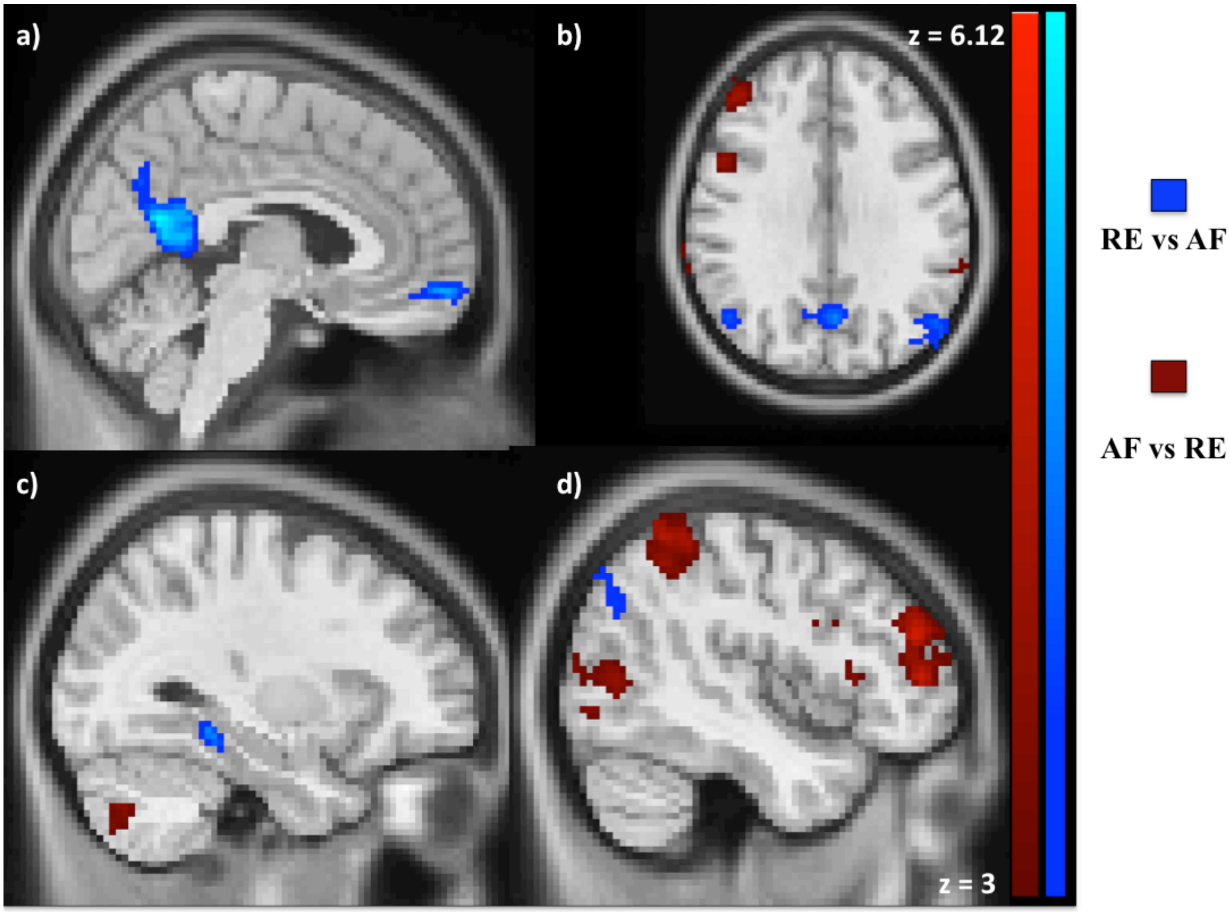


Figure 6. The significant clusters of the contrasts RE vs. AF and AF vs. RE are shown in blue and red, respectively ($z > 3.1$, $p = .05$), overlayed on the MNI template (nb. the left of the brain is on the right). a) Right hemisphere, x = 2.83; b) z = 29.59 for the axial view; c) left hemisphere, x = -30.57 ; d) right hemisphere, x = 43.7.

Discussion

In this study, we compared the neural correlates of closely-matched general facts, autobiographical facts, repeated events, and unique events. The cues and verb tense signalled the temporal orientation and specificity: General facts and autobiographical facts were atemporal; repeated events concerned recurrent events within the last year, and unique events were those that had happened at a specific time within the last week. The conditions shared strong similarities: e.g., GF: Everyone logs on to Facebook; AF: Very often, I log on to Facebook; RE: When at work, I have logged on to Facebook; UE: Yesterday, I logged on to Facebook. In spite of these close similarities that we designed between trial types, we detected some interesting differences in fMRI.

Tight Focus: The Longitudinal Axis of the Hippocampus

When we focused on the hippocampus, several findings were compatible with the continuum perspective on personal semantics overall. The two ends of the continuum, general facts and unique events, were the most distinct from one another in terms of hippocampal activations: Unique events were associated with greater hippocampal activity than were general facts. Some of our findings are more obviously consistent with the update TTT's proposals, whereas others invite a careful reappraisal of the proposals. On the one hand, we observed a small graded increase from GF to AF to RE and UE (with a significant linear trend) in the left pHPC. This corresponds with the theorized greater episodic processing as we go from GF to UE (Renoult et al., 2012), and TTT's view on the pHPC (Sekeres et al., 2018). On the other hand, this pattern was specific to the left pHPC; in fact, none of the memory types differed in the right pHPC. This could be a reflection of the lateralization of the autobiographical memory network for verbal stimuli, which some have observed to be left lateralized (Maguire & Mummery, 1999; Svoboda, McKinnon, & Levine, 2006). Additionally, the aHPC did not appear particularly sensitive to the theorized "gist" of a memory. Rather, a small graded increase on average (with a significant linear trend) was observed in the right aHPC (from GF to UE), and both RE and UE were more active than GF and AF in the left aHPC. Hence, initially, the data does not correspond neatly with the updated TTT, but further examination suggests otherwise (as discussed below).

The pHPC. In this study, it is not so much the item or object that distinguishes the memory types as *how* it is retrieved. As illustrated above, we can retrieve the memory of logging on to Facebook in a specific temporal (and spatial) context, or doing so across multiple events (e.g., secretly at work), or as a personal fact (I use Facebook), or relative to cultural norms (e.g., what most people do). This invokes TTT's principle that the "nature" of the memory dictates whether the HPC or mPFC will be activated (Sekeres et al., 2018). Namely, detailed recollection should produce pHPC activity, whereas the recall of the main elements of an event should relate to aHPC activity. Our study suggests that the left pHPC might be sensitive the episodic-like qualities of semanticized memories or semantics, and not only of a single event. The left pHPC activity was maximal for unique events, somewhat reduced for repeated events, further reduced for autobiographical facts (all on average only), which all differed from the minimal general facts. We still know relatively little about the component processes of personal semantics, such as visual imagery or episodic details. However, some personal semantics appear to be closer to events or contexts. In particular, autobiographical facts vary in proximity to events or contexts, and only those that are experience-near may be impaired by an MTL lesion (Grilli & Verfaellie, 2016). Be it necessary or not (Price, Mummery, Moore, Frackowiak, & Friston, 1999), in healthy people (or neurotypicals), the retrieval of autobiographical facts could be associated with the retrieval of some episodic details or imagery (e.g., could an image of one's personal Facebook page come to mind when thinking about the fact "I have a Facebook account"? or some associative process?). Hence, we propose that it might not be "personal significance" *per se* that explains the personal semantics' relationship with HPC [as suggested in Sekeres et al. (2018)], but whether it engages component processes associated with the HPC. Future research contrasting experience-near to experience-far autobiographical facts, and with ratings of visual imagery or episodic details will be helpful to elucidate the functional correlate of the pHPC in autobiographical memory.

The aHPC. Repeated events—similar to memory for gist—did not relate to increased aHPC activity compared to unique events**.** In fact, Sekeres et al. (2018) mention that memory types do not operate in isolation. Hierarchical views of autobiographical memory predict that accessing extended or repeated events can be a route to retrieve a unique/specific event (Cabeza & St Jacques, 2007; Conway, 2009; Conway & Pleydell-Pearce, 2000). In keeping with this perspective, unique events could be the product of a honing process that involves the retrieval of repeated events and autobiographical facts. The study of McCormick, St-Laurent, Ty, Valiante, and McAndrews (2015) suggests the left aHPC modulates dorsal mPFC activity during construction (the period examined in this study), and the posterior HPC bilaterally during elaboration (at a later stage). The authors positioned their finding within the perspective that a memory of coarser resolution could guide the retrieval of perceptually rich memory (McCormick et al., 2015). These perspectives suggest that aHPC activity could be necessary to retrieve both coarse and refined autobiographical memories. In our study, the left aHPC was more active for both unique events and repeated events compared to general and autobiographical facts.

The mPFC. According to the TTT model, the mPFC should be engaged during the retrieval of schemas, which shares a process of extraction from multiple events with repeated events (the personal semantics). In our study, both UE and RE were more active than AF and GF. UE and RE did not differ from one another (and neither did AF and GF). The mPFC region is large brain region that is often poorly defined (Gilboa & Marlatte, 2017), even when a dorsal and ventral division is considered. Our preliminary selection of the mPFC and frontal pole masks do not correspond impeccably to the vmPFC and dorsal mPFC. Additionally, repeated events and schemas share an ambiguous relationship. This precludes from further interpretation of our finding in relation to the update TTT (see Limitations and future directions below for a discussion of this important issue). Nevertheless, we note that the mPFC is a region of greater activity when comparing repeated events to autobiographical facts in whole brain contrasts (see Figure 6).

Overall, our data corresponds reasonably with previous findings about personal semantics and the long axis of the hippocampus if we consider autobiographical facts (Brown et al., 2018). That is, autobiographical facts were associated with significantly less activation than unique events over the right and left aHPC, but the difference was not significant on the right pHPC, and was a statistical trend on the left pHPC. Brown et al. (2018) did not include hemisphere as a factor. The studies are complementary because of their distinct methods. A number of important distinctions between the studies require a follow-up in future research. Namely, 1) we could use identical ROI (this is difficult here, because we know that effects depend on the hemisphere); 2) we should assess the content of the knowledge (what does a “know” response reflect?) and the component processes involved; 3) we could compare verbal stimuli vs. pictures; 4) we could evaluate whether memory accuracy modifies the results (e.g., in our study, we cannot verify whether the responses are accurate).

Broader focus: PM-AT networks. The repeated events vs. autobiographical facts contrast revealed greater activation for repeated events in regions associated with episodic memory in our whole brain contrasts: left posterior parahippocampal gyrus, precuneus, posterior cingulate cortex, and the vmPFC (Reagh & Ranganath, 2018). Importantly, the posterior cingulate and vmPFC activity of this contrast (see Figure 6, panel a) mirrors the contrast of general events to lifetime periods of Ford et al. (2011), see their Figure 2. All these regions are part of the posterior network of the PMAT framework (Reagh & Ranganath, 2018; Ritchey, Montchal, et al., 2015). Accordingly, our ROI analysis did indicate that repeated events was more active in the PM network than autobiographical facts. The parahippocampus is involved in processing items in relation to their context (Reagh & Ranganath, 2018). The medial prefrontal lobe is part of the autobiographical memory network; it is also within the area activated when processing schemas (Cabeza & St Jacques, 2007; Ghosh & Gilboa, 2014; Gilboa & Marlatte, 2017). The precuneus and the posterior cingulate cortex are involved in visual imagery and the "internally directed thoughts" (Addis, Wiebels, & Devitt, 2017; Leech & Sharp, 2014). Therefore, repeated events showed greater activation than autobiographical facts in areas associated with episodic memory, as indicated previously.

Data driven (e.g. decoding) or hypotheses driven approaches that would target regions of the PM and AT networks could convey a more nuanced portrait (possibly with other techniques like intracranial EEG). In the intracranial EEG study that inspired the design of this task (Foster et al., 2012; Renoult et al., 2016), the posterior medial cortex (which includes posterior cingulate cortex, retrosplenial cortex, and a broader area) responded maximally to unique events, and less to autobiographical facts, and least to rest and mathematical problems. A rare study that compared personal semantics using fMRI included lifetime period, general (extended/repeated) and unique event conditions (Ford et al., 2011). Ford et al. (2011) showed increased activity as event specificity increased (from lifetime period to unique event) in the MTL, posterior cingulate cortex, precuneus (and other regions: medial PFC, dorsolateral PFC, lateral temporal lobes, superior parietal lobes). Across studies (including this one), the PM network—together with the hippocampus and mPFC—stands out as a network that might most clearly distinguish the types of personal semantics according to a continuum perspective (Brown et al., 2018; Ford et al., 2011; Foster et al., 2012; Maguire & Mummery, 1999) see also (Sreekumar, Nielson, Smith, Dennis, & Sederberg, 2017)]. None of the regions of AT network distinguished the memory types in our whole brain or ROI analyses. Reagh & Ranganath (2018) imputed the predominance of the PM network in autobiographical memory to the importance of contextual processing in episodic recollection. Reagh & Ranganath (2018) hypothesized that personal semantics could be more closely associated with the AT network because of their emphasis on item or "entities" rather than the "situational context" (Reagh & Ranganath, 2018). In our study, the items were kept constant across conditions, thus the design might not be optimal to detect a transition from the PM to the AT network when going from unique events to personal semantics. Alternatively, like discussed in the aHPC section above, unique events could depend on semantic retrieval, in which case maybe we should not expect a difference in the AT network across memory types.

Cerebellum and occipital lobe. Cerebellar and occipital activity may not appear at the top of anyone's list when thinking about autobiographical memory. Yet, a recent meta-analysis followed-up with an fMRI study demonstrated the robust activation of the cerebellum in autobiographical memory (Addis, Moloney, Tippett, Roberts, & Hach, 2016). To this day, the role of cerebellum activity in autobiographical memory is little understood, but Addis et al. (2016) speak of its association with semantic processing and working memory. For us, the superior regions of the cerebellum were part of the large cluster encompassing a posterior cluster (a large region of the occipital lobes, parahippocampal gyrus, precuneus, posterior cingulate). We also found separate clusters the right crus II and bilateral IX (see Table 4). Interestingly, autobiographical facts was more active than repeated events in the right VIIb and left crus II. In contrast, we found no cerebellar cluster that was more active for autobiographical facts compared to general facts. Note that motor responses could be a confound for the contrast with the odd even tasks (so these must be interpreted cautiously), but not when memory types are compared to one another. Future research will be essential to understand when and why regions of the cerebellum become active when processing personal facts and events.

In this study, the cluster of activation associated with regions of the posterior medial network extended to the occipital lobe, perhaps because of visual imagery (Lee & Baker, 2016; McCormick et al., 2015). We found those differences for all memory types compared to the baseline condition, as well as several areas of differences within the occipital lobe for the memory contrasts (AF vs. GF, AF vs. RE, RE vs. AF, RE vs. UE). [Note the presence of larger clusters, particularly for the first set of contrasts, limits the ability to determine the area with certainty (Roiser et al., 2016).] A meta-analysis of autobiographical memory found activity in the occipital region for eight out of the 24 studies (Svoboda et al., 2006). Although our task was fairly similar visually across conditions, it was not identical (e.g., one number vs. a sentence). Despite the necessity for circumspection, we propose that the occipital activity coincides with activity in the PM network (Ritchey, Libby, et al., 2015), and could stem from visual imagery, scene construction, or other such processes associated with autobiographical memory.

Limitations and future directions. A challenge to studying personal semantics comes from their intermediate status. General facts was indeed different from unique events commensurate with their proposed distinction as two memory systems and previous literature (Addis et al., 2016; Svoboda et al., 2006). The differences of the personal semantics to the extremes of declarative memory are necessarily smaller, and constrained to be within the range of the general semantics and episodic memory difference. If, for example, the effect size of the general semantics vs. episodic memory contrast was .50, we would expect a smaller effect (say .25) for a contrast of a personal semantics to either general semantics or episodic memory. Unsurprisingly, those effects are harder to detect. In our previous study, the amplitude of the LPC for general facts was also smaller than autobiographical facts, repeated events, and unique events (Renoult et al., 2016). However, the difference between the intermediate LPC amplitude of personal semantics and the maximal unique event was not significant after correction for multiple comparisons ($\eta^2_p = .26$ for repeated events, and $\eta^2_p = .18$ for autobiographical facts). We can only tentatively conclude to a personal semantics distinction with the two extremes of declarative memory in such cases. In this study, we acquired the maximum possible of data per participant with over 70 minutes of task time, and the sample size was large for an fMRI study. In the absence of pilot data, we expected that around 30 participants would be sufficient based on prior similar fMRI studies (which had closer to 20 participants; e.g., Addis, Roberts, & Schacter, 2011; St-Laurent, Abdi, Burianová, & Grady, 2011) and in keeping with current publication standards. An important next step (that we intend to implement) will be to use this fMRI dataset to estimate the required sample size to detect differences between memory types in the HPC (e.g., with Neuropower; Durnez et al., 2016). We intend to replicate our study with at least two changes.

Firstly, the activity in the pHPC, together with regions of the posterior network, is thought to be associated with perceptual details (Sekeres et al., 2018). We plan to obtain ratings of visual imagery after each trial instead of the response screen. That is, in the current version of the fMRI study, participants responded after seeing the cue and sentence. In the next version, the participants would respond as soon as they take their decision when the sentence is displayed, similar to Renoult et al. (2016), and the rating of visual imagery would be obtained after each trial. This modification would allow the addition of a subjective rating for each trial without lengthening an already long experiment. Alternatively, we could verify whether each trial was processed in the expected way (e.g., unique instance, repeated, etc.) inside or outside the scanner (note that we obtained debriefing data outside the scanner for this study, but the data were not coded).

Secondly, surprisingly, repeated events showed an increased activity compared to unique events in occipital regions, whereas unique event was not more active in any region (significantly). We modified one of the cues "when at school" to "when at a clinic", which we assumed to be reasonably frequent for most people. The goal was to ensure that the stimuli are appropriate for any age group for an eventual comparison with older adults. However, combined with our instruction to think about the last year, this cue might have led to trying to retrieve multiple unique events rather than the gist of the repeated events. In our follow-up study, we will use the same cues than Renoult et al. (2016).

Future work could also distinguish between phases of retrieval. The differences in brain activity between "general" (repeated/extended) events and a unique event depended on the stage of retrieval in Holland et al. (2011). In particular, unique events showed increased activity relative to general events during the earlier construction phase [e.g., lateral temporal lobes, right frontal pole, right precuneus, right posterior and anterior cingulate cortex, (ventral and dorsal) lateral prefrontal cortex], but not during later elaboration phase (Holland et al., 2011). On the contrary, the general events were associated with increased activity compared to unique events during elaboration (e.g., middle/medial/superior/inferior frontal gyri on the right or left, right lateral parietal cortex), but not construction (Holland et al., 2011). In our study, our epoch of interest (lasting 6 seconds) corresponds roughly to the construction phase. This arguably short period of time allows us to match the memory conditions in cognitive demand. The retrieval of a semantic fact is faster than the retrieval and elaboration of a personal event in all its details (Chang, 1986; Conway, Pleydell-Pearce, Whitecross, & Sharpe, 2002; Svoboda et al., 2006), as discussed in (Renoult et al., 2016)]. Nevertheless, we would benefit from extracting and analyzing brain activity while taking into account the time course (e.g., by TR, with Partial Least Squares). If the retrieval of autobiographical memory depends on a honing process, like suggested previously, we could expect greater difference between unique events and personal semantics in later stages. This proposal runs counter the results of Holland et al. (2011), but merits future investigation.

The stimuli in the autobiographical facts condition may not be homogeneous: some may be experience-far and others may be experience-near. The delineation of our stimuli as "experience-near" or "experience-far" is ambiguous. However, approximately 12 sentences refer to a spatial location or to an activity with a spatial connotation (e.g., a mall, driving on the highway); this could make them experience-near according to the definition of Grilli and Verfaellie (2016). In future analyses, we could remove these experience-near autobiographical facts to only include stimuli that are the most reflective of experience-far autobiographical facts. This subset of stimuli could reveal that autobiographical facts do not differ from general facts in any region of the hippocampus[1].

In future work, we would benefit from a better understanding how schemas relate to repeated events, and other types of personal semantics (Ghosh & Gilboa, 2014; Gilboa & Marlatte, 2017). According to Gilboa & Marlatte (2017): "Schemas are higher-level knowledge structures that organize lower-level representations from long-term memory." In the language of

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[1] Dr. Matthew Grilli made this observation and suggested this future direction.

models of autobiographical memory, self-knowledge, lifetime periods, and repeated events could provide the organizational structure for unique events (Conway, 2009; Conway & Pleydell-Pearce, 2000; Renoult et al., 2012). The extraction from multiple events is *one* of the elements of schemas (Ghosh & Gilboa, 2014). This study's repeated events retain an episodic quality unlike schemas, e.g., remembering the gist of several instances of sharing a drink with friends at a girl's night out or during the playoff hockey game. This diverges with the noetic rather than autonoetic nature of the other types of personal semantics (and schemas). Therefore, schemas could be further removed from events. For example, "I remember serving food to the homeless every Christmas" could be a type of repeated event, whereas "serving food to the homeless" (in general) might be a schema (see p. 204 for a similar idea; Barsalou, 1988). This division would be similar to the idea of experience-near and experience-far autobiographical facts (Grilli & Verfaellie, 2016), which we hypothesized that could be relevant for self-knowledge as well (Tanguay et al., 2018). However, in practice it would be difficult to dissociate schemas from autobiographical facts (if these are indeed different). Rather than presenting stimuli that differ in the presence of context, we could also compare a "recollection" (autonoetic) response to a "know" (noetic) response to investigate whether these produce different brain activity for repeated events.

The construct of repeated events should be further refined to facilitate its full use in research and applications in clinical settings. For example, in Strikwerda-Brown, Mothakunnel, Hodges, Piguet, and Irish, (2018) categorized "extended events", such as repeated events and life periods, separately from personal semantics. That is an interesting proposal, but as of yet, we still need more research to fully understand the overlap and distinctions between memory types. With the recent research on personal semantics (Grilli et al., 2018; Grilli & Verfaellie, 2016; Renoult et al., 2015, 2016; Strikwerda-Brown et al., 2018; Tanguay et al., 2018), including this one, we are progressing towards a more exhaustive model declarative memory.

Acknowledgements

Many thanks to participants who generously took part in the study. Thanks to Sara Trincao-Batra and Talia Chin who helped with recruitment, testings and/or preparing the data for analysis. We are grateful for the dedication of the team at the Brain Imaging Centre of the Royal Ottawa. We thank Drs. Andra Smith, Stuart Fogel and Ovidiu Lungu for advice, especially at the early stages. We thank Drs. Maureen Ritchey and Charan Ranganath for providing information and masks for the PMAT analyses. Lastly, immense thanks to those who contributed to fMRIPREP, and to the scientific community that promotes replicability and transparency in fMRI research.

Annick Tanguay, Daniela J. Palombo, Louis Renoult, Patrick S. R. Davidson designed study, and agreed on the analyses plan. AT processed and analyzed the MRI data with support from DJP. AT wrote this version of this manuscript and is responsible for the interpretation of the data with critical input from PSRD. The work was supported by funds from the Natural Sciences and Engineering Research Council (NSERC) of Canada to PSRD, from the British Academy to LR, and a NSERC Canada Graduate Scholarship and an Ontario Graduate Scholarship to AT.

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Appendix A - Stimuli

Run	Unique Events(UE): Cue	Unique Events: Sentence
A	Yesterday	I ate a chocolate?
A	Last week-end	I hugged a friend?
A	This week	I ate a sandwich?
A	Last night	I sang a tune?
A	This week	I went to the movies?
A	Today	I read a newspaper?
A	Today	I spent money?
A	Yesterday	I read a magazine?
A	This morning	I kissed somebody?
A	Last week-end	I bought a gift?
B	Yesterday	I listened to music.
B	Yesterday	I washed dishes.
B	Yesterday	I wore white socks.
B	This week	I worked out.
B	Last night	I cooked dinner.
B	This week	I played with a dog.
B	This morning	I went to the bank.
B	Last night	I had a drink.
B	Today	I checked the news online.
B	Last night	I drove my car.
C	Last night	I used a computer.
C	Today	I washed my face.
C	This week	I ate at a restaurant.
C	Last night	I slept well.
C	Last week-end	I went dancing.
C	This week	I bought a CD.
C	Last week-end	I played a video game.
C	Today	I missed a meeting.
C	This morning	I prayed.
C	This week	I gave to a charity.
D	Today	I ate breakfast.
D	Yesterday	I logged on to Facebook.
D	This morning	I drank coffee.

D	Today	I talked on the phone.
D	Last week-end	I rented a movie.
D	This week	I watched sports.
D	This week	I ate fries.
D	Yesterday	I took a picture.
D	Today	I went to a pharmacy.
D	This week	I went swimming.
E	This week	I talked to a family member.
E	Yesterday	I ate fruit.
E	Last night	I took a shower.
E	Last night	I watched tv.
E	This week	I went shopping.
E	Last night	I ate pizza.
E	Last week-end	I ate pancakes.
E	This morning	I went to the gym.
E	Last week-end	I visited a museum.
E	Last week-end	I had a cold.
F	Yesterday	I sent a text message.
F	Yesterday	I wore jeans.
F	This morning	I woke up early.
F	Today	I had chicken.
F	Last night	I went to bed early.
F	Yesterday	I took a nap.
F	This morning	I drank juice.
F	Yesterday	I ate candy.
F	Last week-end	I watered a plant.
F	Last night	I heard jokes.
G	This morning	I checked my email.
G	Yesterday	I brushed my teeth.
G	Last week-end	I drove on a highway.
G	This week	I read a book.
G	This morning	I made my bed.
G	Today	I listened to the radio.
G	Last week-end	I went to the mall.
G	Today	I went on a walk.
G	Last week-end	I did my laundry.
G	Yesterday	I took a course.
Run	**Repeated Events (RE): Cue**	**Repeated Events: Sentence**
A	When alone	I have gone on a walk?

A	When alone	I have slept well?
A	When at work	I have worn jeans?
A	When going to a clinic	I have driven my car?
A	When on the bus	I have read books?
A	When on the bus	I have talked on the phone?
A	When at work	I have gone swimming?
A	When at work	I have missed a meeting?
A	When at work	I have washed dishes?
A	When at work	I have watched TV?
B	When alone	I washed my face.
B	When at work	I have eaten a sandwich.
B	When on vacation	I have gone shopping.
B	When on vacation	I have gone to the mall.
B	When on vacation	I have kissed somebody.
B	When shopping	I ate fruit.
B	When going to a clinic	I have driven on a highway.
B	When on the bus	I have eaten fries.
B	When on vacation	I have been to the gym.
B	When on vacation	I have been to the pharmacy.
C	When at work	I have listened to music.
C	When at work	I have spent money.
C	When alone	I have had a drink.
C	When alone	I have played a video game.
C	When shopping	I have drunk juice.
C	When alone I	have eaten at a restaurant.
C	When alone	I have gone dancing.
C	When alone	I have gone to the movies.
C	When alone	I have played with a dog.
C	When alone	I have rented a movie.
D	When on the bus	I have checked my email.
D	When on the bus	I have sent a text message.
D	When at work	I have eaten candy.
D	When at work	I have eaten chicken.
D	When at work	I have logged on to Facebook.
D	When alone	I have watched sports.
D	When at a clinic	I have checked the news online.
D	When at a clinic	I have listened to the radio.
D	When at a clinic	I brushed my teeth.
D	When at a clinic	I have talked to a family member.
E	When on vacation	I have taken naps.

E	When at work	I have used a computer.
E	When shopping	I have drunk coffee.
E	When shopping	I have eaten a chocolate.
E	When shopping	I have heard jokes.
E	When shopping	I have sung a tune.
E	When on vacation	I have worked out.
E	When shopping	I have eaten pizza.
E	When shopping	I have given to charity.
E	When with friends	I have done my laundry.
F	When on vacation	I have hugged a friend.
F	When on vacation	I have taken a shower.
F	When shopping	I have taken a picture.
F	When with friends	I have bought a gift.
F	When with friends	I have cooked dinner.
F	When with friends	I have eaten breakfast.
F	When with friends	I have gone to bed early.
F	When with friends	I have made my bed.
F	When with friends	I have prayed.
F	When with friends	I have read a magazine.
G	When on vacation	I have woken up early.
G	When shopping	I have worn white socks.
G	When with friends	I have eaten pancakes.
G	When with friends	I have gone to the bank.
G	When on the bus	I have read a newspaper.
G	When with friends	I have visited a museum.
G	When on vacation	I have bought CDs.
G	When on vacation	I have had a cold.
G	When on vacation	I have taken a course.
G	When on vacation	I have watered a plant.
Run	**Autobiographical Facts:cue**	**Autobiographical Facts (AF) :Sentence**
A	Sometimes	I wear jeans?
A	Sometimes	I go on walks?
A	Rarely	I go to the pharmacy?
A	Rarely	I read a newspaper?
A	Very often	I have a drink?
A	Very often	I take pictures?
A	Often	I take naps?
A	Very often	I drink juice?
A	Sometimes	I pray?
A	Every day	I take a course?

B	Very often	I use a computer.
B	Very often	I do my laundry.
B	Rarely	I visit a museum.
B	Rarely	I eat candy.
B	Rarely	I have a cold.
B	Sometimes	I go swimming.
B	Often	I read magazines.
B	Usually	I go to bed early.
B	Often	I watch sports.
B	Every day	I kiss somebody.
C	Often	I talk to a family member.
C	Usually	I sleep well.
C	Rarely	I buy CDs.
C	Every day	I spend money.
C	Very often	I log on to Facebook.
C	Every day	I hear jokes.
C	Very often	I go shopping.
C	Every day	I listen to the radio.
C	Often	I go to the mall.
C	Every day	I eat fruits.
D	Often	I take showers.
D	Often	I listen to music.
D	Every day	I send text messages.
D	Every day	I wash the dishes.
D	Usually	I wake up early.
D	Rarely	I buy gifts.
D	Rarely	do I eat chocolate.
D	Every day	I drink coffee.
D	Very often	I play video games.
D	Often	I miss a meeting.
E	Very often	I talk on the phone.
E	Sometimes	I eat pancakes.
E	Sometimes	I hug a friend.
E	Very often	I work out.
E	Sometimes	I go to the gym.
E	Every day	I check the news online.
E	Often	I go dancing.
E	Usually	I give to charity.
E	Very often	I brush my teeth.
E	Usually	I wash my face.

F	Usually	I eat breakfast.
F	Sometimes	I eat chicken.
F	Sometimes	I sing a tune.
F	Rarely	I rent movies.
F	Rarely	I eat fries.
F	Usually	I wear white socks.
F	Every day	I make my bed.
F	Every day	I eat pizza.
F	Rarely	I eat sandwiches.
F	Very often	I drive my car.
G	Sometimes	I go to the movies.
G	Often	I check my email.
G	Sometimes	I go to the bank.
G	Very often	I watch TV.
G	Rarely	I play with dogs.
G	Rarely	I drive on a highway.
G	Rarely	I read books.
G	Often	I eat at restaurants.
G	Rarely	I cook dinner.
G	Often	I water a plant.
Run	**General Facts: cue**	**General Facts (GF): Sentence**
A	Most people	eat chocolate?
A	Most people	eat pizza?
A	Some people	go to bed early?
A	Some people	send text messages?
A	Many people	water plants?
A	Few people	pray?
A	Few people	go to the bank?
A	Everyone	logs on to Facebook?
A	No one	misses meetings?
A	Most people	eat fruit?
B	Many people	drink juice.
B	Some people	eat pancakes.
B	Some people	eat sandwiches.
B	Many people	have a drink.
B	Few people	make their bed.
B	Most people	kiss others.
B	Everyone	reads a newspaper.
B	Few people	go to the gym.
B	Few people	give to charity.

B	Many people	have a cold.
C	Many people	drink coffee.
C	Many people	eat fries.
C	Some people	work out.
C	Everyone	watches TV.
C	Everyone	goes to the pharmacy.
C	Everyone	wears white socks.
C	Few people	read books.
C	No one	sleeps well.
C	No one	wakes up early.
C	Everyone	eats chicken.
D	Most people	take showers.
D	Many people	go to the movies.
D	Most people	talk to family members.
D	Some people	play with dogs.
D	Many people	visit museums.
D	No one	spends money.
D	Few people	go dancing.
D	Everyone	watches sports.
D	No one	buys CDs.
D	Most people	play video games.
E	Most people	wear jeans.
E	Some people	eat candy.
E	Many people	hug friends.
E	Many people	take a course.
E	Everyone	buys gifts.
E	No one	takes naps.
E	No one	goes to the mall.
E	Few people	take pictures.
E	No one	goes swimming.
E	Everyone	brushes their teeth.
F	Some people	skip breakfast.
F	Everyone	talks on the phone.
F	Many people	cook dinner.
F	Some people	go on walks.
F	Everyone	does their laundry.
F	Everyone	hears jokes.
F	Few people	go shopping.
F	Few people	listen to the radio.
F	No one	sings tunes.

F	Few people	check the news online.
G	Most people	drive on the highway.
G	Some people	rent movies.
G	Most people	listen to music.
G	Most people	drive their car.
G	Most people	read magazines.
G	Everyone	checks their email.
G	Few people	use a computer.
G	No one	eats at restaurants.
G	No one	washes the dishes.
G	No one	washes their face.

Appendix B - Debriefing

We have a lot of information about what you did. We have your brain activity and your responses, but we don't have your actual thoughts. I am going to ask you to think back to some of the sentences during the last task and what you were thinking when responding to them. Please give me as much detail as possible about what you were thinking, for example: if you were thinking about yourself or other people, if it is something you imagined or just know, if events/facts came to mind and what they were, etc. It is possible you don't remember your original thoughts or maybe you didn't have particular thoughts. That's totally fine, just tell me what you remember.

[Note: Do verify that the answer is complete, but due to time constraints, do not proceed to specific probes. Ask for clarifications as necessary.]

General Facts

- Some people skip breakfast?
- Most people talk to family members?
- Most people take showers?
- No one spends money?

Autobiographical facts

- Usually I eat breakfast?
- Often I talk to a family member?
- Often I take showers?

- Every day I spend money?

Repeated events

- When with friends I have eaten breakfast?
- When at a clinic I have talked to a family member?
- When on vacation I have taken a shower?
- When at work I have spent money?

Unique Events

- Today I ate breakfast?
- This week I talked to a family member?
- Last night I took a shower?
- Today I spent money?

The ERP correlates of self-knowledge: Are assessments of one's past, present, and future traits closer to semantic or episodic memory?

Annick N. Tanguay[a, *], Lauren Benton[b], Lorenza Romio[c], Carolin Sievers[c], Patrick S. R. Davidson[a], Louis Renoult[c]

[a] School of Psychology, University of Ottawa, Ontario, Canada

[b] Department of Neuroscience, Dickinson College, Pennsylvania, USA

[c] School of Psychology, University of East Anglia, Norfolk, UK

Author Note

The final version of this paper is: Tanguay, A. N., Benton, L., Romio, L., Sievers, C., Davidson, P. S. R., & Renoult, L. (2018). The ERP correlates of self-knowledge: Are assessments of one's past, present, and future traits closer to semantic or episodic memory? Special issue: Autobiographical memory. *Neuropsychologia, 110,* 65-83. https://doi.org/10.1016/j.neuropsychologia.2017.10.024

Abstract

Self-knowledge concerns one's own preferences and personality. It pertains to the self (similar to episodic memory), yet does not concern events. It is factual (like semantic memory), but also idiosyncratic. For these reasons, it is unclear where self-knowledge might fall on a continuum in relation to semantic and episodic memory. In this study, we aimed to compare the event-related potential (ERP) correlates of self-knowledge to those of semantic and episodic memory, using N400 and Late Positive Component (LPC) as proxies for semantic and episodic processing, respectively. We considered an additional factor: time perspective. Temporally distant selves have been suggested to be more semantic compared to the present self, but thinking about one's past and future selves may also engage episodic memory. Twenty-eight adults answered whether traits (e.g., *persistent*) were true of most people holding an occupation (e.g., soldiers; semantic memory condition), or true of themselves 5 years ago, in the present, or 5 years from now (past, present, and future self-knowledge conditions). The study ended with an episodic recognition memory task for previously seen traits. Present self-knowledge produced mean LPC amplitudes at posterior parietal sites that fell between semantic and episodic memory. Mean LPC amplitudes for past and future self-knowledge were greater than for semantic memory, and not significantly different from episodic memory. Mean N400 amplitudes for the self-knowledge conditions were smaller than for semantic memory at sagittal sites. However, this N400 effect was not separable from a preceding P200 effect at these same electrode sites. This P200 effect can be interpreted as reflecting the greater emotional salience of self as compared to general knowledge, which may have facilitated semantic processing. Overall, our findings are consistent with a distinction between knowledge of

others and self-knowledge, but the closeness of self-knowledge's neural correlates to either semantic or episodic memory appears to depend to some extent on time perspective.

Keywords*:* Personal semantics, Self-knowledge, Episodic memory, Semantic memory, Time perspective, ERPs, N400, LPC

Highlights

- Self-knowledge (SK) is thought to be distinct from semantic and episodic memory (EM)
- SK's relationship to semantic and EM may depend to some extent on time perspective
- LPC amplitude distinguished EM from present but not from past or future SK
- P200, N400 and LPC amplitudes differentiated semantic memory from SK
- The relationship between SK's LPC and episodic memory depends on time perspective

The ERP correlates of self-knowledge: Are assessments one's past, present, and future traits closer to semantic or episodic memory?

1. Introduction

The ancient Greeks' invitation to "Know thyself" resonates to this day in popular culture. Despite this, self-knowledge is rarely integrated into current models of declarative memory. Declarative memory is usually described as consisting of semantic and episodic memory, which are depicted as two branches of a tree diagram (Squire & Wixted, 2015) or two extremes of a continuum (e.g., Jacoby & Craik, 1979; Cabeza & St Jacques, 2007). At one extreme, semantic memory concerns knowledge of facts that are detached from their context of acquisition and shared with other people in the culture (Binder & Desai, 2011; Lambon Ralph, Jefferies, Patterson, & Rogers, 2017). At the other extreme, episodic memory concerns our ability to remember events from our past and related contextual information (Tulving, 2002). Between these two extremes arguably falls *personal semantics*, which (like semantic memory) are factual and limited in spatial/temporal details, but (like episodic memory) are idiosyncratically personal. Personal semantics were broken down into four types in a recent review and taxonomy (Renoult, Davidson, Palombo, Moscovitch, & Levine, 2012). Two of the four types were hypothesized to be closer to episodic memory (i.e., memory for repeated events, autobiographically significant concepts), one as being closer to semantic memory (i.e., autobiographical facts), and one as being relatively distinct from both (i.e., self-knowledge; see Figure 1; Renoult et al., 2012). Recently, we have used ERPs to compare repeated events, autobiographically significant concepts, and autobiographical facts to semantic and episodic memory (Renoult et al., 2015, 2016). Here we turn to the fourth operationalization of personal semantics: self-knowledge.

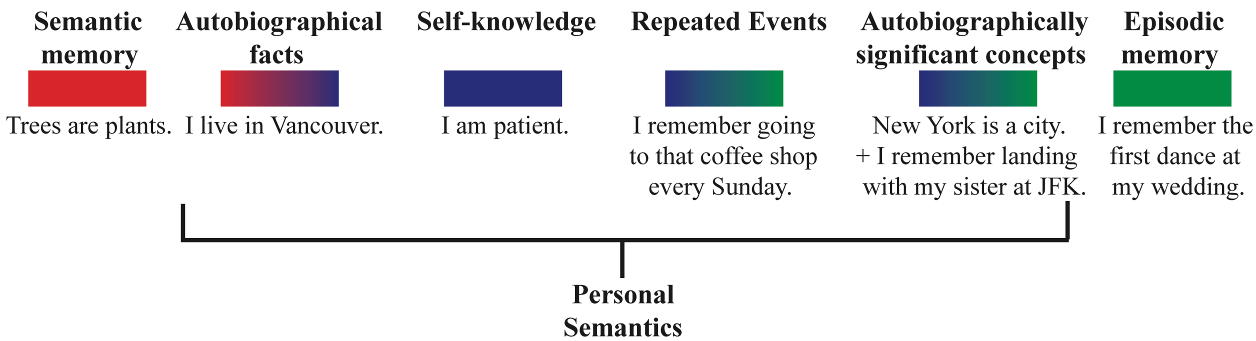

Figure 1. The 4 types of personal semantics in relation to semantic and episodic memory.

1.1 Self-knowledge

Self-knowledge entails evaluative judgments of oneself, and includes knowledge of one's own traits and preferences (Renoult et al., 2012). Self-knowledge is arguably a highly abstract form of knowledge (Grilli & Verfaellie, 2014; Renoult et al., 2012), which in part could explain its apparent independence from episodic and semantic memory impairment (Klein & Gangi, 2010). For example, amnesic patients can describe their post-morbid personality, indicating that self-knowledge can be updated despite episodic memory impairment (Craver, Kwan, Steindam, & Rosenbaum, 2014; Grilli & Verfaellie, 2015). In addition, self-knowledge can remain intact when another kind of personal semantics is impaired [i.e., autobiographical facts: knowledge of facts about oneself that resemble an autobiographical "CV", including jobs, hobbies, diplomas; etc. (Klein, Cosmides, & Costabile, 2003; Klein, Cosmides, Costabile, & Mei, 2002; Renoult et al., 2012; Warrington & McCarthy, 1988)]. The reverse pattern has also been found: A patient with damage to medial prefrontal cortex (mPFC) showed impaired insight into his own traits (i.e., self-knowledge) in the face of accurate knowledge of an acquaintance's traits (Marquine et al., 2016).

1.2 Knowledge of past, present and future selves

Conceptualizations of self-knowledge usually focus on the present self, but knowledge can extend to past selves and future "possible selves" (Markus & Nurius, 1986) or the "temporally extended self" (Prebble, Addis, & Tippett, 2013). Two perspectives have been taken on the relative contribution of semantic and episodic memory to self-knowledge across time. From the first perspective, several have posited that episodic memory shapes self-knowledge through the elaboration of self-defining events in one's past and future, and contributes to a sense of continuity of one's identity in time (Demblon & D'Argembeau, 2016; Prebble et al., 2013). In these respects, traits are concepts that can acquire a personal significance through events, particularly when considering the past or the future (Demblon & D'Argembeau, 2016; Renoult et al., 2015). Semantic memory is usually argued to be associated with a subjective awareness based in the present, whereas episodic memory is associated with a subjective awareness oriented towards the past and possibly also the future (Tulving, 2001, 2002). This difference in temporal orientation might suggest that present self-knowledge is more similar to semantic memory, whereas past and future self-knowledge are more similar to episodic memory. However, the relationship between temporal orientation and episodic memory lends itself to potential confusion. A case study of amnesic patient KC found that he understood time as a concept, and he could orient to his past, present, and future (that is, he was not "stuck in the present"; Craver et al., 2014). To nuance this perspective, one might consider episodic memory as associated with awareness of oneself in a specific temporal context, including the ever-changing present. If so, the neural correlates of present self-knowledge may be intermediate between semantic and episodic memory (Prebble et al., 2013). Present self-knowledge shares the personal and introspective characteristics of episodic memory that are absent from semantic memory. The (re)construction of self-defining events and the maintenance of a sense of continuity of one's identity may additionally engage episodic memory in the past and the future. Although neuropsychological studies indicate that self-knowledge is independent of episodic memory (Klein & Gangi, 2010), it may become less so when the self-knowledge is accompanied by a spatial or temporal context (for example, the distant past or the future; see Grilli & Verfaellie, 2016).

From the second perspective, however, some have suggested that semantic memory is essential for thinking about the past and future, particularly when events are novel (Irish, Addis, Hodges, & Piguet, 2012; Irish & Piguet, 2013; Wang, Yue, & Huang, 2016; Weiler, Suchan, Koch, Schwarz, & Daum, 2011) . Semantic memory encompasses a variety of knowledge about the world, including knowledge of one's culture's typical "life periods" or "life chapters" and what novel experiences might involve (Thomsen, 2015). For example, young adults could muse about or appraise their future identity in relation to the prototypical life narrative: (*I will graduate from university, obtain a fulfilling job, buy a house, get married, have children*, et cetera). As the case of KC has shown, semantic memory includes knowledge of time as a concept, and we note that he could order his autobiographical facts mostly correctly (Craver et al., 2014). The construal-level theory of psychological distance of Trope & Liberman (2010) stipulates that temporal distance makes us think more abstractly and thus in a more meaning-based (i.e., semantic) than experience-based (i.e., episodic) manner. In a similar logic, La Corte and Piolino (2016) have suggested that thinking about a distant future increases the use of general or semanticized memories (including personal semantics) relative to a closer time. Concordant neuroimaging findings indicate that the neural correlates of thinking about temporally distant selves may be more similar to thinking about other people compared to the present self (D'Argembeau et al., 2008, 2010; see also Palombo, Hayes, Peterson, Keane, &

Verfaellie, in press). Taken together, this second perspective suggests that past and particularly future self-knowledge may rely more on semantic memory than present self-knowledge does.

1.3.The present study

Personal semantics are often compared to either semantic or episodic memory alone, but rarely to both. Yet, as seen in the review above, both semantic and episodic memory could be significantly related to self-knowledge. In the present study, we designed a novel task to compare the behavioral and electrophysiological correlates of self-knowledge to semantic and episodic memory in a within-subject design, and tested whether the temporal orientation of the self-knowledge influences the relationship to semantic versus episodic memory. Thus, the study included five closely matched memory conditions: semantic and episodic memory, and past, present, and future self-knowledge. We operationalized self-knowledge as knowledge of one's own personality traits, as this has been the most frequently studied operationalization (Renoult et al., 2012). In the self-knowledge tasks, participants decided whether target words (e.g., *generous*) reflected their past traits, present traits, or future traits. In the semantic memory task, participants indicated whether the words reflected the traits of most people holding a certain occupation. The episodic memory task also involved being shown traits, but deciding whether each trait had been seen previously during the study or not. We used positive (e.g., *generous*) and negative (e.g., *jealous*) traits, which we expected to show a distinct behavioral pattern across time perspectives. People tend to exhibit an optimistic belief that their personality improves through time and will become even "better than average" in the future (D'Argembeau et al., 2010; Kanten & Teigen, 2008; Wilson & Ross, 2001).

1.3.1 Semantic versus episodic: N400 versus LPC event-related potentials. We examined the neural correlates of the memory conditions using electroencephalography (EEG). We focused on two ERP components: the N400 and the LPC. The N400 is a negative amplitude ERP component occurring 250 to 500 ms after stimulus onset, maximal over centro-parietal sites (Kutas & Federmeier, 2011). The N400 is sensitive to semantic processing; for example it is larger when words are unexpected or incongruent within the context of a sentence (e.g., "I take coffee with cream and *dog*"; Kutas and Federmeier (2011), but also, importantly, when words violate our knowledge of the world (Hagoort, Hald, Bastiaansen, & Petersson, 2004). In addition to these contextual effects, the N400 is also sensitive to the structure of semantic memory, as demonstrated for example by effects of concreteness, semantic category or semantic richness (reviewed in Renoult, 2016). Its main neural generators are in the left temporal and inferior parietal cortex, consistent with N400's role in the binding of multimodal conceptual representations (Kutas and Federmeier, 2011; Renoult, 2016). Lesion studies have shown that left temporal-parietal lesions reduce N400 amplitudes and impair semantic comprehension (Friederici, Hahne, & von Cramon, 1998; Hagoort, Brown, & Swaab, 1996; Swaab, Brown, & Hagoort, 1997).

The Late Positive Component (LPC) – also known as "the parietal old new effect" – is a positive amplitude component occurring 500 to 800 ms after stimulus onset, with a posterior parietal scalp distribution (Rugg & Curran, 2007). The LPC is reliably associated with episodic recollection, although it is also sensitive to the "true" status of the memory, and memory strength (Brezis, Bronfman, Yovel, & Goshen-Gottstein, 2016; Friedman & Johnson, 2000; Rugg & Curran, 2007; Wilding & Ranganath, 2011). Bilateral hippocampal lesions greatly reduce the LPC (Addante, Ranganath, Olichney, & Yonelinas, 2012; Düzel, Vargha-Khadem, Heinze, &

Mishkin, 2001; Olichney et al., 2000). Simultaneous EEG-fMRI associate the LPC with activity in the right posterior hippocampus, and parahippocampal and retrosplenial cortices (Hoppstädter, Baeuchl, Diener, Flor, & Meyer, 2015). The LPC may be sensitive to self-relevance as suggested in Coronel & Federmeier (2016), based partly on Fields and Kuperberg (2012), but a recent study indicates that the relationship may depend on various factors (Fields & Kuperberg, 2016; see Renoult et al., 2016). Thus, the N400 and the LPC are neural correlates of semantic and episodic processing, respectively, and they are distinguishable from one another (Düzel et al., 2001; Olichney et al., 2000).

In a recent study, Coronel and Federmeier (2016) compared self-knowledge - operationalized as knowledge of personal preferences (e.g., do I like to wear pink clothes?) - to knowledge of people's preferences in general (e.g., do most people like to wear pink clothes?). Self-knowledge was associated with a larger LPC amplitude compared to others' preferences at centro-parietal sites (Coronel & Federmeier, 2016). The N400 tended to be less negative for personal than others' preferences at 26 sites over the scalp (qualitatively), but the scalp distribution, latency, and amplitude were not significantly different. Coronel and Federmeier's (2016) main goal was to compare the N400 of personal semantics and semantic memory, so they did not include a memory condition equivalent to episodic memory (e.g., did I wear pink clothes yesterday?). Other recent studies have demonstrated that personal semantics can be associated to different degrees with the N400 or LPC components (Choi, Cha, Jung, & Kim, 2017; Renoult et al., 2015, 2016).

EEG allows us to test the opposing (but not mutually exclusive) hypotheses about the neural correlates of self-knowledge reviewed in Section 1.2 above (see also Table 1): past and future self-knowledge may involve more semantic processing or more episodic processing, or possibly more of both, relative to present self-knowledge. The last scenario would translate into: 1) A maximal N400 – the index of semantic processing – for semantic memory, followed by past and future self-knowledge, while it would be minimal for episodic memory (and possibly also for present self-knowledge), and 2) a maximal LPC – the index of episodic processing – for episodic memory, followed by past and future self-knowledge, and minimal for semantic memory, with present self-knowledge in the intermediate between semantic and episodic memory. While the above hypotheses for a time-related modulation of the LPC have a solid basis, the direction of a temporal modulation for the N400 lends itself to multiple interpretations. Present self-knowledge shares important conceptual similarities with semantic memory, rendering the opposite hypothesis equally likely (i.e., semantic memory > present self-knowledge > past and future self-knowledge). For instance, present self-knowledge represents best the stable (present/atemporal) portion of personality (Anusic & Schimmack, 2016); that is, the stable traits that are detached from a context of acquisition (or projection). Lastly, in keeping with a vast literature (Friedman & Johnson, 2000; Rugg & Curran, 2007; Wilding & Ranganath, 2011), modulation of the LPC by the old/new effect (i.e., greater amplitude for hits than correct rejections) should be observed for the recognition memory task.

Table 1: Hypotheses for ERP data based on the first or second perspective.

Predictions based on the first perspective (self defined through events)			
N400			
Maximal (i.e., most negative)			Minimal (i.e., least negative)
semantic memory task	>/= present self	>/= past and future self	episodic memory task

LPC			
Maximal (i.e., most positive)			Minimal (i.e., least positive)
episodic memory task	>/= past and future self	>/= present self	semantic memory task
Predictions based the second perspective (self-construal theory)			
N400			
Maximal (i.e, most negative)			Minimal (i.e, least negative)
semantic memory task	>/= past and future self	>/= Present self	episodic memory task
LPC			
Maximal (i.e., most positive)			Minimal (i.e., least positive)
episodic memory task	>/= present self	>/= past and future self	semantic memory task

2. Methods

2.1 Participants

Thirty-two participants (15 men) took part in the study. They were aged between 18 and 33 years old (mean age: 20.97 ± 0.66 *SE*; one participant did not report his age), and had completed an average of 14.84 (± 0.39 *SE*) years of education. Undergraduate psychology students at the University of East Anglia were recruited through an online system and awarded partial course credit. Others were recruited through a participant panel at the School of Psychology of the University of East Anglia; they contacted the researcher after obtaining information about the study via email, and received £13 for their participation. Exclusion criteria consisted of a history of head injury with loss of consciousness longer than 5 min, other neurological or medical conditions known to compromise brain function, and active substance abuse. All participants had normal or corrected-to-normal vision, were English native speakers, and were right-handed. Two participants did not meet eligibility criteria, and two were excluded due to a low number of yes responses (< 15), resulting in a sample of 28 participants.

The study received ethics approval from the Research Ethics Committee of the School of Psychology at the University of East Anglia (2016-0195-000370) and the Health Sciences and Science Research Ethics Board of the University of Ottawa (H10-16-20).

2.2 Experimental tasks

Our study included five memory conditions: semantic memory, episodic memory, and past, present, and future self-knowledge conditions. The inclusion of these self-knowledge conditions was inspired by D'Argembeau et al. (2010). A key difference was that we increased the number of traits from 20 to 80 per condition to adapt the paradigm to EEG.

2.2.1 Stimuli. We retrieved a total of four-hundred words descriptive of people from Dumas, Johnson, & Lynch (2002). From this database, we also retrieved the words' frequency of occurrence in texts (Kučera & Francis, 1967), as well as ratings of familiarity and likability. We obtained valence ratings of the words or their root word (e.g., snob for snobbish) from Warriner, Kuperman, & Brysbaert (2013), when available. Words with a mean valence score below five and a mean score above five were classified as negative and positive, respectively. Five is the neutral point on the self-assessment manikins (Bradley & Lang, 1994), and Warriner et al. (2013) reversed the scale, thus words below 5 were negative, and words above 5 were positive. We excluded the words we judged as ambiguous because their scores were too close to 5, that is, the neutral point [e.g., "nonchalant" ($M = 4.58$) and "conservative" ($M = 4.55$)]. 48 of the 400 words were absent from Warriner et al.'s (2013) database and thus we relied on their definition (Cambridge Dictionary, 2015) and likableness scores to classify them as either positive or negative (likeableness and valence are highly correlated; $r = .931$ in our selection). We generated six lists of 80 words each (40 positive, 40 negative): two lists for the episodic memory condition (target words that were already encountered during the experiment, and new words), one for semantic memory, and one for each of the three self-knowledge conditions. The list of target words for the episodic memory task was formed by randomly selecting 10 positive and 10 negative words from each of the semantic memory and self-knowledge lists. We distributed the original words randomly across the other lists using the randomization excel function and made adjustments as necessary to match lists in word length (i.e., number of letters), familiarity, the words' frequency (Kučera & Francis, 1967), and likableness (all $p \geq .77$; lowest p value obtained with the target words for the recognition memory task included or excluded from the analyses). We also rotated three lists between the three self-knowledge tasks (past, present, future) to obtain six combinations randomized across participants, further reducing the likelihood of a spurious difference between time perspectives. Negative words had significantly lower likableness scores compared to positive words in all lists ($p < .001$). Valence and likableness were strongly correlated ($r = .931$, $p < .001$), and 48 words did not have valence values in the norms that we used (Warriner et al., 2013), thus these analyses focused on the latter.

2.2.2. Experimental conditions. During the task, participants were shown character traits and they were asked to make decisions about them in five ways. In the "self-knowledge" tasks, participants decided whether the word reflected either past (five years ago), present or future (five years from now) character traits. Five years was modeled on D'Argembeau et al. (2010) who argued that young university students had undergone – and then will undergo – significant changes in life circumstances during that time period. Indeed, a sense of continuity of one's own traits diminishes gradually through time, but changes temper down between 5 to 10 years for young adults (that is, the effect is not proportional with time; Rutt & Löckenhoff, 2016).

In the semantic memory task, participants determined whether the word reflected the character traits of most people holding an occupation (i.e., soldiers, priests, lawyers, scientists). Some traits are easier to associate with occupations. For instance, it is easy to agree that a priest is "solemn", but the same trait would be surprising (and disappointing) in a clown. The traits were assigned to occupations purposefully to ensure traits would vary in relevance, much like the relevance of traits in the self-knowledge task would (see stimuli in Appendix A). Nine additional people, who did not participate in the EEG study, completed a survey on Qualtrics (Qualtrics, Provo, UT) to verify whether traits were associated with the occupations using a 7-point Likert scale (1 = *not at all associated*, and 7 = *highly associated*). Responses 1 to 3 were grouped as "not associated" and responses 5 to 7 were considered to be "associated". We classified words as either associated or not associated when 6 out of 9 people made responses at the same end of the spectrum. 47.5% of the traits were not associated with the occupations (26.25% negative traits, 21.25% positive), 30% were associated with occupations (7.5% negative, 22.5% positive), and 22.5% received mixed responses (16.25% negative, 6.25% positive). For example, when speaking of scientists, “inventive” was thought to be associated, “social” not associated, and responses were mixed for “humorous”. After the self-knowledge and semantic memory tasks, participants completed a recognition memory task. In that case, participants indicated whether the words were presented previously (i.e., target words) or if they were new (80 old, 80 new), and how confident they were in their response.

2.2.3. Procedure. Participants sat in front of a computer screen placed about 1 m from their eyes. During cap preparation, the researchers interviewed participants about their life circumstances five years ago, five years from now, and in the present, in this order (adapted from D’Argembeau et al., 2010). The aim of the interview was to allow participants to elaborate past, present, and future life circumstances prior to the task, and to reduce the likelihood of order effects (Cordonnier, Barnier, & Sutton, 2016), and potential discrepancies in cognitive demand between experimental conditions (Weiler et al., 2011) . The semi-structured interview centered on activities (e.g., school, leisure), geographical location and housing. The same topics were addressed in the three time perspectives. Presumably, our participants kept life circumstances in mind when judging whether traits were relevant to a specific life period, but we did not instruct them to do so (unlike D’Argembeau et al., 2010). We reasoned that inviting participants to think of life events during the task could bias self-knowledge towards appearing closer to episodic rather than semantic memory.

E-Prime 2.0 (Psychology Software Tools, Pittsburgh, PA) was used for stimulus presentation. The five experimental conditions (semantic memory, episodic memory, and past, present, future self-knowledge) were presented in blocks (i.e., all stimuli for a condition presented together), so participants could maintain a specific mode of processing when judging the traits. To reduce switching between modes of processing, we also presented randomly semantic memory either before or after the self-knowledge tasks. Following a similar logic, all the traits for a given occupation were presented in a block. The order of the occupations was randomized in E-Prime. The 3 self-knowledge tasks could take 3 orders using the Latin Square method. The 3 orders of the self-knowledge tasks were crossed with the 6 possible combinations of 3 lists with the 3 time perspectives, yielding a total of 18 versions of the task. The assignation of the versions was randomized for the first set of 18 participants, and this order was repeated for the second set. We chose that strategy because most women were recruited in the first half of study inadvertently, and men in the second half. The recognition memory task always ended the study. Finally, the order of the traits was randomized within each block using an E-Prime function. Participants took short breaks between the blocks as necessary.

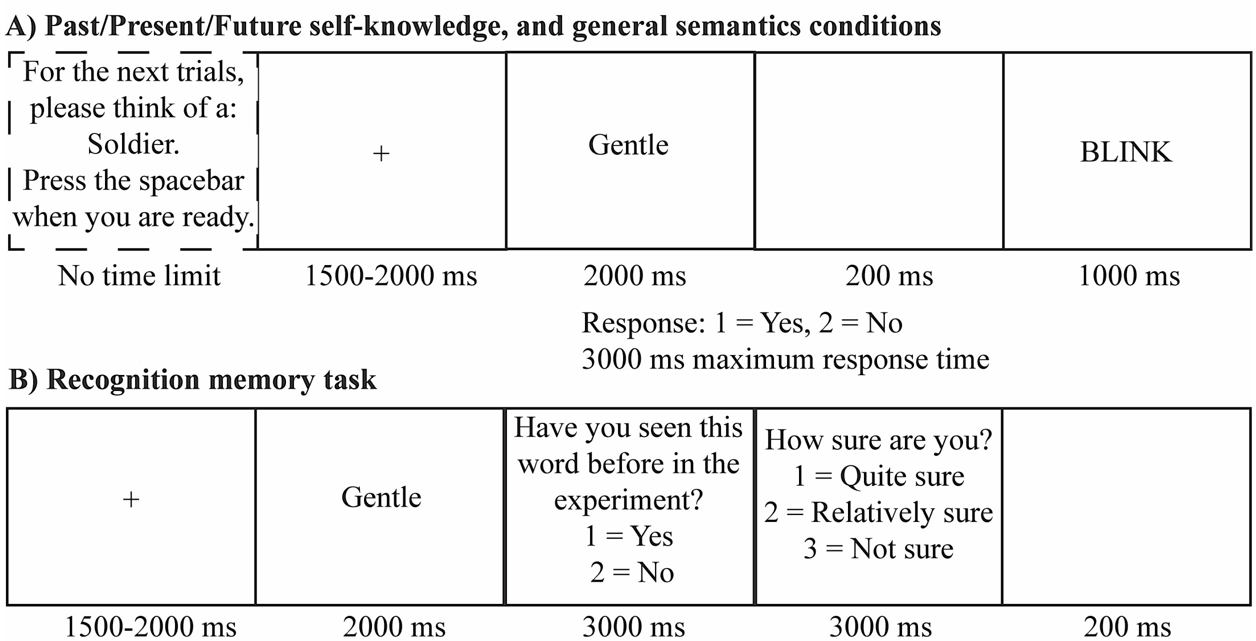

Figure. 2. The structure of A) the self-knowledge and general semantics tasks, and B) the recognition memory task. In A), an additional instruction screen was included to specify an occupation every 20 trials for the general semantics task (surrounded by dotted lines).

As a general rule, each trial started with a fixation cross of a variable duration (1500 to 2000 ms), after which a trait was shown for 2000 ms (see Figure 2). The maximum response time was 3000 ms, during which people could press 1 or 2 to respond. A "1" signified "I think the word reflects my (past/ present/ future) traits" and "2" meant "I think the word does not reflect my (past/present/future) traits". Similarly, in the semantic memory task, a "1" represented agreement with the statement "I think the word reflects the traits of most people holding the occupation", and a "2" showed a disagreement. A white screen followed the trait screen for 200 ms, and this sequence of events ended with a blink screen for 1000 ms (inviting participants to blink).

We adapted the stimulus presentation of the semantic and episodic memory tasks in a few ways. In the case of semantic memory, additional instructions were shown every 20 trials to specify in relation to what occupation the judgements on traits should be made. These instructions, like those introducing each task, were self-paced. The differences in the episodic memory task lay in the response screens. The options for the recognition memory task (i.e., 1 = old, 2 = new) were displayed after the trait screen. Subsequently, participants were shown the options for the confidence rating (1 = Quite sure; 2 = Relatively sure; 3 = Not sure; based on Renoult et al., 2015). For both the old/new and the confidence screens, participants had up to 3000 ms to respond. A response ended the screen and triggered the onset of the next screen. Participants could blink when making the responses in this case, thus we did not include a "blink" screen during the recognition memory task.

2.3 EEG acquisition and pre-processing

The Electroencephalogram (EEG) was recorded with a 63-channel active electrode system (Brain Products GmbH) embedded in a nylon cap (10/10 system extended). An additional electrode was placed under the left eye in order to monitor vertical eye movements (lower EOG). The continuous EEG signal was acquired at a 500 Hz sampling rate using an FCz reference. The high filter was set at 250 Hz and the time constant was 10 s. The impedance was kept below 20 kΩ. A vertical EOG was reconstructed offline as the difference between the lower EOG and FP1 activity. A horizontal EOG was constructed by subtracting FT9 from FT10 activity.

Offline analyses were conducted using Brain Vision Analyzer 2.1. Manual visual inspection was performed to remove excessive movement artifacts or drifts. High and low band-pass filter half-amplitude cutoffs were set at 0.01 and 30 Hz (12 dB/oct), respectively. We removed components representing eye movement and blinks with an automatic ICA ocular correction (Jung et al., 2000). Noisy channels were interpolated using spherical interpolation. An average reference was computed offline and used for all analyses. The EEG was segmented into epochs of 1 s (from -200 ms prior to, to 800 ms after the onset of the words). Trials were rejected after a 200 ms baseline correction: 1) if the absolute difference of two contiguous sampling points was larger than 75 μV, 2) if the difference between the minimal and maximal voltage was larger than 150 μV within a 200 ms interval, 3) if the voltage was above 100 μV or below -100 μV, or 4) if the difference between the minimum and maximum voltage was less than 0.5 μV for 100 ms.

The percentage of rejected trials followed by a *yes*/*no* response was: Semantic Memory: *Yes M* =7.08 % ± 1.68 *SE*/ *No M* = 6.87% ± 1.65 *SE*; Past self-knowledge: *Yes M* = 5.67% ± 1.02 *SE* / *No M* = 5.64% ± 1.32 *SE*; Present self-knowledge: *Yes M* = 4.57% ± 0.93 *SE*/ *No M* = 4.18% ± 0.86 *SE*; Future self-knowledge: *Yes M* = 5.56% ± 1.18 *SE*/ *No M* = 6.7% ± 1.36 *SE*; Episodic Memory: (high confidence hits) *M* = 3.34% ± 0.69 *SE*/ (correct rejections) *M* = 3.49% ± 0.67 *SE*. This resulted in the following average number of trials: Semantic Memory: *Yes M* =

30.25 ± 1.23 *SE/ No M* = 40.25 ± 1.27 *SE*; Past self-knowledge: *Yes M* = 33.04 ± 1.19 *SE/ No M* = 39.68 ± 1.36 *SE*; Present self-knowledge: *Yes M* = 33.96 ± 1.39 *SE/ No M* = 39.57 ± 1.42 *SE*; Future self-knowledge: *Yes M* = 33.21 ± 1.05 *SE/ No M* = 39.75 ± 1.19 *SE*; Episodic Memory: (high confidence hits) *M* = 45.71 ± 2.4 *SE/* (correct rejections) *M* = 50.39 ± 1.79 *SE*. The small difference in the number of trials does not affect our analyses, because mean amplitude is little influenced by noise (Tavakoli & Campbell, 2015).

The amplitudes of the N400 and the LPC were measured as the mean of all data points between 250 to 500 ms and 500 to 800 ms, respectively. The N400 is typically studied at sagittal or parasagittal sites, and the LPC at the posterior parietal sites. The sagittal subset included the electrodes FCz, Cz, CPz, and Pz, the parasagittal subset included C1/C2, C3/C4, Cp3/Cp4, and the posterior parietal subset included P1/2, P3/4, and PO3/4 (see Figure 3). Our key hypotheses and core analyses focus on the N400 and LPC at their typical maximal sites (see Table 1, and sections 3.1.2, 3.1.3 below). Moreover, we included frontal sites in preliminary and exploratory analyses for comparability with our other ERP studies on personal semantics (Renoult et al., 2015, 2016). The frontal subset included the electrodes F1/F2, F3/F4, FC3/FC4. A visual inspection of the grand average ERPs upon suggestion by a reviewer (see Figure 4) prompted the addition of an earlier time window, because a P200 effect of memory type may precede the N400 effect. The P200 time window was defined as ranging from 150 to 250 ms, and studied over all regions of interest, as P200 effects often have an anterior and central distribution, but posterior effects are also observed (Luck & Kappenman, 2012).

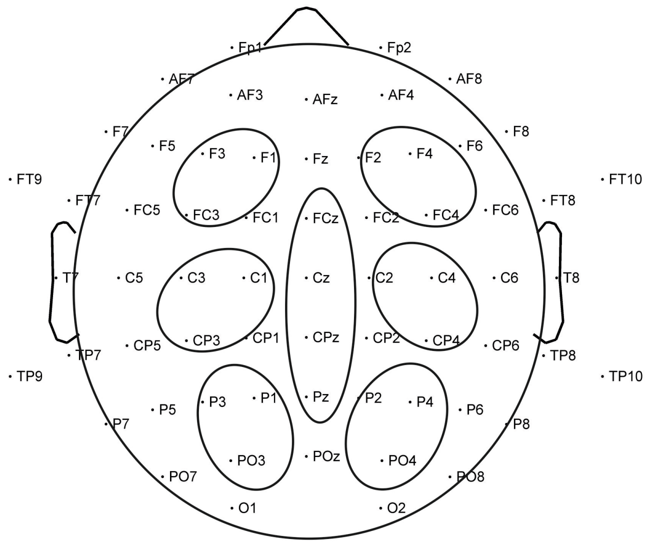

Figure 3. Circles surround the frontal, sagittal, parasagittal, and posterior parietal region of interests (ROI).

2.4 Statistical analyses

We ran repeated-measures ANOVAs on behavioral and electrophysiological data. Only "yes" responses were retained for these ERP analyses as these suggest participants were sufficiently confident in the presence of a memory trace. Further, we operationalized episodic memory as correct recognition of old items with high confidence (Rugg & Curran, 2007). Daselaar, Fleck, and Cabeza (2006), and Yonelinas (2002) consider that high confidence hits derive from recollection.

The Greenhouse & Geisser (1959) procedure was used to compensate for violations of the sphericity assumption, when appropriate. In this case, the original degrees of freedom are reported together with the epsilon (E) and the corrected probability level.

For both behavioral and ERP data, partial eta-squared (η_p^2) is indicated as a measure of effect size.

3. Results

3.1 Electrophysiological data: core analyses

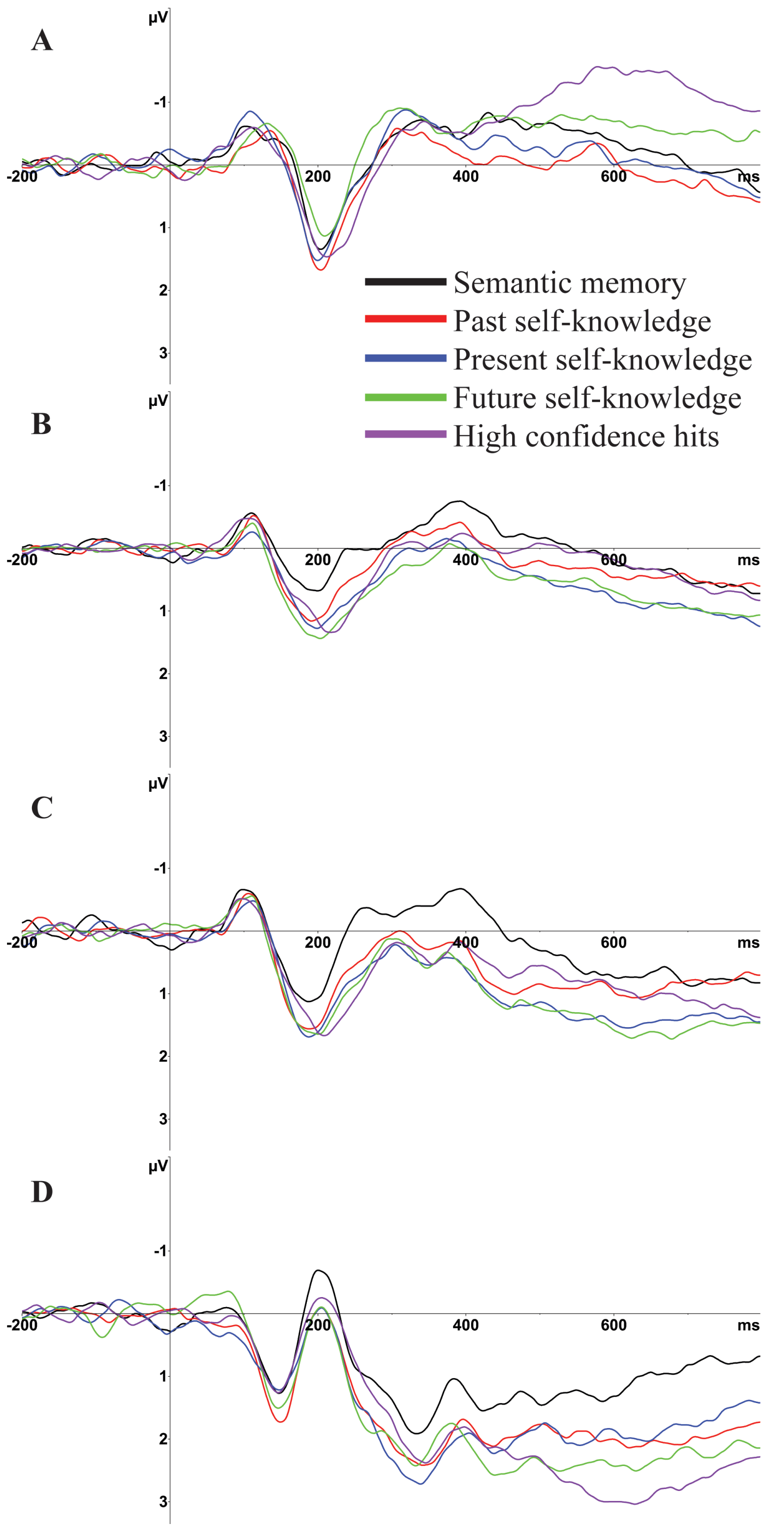

Figure 4. Grand average ERPs (N = 28) of yes responses for semantic memory and personal semantics, and high confidence hits for episodic memory, over A) frontal, B) parasagittal, C)

sagittal, and C) posterior parietal sites. Negative voltage is plotted upwards. A low pass filter of 20Hz was applied on the grand averages.

3.1.1 P200 time window (150-250 ms). We tested whether a difference between the 5 memory types (semantic memory, past self-knowledge, present self-knowledge, future self-knowledge, and episodic memory) emerged early, prior to the onset of the N400. The P200 scalp maps (episodic memory subtracted from semantic memory, and self-knowledge subtracted from semantic memory) showed a large distribution on central sites extending to frontal and posterior parietal sites (see Figure 5). We conducted separate repeated-measures ANOVA for frontal, sagittal, parasagittal, and posterior parietal subsets (see Figure 4), with Electrode as a factor for all subsets, and Hemisphere as an additional factor for the frontal, parasagittal and posterior parietal subsets. The main effect of Memory was not significant at the frontal subset, $F(4, 108) = 1.03$, $p = .395$, $\eta^2_p = 0.04$, nor the sagittal subset, $F(3.12, 84.22) = 2.14$, $p = .098$, $\eta^2_p = 0.07$, or the posterior parietal subset, $F(2.78, 75.16) = 1.05$, $p = .373$, $\eta^2_p = 0.04$. The main effect of Memory interacted with electrodes at the posterior parietal subset, $F(3.22, 87) = 3$, $= p = .032$, $\eta^2_p = 0.1$. Follow-up analyses showed the Memory effect was nearly significant at P2, $F(4, 108) = 2.37$, $p = .057$, $\eta^2_p = 0.08$, and no other sites were significant. Present self-knowledge had the maximal positive amplitude at the electrode P2.

The main effect of Memory was significant at the parasagittal subset, $F(2.89, 77.95) = 3.58$, $p = .019$, $\eta^2_p = 0.12$. Semantic memory was less positive than present self-knowledge, $p = .012$, $\eta^2_p = 0.21$, future self-knowledge, $p = .001$, $\eta^2_p = 0.36$, and episodic memory, $p < .001$, $\eta^2_p = 0.45$ but not past self-knowledge, $p = .07$, $\eta^2_p = 0.12$. The main effect of Memory was only a statistical trend over the sagittal site ($p = .098$). However, it is worth noting that post-hoc tests also revealed a less positive mean amplitude for semantic memory compared to all other memory types, $p \leq .048$. No other of the two-way interactions between Memory and Electrode or Memory and Hemisphere, or three-way interactions, were significant.

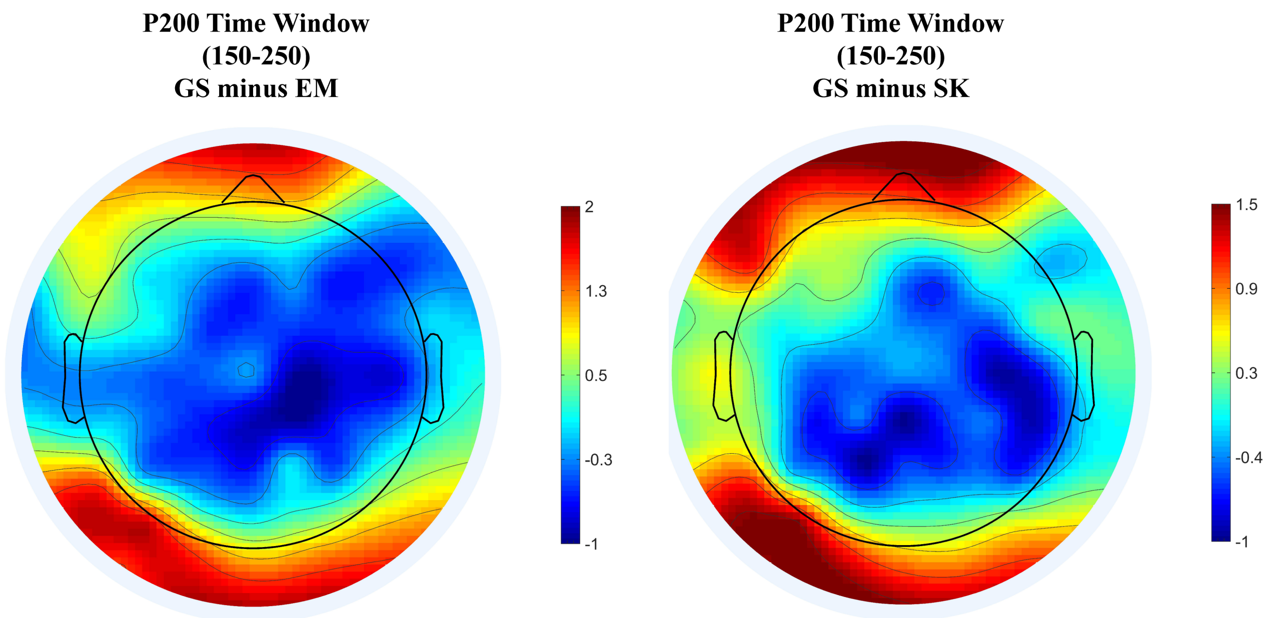

Figure 5. Spline interpolated isovoltage maps of semantic memory (SM, yes responses) minus high confidence hits (EM) at the left, and semantic memory (SM, yes responses) minus the average of all self-knowledge conditions (SK; yes responses) at the right from 150 to 250 ms. Scalp maps were prepared in EEGLAB (Delorme & Makeig, 2004).

3.1.2 N400 time window (250-500 ms). We examined whether the 5 memory types had a different mean voltage amplitude over the sagittal and parasagittal subsets as outlined in Table 1 (see Figure 4 panel A & B, and Figure 6). The N400 scalp maps (episodic memory subtracted from semantic memory, and self-knowledge subtracted from semantic memory) showed a classic centro-parietal N400 distribution (see Figure 6). The main effect of Memory was significant, $F(4, 108) = 2.8$, $p = .029$, $\eta^2_p = 0.09$ over the sagittal subset. Semantic memory produced more negative amplitudes compared to all other memory conditions (past self-knowledge, p = .033, η^2_p = 0.16; present self-knowledge, p = .015, η^2_p = 0.2; future self-knowledge, p = .007, η^2_p = 0.24; episodic memory, p = .009, η^2_p = 0.23; see Table 2). The main effect of Memory type was not significant over the parasagittal subsets, $F(2.52, 67.93) = 1.81$, p = .162, η^2_p = 0.06. At both sagittal and parasagittal sites, Memory did not interact with other factors [sagittal: Memory and Electrodes: $F(7.11, 192) = 1.03$, p = .413, η^2_p = 0.04; parasagittal: Memory and Electrodes: $F(5.1, 137.61) = 1.07$, p = .382, η^2_p = 0.04; Memory and Hemisphere: $F(4, 108)$ = .74, p = .567, η^2_p = 0.03; Memory, Electrodes and Hemisphere: $F(5.28, 142.46)$ = .73, p = .612, η^2_p = 0.03].

The P200 may have contributed to the N400 effect. Semantic memory was less positive compared to other memory types from 150 to 250 ms, this effect being statistically significant at the parasagittal site, and a statistical trend at the sagittal site. We adopted a peak-to-peak approach to compare the N400 between memory types while taking into account the preceding P200 amplitude. The data was filtered a second time with a low pass cut-off of 10 Hz (12 dB/oct) allowing clear peaks to emerge. We selected the maximal positive peak from 150 to 250 ms (P200) and the maximal negative peak from 250 to 500 ms (N400), using the Analyzer software. We then subtracted the N400 voltage from the P200 voltage and entered this peak-to-peak measurement in a repeated measures ANOVA including the 5 memory types and the 4 electrodes of the sagittal site (where the N400 effect of Memory was significant with the mean amplitude data). The main effect of Memory was non-significant, $F(4, 108)$ = .23, p = .922, η^2_p = 0.01, nor was the Memory and Electrode interaction, $F(6.07, 163.79) = 1.03$, p = .409, η^2_p = 0.04. This analysis thus revealed that the N400 effect cannot be dissociated from the preceding P200 effect at these electrode sites.

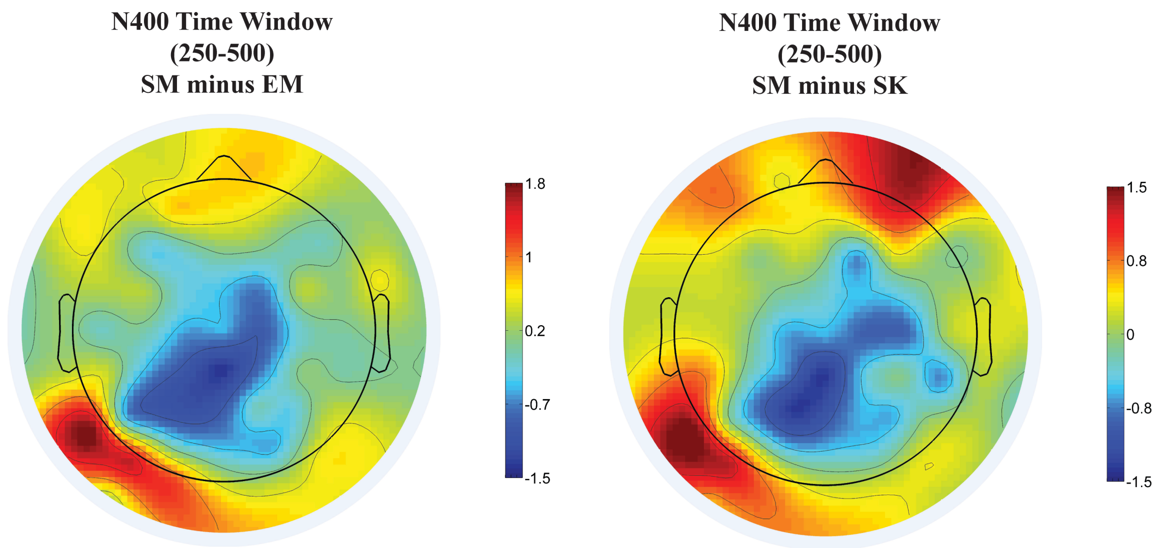

Figure 6. Spline interpolated isovoltage maps of semantic memory (SM) minus episodic memory (EM; left) and semantic memory (SM) minus the average of all self-knowledge conditions (SK; right) from 250 to 500 ms. Scalp maps were prepared in EEGLAB (Delorme & Makeig, 2004).

Table 2: Comparisons between memory types over the sagittal subset in the N400 time window.

Multiple Comparisons					
Dir.	**SM *vs* Past SK**	**Dir.**	**SM *vs* Present SK**	**Dir.**	**SM *vs* Future SK**
>	F(1, 27) = 5.07, p = .033, η^2_p = 0.16	>	F(1, 27) = 6.75, p = .015, η^2_p = 0.2	>	F(1, 27) = 8.68, p = .007, η^2_p = 0.24
Dir.	**EM *vs* Past SK**	**Dir.**	**EM *vs* Present SK**	**Dir.**	**EM *vs* Future SK**
ns	F(1, 27) = .01, p = .939, η^2_p < 0.01	*ns*	F(1, 27) = .58, p = .452, η^2_p = 0.02	*ns*	F(1, 27) = .42, p = .521, η^2_p = 0.02
Dir.	**Past SK *vs* Present SK**	**Dir.**	**Past SK *vs* Future SK**	**Dir.**	**Present *vs* Future SK**
ns	F(1, 27) = .54, p = .468, η^2_p = 0.02	*ns*	F(1, 27) = .3, p = .588, η^2_p = 0.01	*ns*	F(1, 27) = .01, p = .95, η^2_p < 0.01

Dir.	SM *vs* EM*		
>	$F(1, 27) = 7.94$, $p = .009$, $\eta^2_p = 0.23$		

Note: > = "more negative"; < = "less negative", *ns* = non-significant. *Two-way interaction between memory and electrodes. SK = self-knowledge, SM = semantic memory.

3.1.3 LPC time window (500-800 ms). We tested whether the 5 memory types have a different mean voltage amplitude over the posterior parietal sites (see Table 1 for the hypotheses). The main effect of Memory was significant, $F(4, 108) = 5.19$, $p = .001$, $\eta^2_p = 0.16$. As can been observed in Figure 4 panel D, at one extreme, episodic memory was associated with more positive amplitudes compared to present self-knowledge, $p = .049$, $\eta^2_p = 0.14$, and semantic memory, $p < .001$, $\eta^2_p = 0.43$, but not past self-knowledge, $p = .102$, $\eta^2_p = 0.1$, or future self-knowledge, $p = .338$, $\eta^2_p = 0.03$ (see Table 3). The three self-knowledge conditions were not statistically different from one another (past *vs* present: $p = .719$, $\eta^2_p < 0.01$; past *vs* future: , $p = .292$, $\eta^2_p = 0.04$; present *vs* future: $p = .217$, $\eta^2_p = 0.06$; see Table 3). All personal types of memory had greater positive amplitudes compared to semantic memory: (past self-knowledge, $p = .021$, $\eta^2_p = 0.18$; present self-knowledge, $p = .031$, $\eta^2_p = 0.16$, future self-knowledge, $p = .001$, $\eta^2_p = 0.33$, episodic memory, $p < .001$, $\eta^2_p = 0.43$). The Memory factor did not interact with Hemisphere, $F(4, 108) = 0.75$, $p = .562$, $\eta^2_p = 0.03$, Electrode, $F(4.51, 121.71) = 1.29$, $p = .274$, $\eta^2_p = 0.05$, and there was no three-way interaction, $F(4.96, 133.85) = 1$, $p = .422$, $\eta^2_p = 0.04$. The LPC for episodic memory relative to semantic memory had a left-sided posterior parietal scalp distribution (see Figure 7). The LPC for episodic memory relative to present self-knowledge had a more posterior scalp distribution with maximal amplitudes at left posterior parietal sites, extending to parietal-occipital sites.

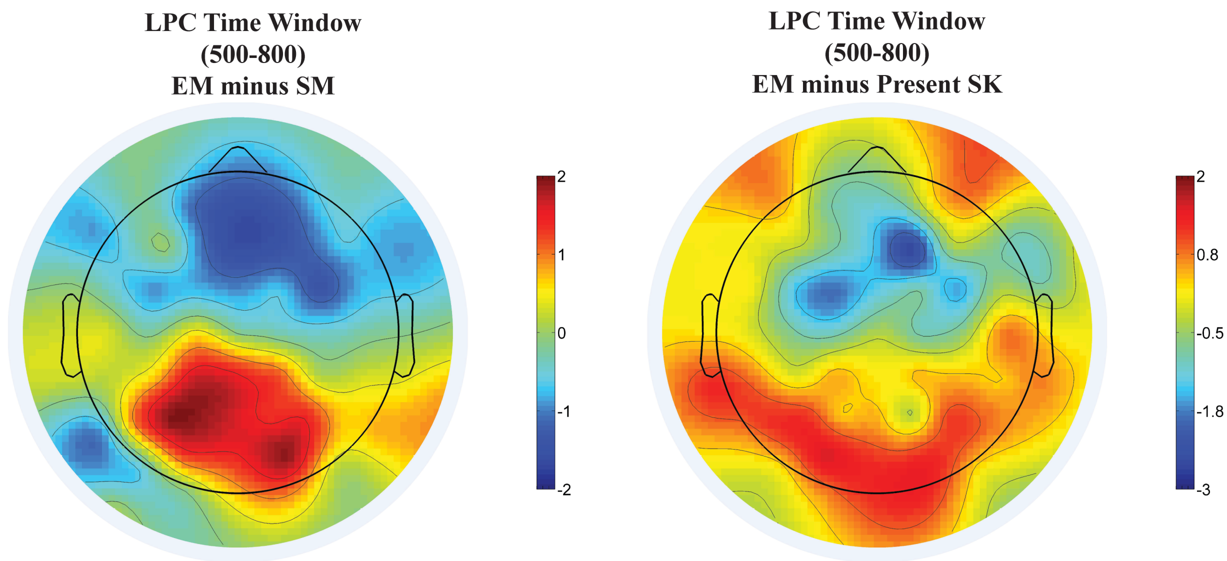

Figure 7. Spline interpolated isovoltage maps of high confidence hits (EM) minus semantic memory (SM; yes responses) at the left and high confidence hits (EM) minus present self-knowledge (SK; *yes* responses) at the right during the 500 to 800 ms time window. Scalp maps were prepared in EEGLAB (Delorme & Makeig, 2004).

Table 3: Paired comparisons between memory types over the posterior parietal subset in the LPC time window.

Multiple Comparisons					
Dir.	**EM *vs* Past SK**	**Dir.**	**EM *vs* Present SK**	**Dir.**	**EM *vs* Future SK**
ns	$F(1, 27) = 2.87, p = .102, \eta^2_p = 0.1$	>	$F(1, 27) = 4.26, p = .049, \eta^2_p = 0.14$	*ns*	$F(1, 27) = .95, p = .338, \eta^2_p = 0.03$
Dir.	**Past SK *vs* SM**	**Dir.**	**Present SK *vs* SM**	**Dir.**	**Future SK *vs* SM**
>	$F(1, 27) = 6, p = .021, \eta^2_p = 0.18$	>	$F(1, 27) = 5.16, p = .031, \eta^2_p = 0.16$	>	$F(1, 27) = 13.05, p = .001, \eta^2_p = 0.33$
Dir.	**Past SK *vs* Present SK**	**Dir.**	**Past SK *vs* Future SK**	**Dir.**	**Present *vs* Future SK**

ns	$F(1, 27) = .13, p = .719, \eta^2_p < 0.01$	*ns*	$F(1, 27) = 1.16, p = .292, \eta^2_p = 0.04$	*ns*	$F(1, 27) = 1.6, p = .217, \eta^2_p = 0.06$
Dir.	**EM *vs* SM**				
>	$F(1, 27) = 20.25, p < .001, \eta^2_p = 0.43$				

Note: > = "more positive"; < = "less positive"; *ns* = non-significant.

3.2 Electrophysiological data: manipulation checks and exploratory analyses

3.2.1 N400 time window (250-500 ms). The N400 is a well-established ERP component that typically displays larger negative amplitude over centroparietal sites for a semantically incongruent word (e.g., "I take coffee with cream and *dog*") compared to a semantically congruent word (e.g., "I shaved off my mustache and *beard*") in specific sentential or prime-target contexts (examples taken from Kutas & Federmeier, 2011). If we consider *no* responses as signifying that the trait is "incongruent" with an occupation or the self-concept, its mean N400 amplitude might be more negative than when people respond *yes*.

To test this hypothesis, we conducted separate repeated-measure ANOVAs for the sagittal and parasagittal subsets of electrodes with Memory condition (4 levels: semantic memory, past self-knowledge, present self-knowledge, future self-knowledge), Response (*yes, no*), Electrode and Hemisphere (for the parasagittal subset) as factors. We focus on the main effect of Response, interactions between Response and Memory, and three- or four-way interactions including Response, Memory as factors for these preliminary analyses. Over the sagittal site, *no* responses resulted in a more negative amplitude (M = 0.13 µV ± 0.21 *SE*) compared to *yes* responses (M = 0.38 µV ± 0.21 *SE*), $F(1, 27) = 5.02, p = .033, \eta^2_p = 0.16$ (see Figure 8). The main effect of Response did not reach significance over the parasagittal sites, F(1,

27) = 2.83, p = .104, η^2_p = 0.1. None of the interactions were significant, thus they are presented in Table 4 for simplicity.

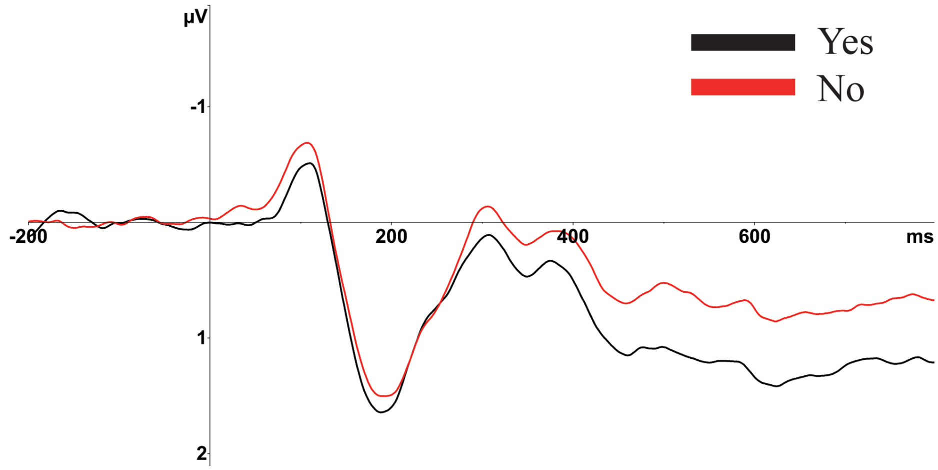

Figure 8. Grand average ERPs (N = 28) of the three self-knowledge conditions over sagittal sites. Negative voltage is plotted upwards. A low pass filter of 20 Hz was applied on the grand averages.

Table 4: Interactions between Response (*yes, no*) and Memory types, and other factors (i.e., Hemisphere, Electrode).

Interactions with Response		
	Dir. *Mem	**Dir. *Mem*Elec**
Sagittal Subset	F(3, 81) = 1.3, p = .281, η^2_p = 0.05	F(9, 243) = .82, p = .595, η^2_p = 0.03
	Dir. *Mem	**Dir. *Mem*Elec**
Para-sagittal Subset	F(3, 81) = .61, p = .612, η^2_p = 0.02	F(4.13, 111.53) = .49, p = .748, η^2_p = 0.02
	Dir. *Mem*Hem	**Dir. *Mem*Elec*Hem**
Para-sagittal Subset	F(3, 81) = .76, p = .518, η^2_p = 0.03	F(3.9, 105.47) = .92, p = .454, η^2_p = 0.03

Note: *ns* = non-significant, Mem = memory, Hem = hemisphere, Elec = electrode.

3.2.2 LPC time window (500-800 ms). Another established finding in ERP research is the parietal old/new effect: LPC amplitude is more positive for hits compared to correct rejections over posterior parietal sites (Rugg & Curran, 2007). We ran a repeated-measures ANOVA with Memory performance (2 levels: high confidence hits, correct rejection), Hemisphere, Electrode as factors on the mean amplitude between 500 to 800 ms. As expected, the amplitude of hits was more positive (M = 2.71 μV ± 0.42 SE) compared to correct rejections (M = 2.07 μV ± 0.39 SE), $F(1, 27) = 16.26$, $p < .001$, $\eta^2_p = 0.38$ (see Figure 9). However, the type of memory response did not interact with Hemisphere, $F(1, 27) = .05$, $p = .83$, $\eta^2_p < 0.01$, or Electrodes, $F(2, 54) < .01$, $p = .996$, $\eta^2_p < 0.01$, and the three-way interaction was not significant, $F(2, 54) = .37$, $p = .692$, $\eta^2_p = 0.01$. The LPC had a posterior parietal distribution, with local maxima at left posterior parietal sites and right centro-parietal sites (see Figure 10).

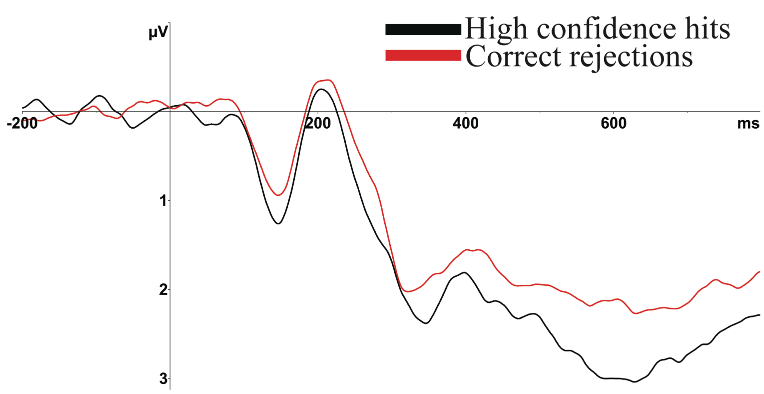

Figure 9. Grand average ERPs (N = 28) of high confidence hits and correct rejections over posterior parietal sites. Negative voltage is plotted upwards. A low pass filter of 20 Hz was applied on the grand averages.

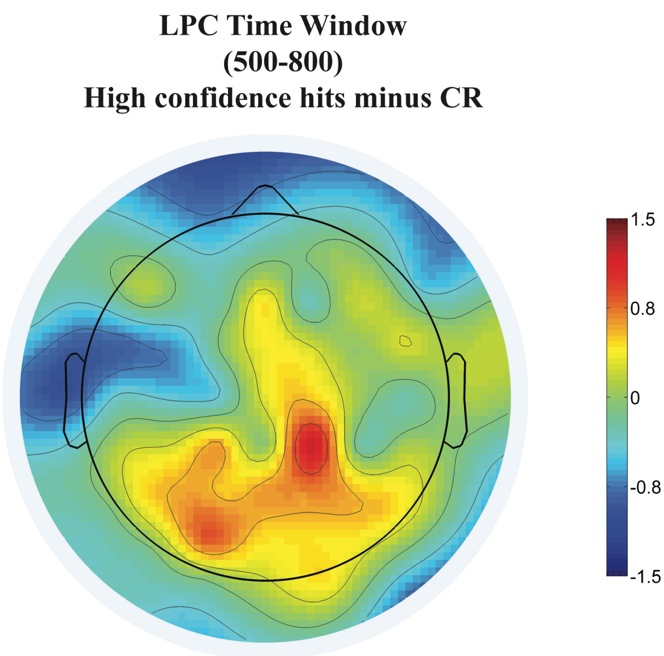

Figure 10. Spline interpolated isovoltage maps of high confidence hits minus correct rejections from 500 to 800 ms. Scalp maps were prepared in EEGLAB (Delorme & Makeig, 2004).

3.2.3 Frontal ROI. We investigated the main effect of Memory over the frontal subset during the N400 and LPC time window (see 3.1.1 for P200). The FN400, or the midfrontal old/new effect, is commonly thought to index familiarity in recognition, often used as the counterpart to the LPC, or the parietal old/new effect, which indexes recollection (Rugg & Curran, 2007).

As preliminary check, the FN400 effect was not observed on frontal site when comparing high confidence hits and correct rejection, $F(1, 27) = .14$, $p = .71$, $\eta^2_p = 0.01$. Response Type did not interact with Electrode, $F(2, 54) = .2$, $p = .816$, $\eta^2_p = 0.01$, or Hemisphere, $F(1, 27) = .23$, $p = .639$, $\eta^2_p = 0.01$, Electrode and Hemisphere, $F(2, 54) = .4$, $p = .673$, $\eta^2_p = 0.02$, which are also included in this set of analyses.

Next, we considered whether the 5 memory conditions differed over frontal sites during the N400 time window, and they did not, $F(4, 108) = .73$, $p = .572$, $\eta^2_p = 0.03$. Memory did not interact with Electrode, $F(8, 216) = 1.02$, $p = .425$, $\eta^2_p = 0.04$, or Hemisphere, $F(4, 108) = .6$, $p = .667$, $\eta^2_p = 0.02$, and there was no three-way interaction, $F(5.13, 138.57) = .77$, $p = .577$, $\eta^2_p = 0.03$. Lastly, we tested if the 5 memory types differed in the later time window over the frontal subset, that is, from 500 to 800 ms. Indeed, the main effect of Memory was significant, $F(4, 108) = 4.73$, $p = .001$, $\eta^2_p = 0.15$. Episodic memory was more negative than general semantics, $p = .002$, $\eta^2_p = 0.3$, past self-knowledge, $p = .001$, $\eta^2_p = 0.35$, present self-knowledge, $p = .004$, $\eta^2_p = 0.27$, but not future self-knowledge, $p = .084$, $\eta^2_p = 0.11$. Future self-knowledge was also more negative than past self-knowledge, $p = .014$, $\eta^2_p = 0.21$. Memory did not interact with Electrode, $F(8, 216) = 1.35$, $p = .223$, $\eta^2_p = 0.05$, or Hemisphere, $F(4, 108) = .88$, $p = .481$, $\eta^2_p = 0.03$, and there was no three-way interaction, $F(5.15, 139.04) = 1.14$, $p = .343$, $\eta^2_p = 0.04$. This effect is likely due to the use of the average reference, consistent with findings of FN400 and LPC effects of opposite polarity when using this reference (Curran & Friedman, 2004; e.g., Curran, Tanaka, & Weiskopf, 2002; Renoult et al., 2015).

3.3 Behavioral data: preliminary analyses and manipulations checks

3.3.1 Behavioral data: reaction times. We tested whether the memory conditions differ in their mean reaction times (this section) or responses (next section). Through these analyses, we aimed to verify if our study replicates previous findings of an optimism bias (D'Argembeau et al., 2010; Kanten & Teigen, 2008; Wilson & Ross, 2001). We tested whether mean Reaction Time (RT) differed between Valence (2 levels: positive, negative), Response (2 levels: *yes*, *no*), and the Memory conditions (4 levels: semantic memory, past, present, and future self-knowledge), and whether these factors interacted (see Figure 11). Participants made recognition responses after trait presentation (rather than during presentation) for the episodic memory condition, thus there was no reaction times to analyze for this condition.

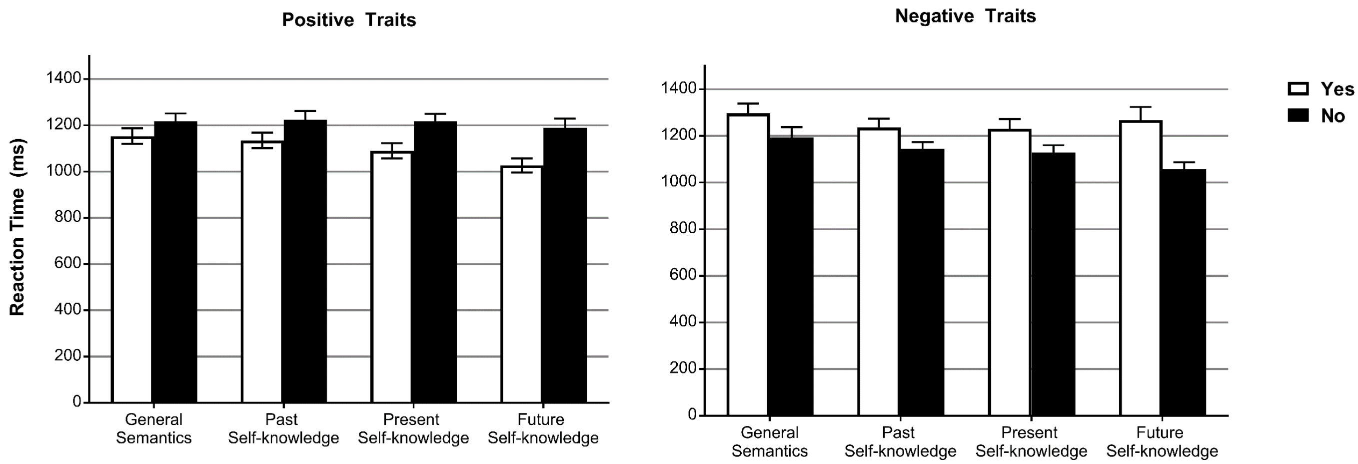

Figure 11. Mean RTs for positive traits (left) and negative traits (right) for *yes* and *no* responses in each of the memory conditions. Error bars represent ± 1 *SE*.

The repeated-measures ANOVA revealed a main effect of Memory, $F(3, 81) = 3.89$, $p = .012$, $\eta^2_p = 0.13$, and a main effect of Valence, $F(1, 27) = 12.27$, $p = .002$, $\eta^2_p = 0.31$. Memory, Valence, and Response interacted, $F(3, 81) = 6.98$, $p < .001$, $\eta^2_p = 0.21$. We ran separate repeated-measures ANOVAs for positive and negative traits to follow-up on this three-way interaction. Memory and Response interacted for positive traits, $F(3, 81) = 3.07$, $p = .032$, $\eta^2_p = 0.1$, and negative traits, $F(2.23, 60.14) = 3.55$, $p = .031$, $\eta^2_p = 0.12$. The most important finding (given that we emphasized *yes* responses in our ERP analyses) was that, for positive traits, the main effect of Memory was significant, $F(2.24, 60.46) = 7.86$, $p = .001$, $\eta^2_p = 0.23$. Participants were faster to respond *yes* in the future self-knowledge condition compared to past self-knowledge ($p < .001$, $\eta^2_p = 0.44$), present self-knowledge ($p = .008$, $\eta^2_p = 0.23$), and semantic memory ($p < .001$, $\eta^2_p = 0.39$). Participants were also faster to respond *yes* for present compared to past self-knowledge (p = .046, η^2_p = 0.14; see Table 5). The rapidity of *no* responses to positive traits did not differ between memory conditions, $F(3, 81) = .47$, $p = .706$, $\eta^2_p = 0.02$. For negative traits, RTs to *yes* responses were not significantly different between memory types, $F(2.2, 59.47) = 1.22$, $p = .305$, $\eta^2_p = 0.04$. However, the main effect of Memory was significant for *no* response to negative traits, $F(2.07, 55.9) = 6.33$, $p = .003$, $\eta^2_p = 0.19$. Participants were significantly faster to respond *no* for future self-knowledge compared to past self-knowledge (p = .001, η^2_p = 0.33), present self-knowledge (p = .011, η^2_p = 0.22), and semantic memory (p = .001, η^2_p = 0.36). Thus, participants were faster to endorse positive traits and reject negative traits when they pertained to the future relative to the past or present selves, or other people.

Table 5: Comparisons of the RT between Memory types as a factor of Response (*yes or no*).

Multiple Comparisons					
Positive Traits			**Negative Traits**		
Response	**Dir.**	**Future SK *vs* SM**	**Response**	**Dir.**	**Future SK *vs* SM**
Yes	<	$F(1, 27) = 17.03$, $p < .001$, $\eta^2_p = 0.39$	**No**	<	$F(1, 27) = 15.19$, $p = .001$, $\eta^2_p = 0.36$
Response	**Dir.**	**Future SK *vs* Past SK**	**Response**	**Dir.**	**Future SK *vs* Past SK**
Yes	<	$F(1, 27) = 21.38$, $p < .001$, $\eta^2_p = 0.44$	**No**	<	$F(1, 27) = 12.98$, $p = .001$, $\eta^2_p = 0.33$
Response	**Dir.**	**Future *vs* Present SK**	**Response**	**Dir.**	**Future *vs* Present SK**
Yes	<	$F(1, 27) = 8.23$, $p = .008$, $\eta^2_p = 0.23$	**No**	<	$F(1, 27) = 7.38$, $p = .011$, $\eta^2_p = 0.22$
Response	**Dir.**	**Past SK *vs* Present SK**	**Response**	**Dir.**	**Past SK *vs* Present SK**
Yes	>	$F(1, 27) = 4.38$, $p =$	**No**	*ns*	$F(1, 27) = .42$, $p = .523$, $\eta^2_p =$

		.046, η^2_p = 0.14			0.02
Response	**Dir.**	**SM *vs* Past SK**	**Response**	**Dir.**	**SM *vs* Past SK**
Yes	*ns*	$F(1, 27) = .28$, $p = .605$, $\eta^2_p = 0.01$	**No**	*ns*	$F(1, 27) = 2.16$, $p = .154$, $\eta^2_p = 0.07$
Response	**Dir.**	**SM *vs* Present SK**	**Response**	**Dir.**	**SM *vs* Present SK**
Yes	*ns*	$F(1, 27) = 3.41$, $p = .076$, $\eta^2_p = 0.11$	**No**	*ns*	$F(1, 27) = 2.27$, $p = .144$, $\eta^2_p = 0.08$

Note: > = "slower"; < = "faster", *ns* = non-significant, SK = self-knowledge, SM = semantic memory

3.3.2 Behavioral data: percentage of yes responses. We ran a repeated-measures ANOVA on the percentage of *yes* responses with Valence and Memory conditions (4 levels: semantic memory, past, present, and future self-knowledge) as within-subject factors. The percentage of *yes* responses did not differ between Memory types when averaging responses to positive and negative traits together, $F(3, 81) = 1.75$, $p = .164$, $\eta^2_p = 0.06$ (see Figure 12).

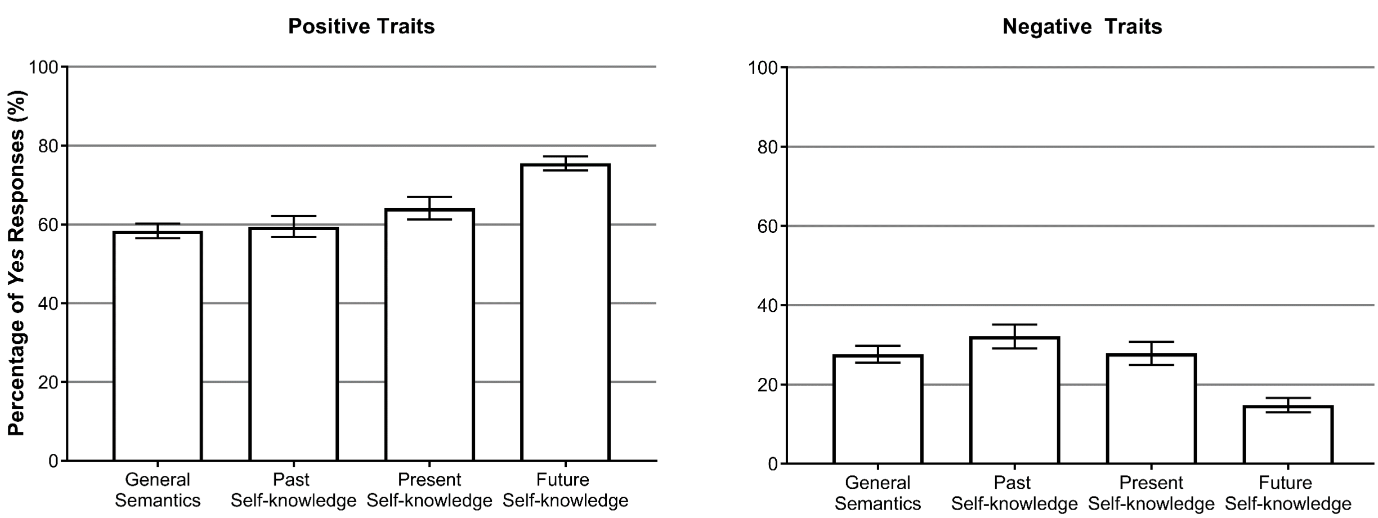

Figure 12. Mean percentage of *yes* responses for positive traits (left) and negative traits (right) in each of the memory conditions. Error bars represent ± 1 *SE*.

Overall, participants made a greater percentage of *yes* responses for positive than negative traits, $F(1, 27) = 241.57$, $p < .001$, $\eta^2_p = 0.9$. Memory types and Valence interacted, $F(3, 81) = 20.15$, $p < .001$, $\eta^2_p = 0.43$. The percentage of *yes* responses to positive traits was higher for future self-knowledge compared to all other conditions (semantic memory: $p < .001$, $\eta^2_p = 0.73$; past self-knowledge: $p < .001$, $\eta^2_p = 0.54$; present self-knowledge: $p < .001$, $\eta^2_p = 0.45$, see Table 6). In addition, participants endorsed a higher percentage of positive traits in present self-knowledge relative to the positive traits they attributed to other people (semantic memory), $p = .047$, $\eta^2_p = 0.14$. The mirrored effect was observed for negative traits: the percentage of *yes* responses was lower for future self-knowledge compared to all others conditions (semantic memory: $p < .001$, $\eta^2_p = 0.48$; past self-knowledge: $p < .001$, $\eta^2_p = 0.55$; present self-knowledge: $p < .001$, $\eta^2_p = 0.41$).

Table 6: Comparisons of the percentage of *yes* responses between memory types.

Multiple Comparisons			
Positive Traits		**Negative Traits**	
Dir.	**Future SK *vs* SM**	**Dir.**	**Future SK vs. SM**
>	$F(1, 27) = 73.78$, $p < .001$, $\eta^2_p = 0.73$	<	$F(1, 27) = 24.44$, $p < .001$, $\eta^2_p = 0.48$
Dir.	**Future SK *vs* Past SK**	**Dir.**	**Future SK *vs* Past SK**
>	$F(1, 27) = 31.05$, $p < .001$, $\eta^2_p = 0.54$	<	$F(1, 27) = 33.29$, $p < .001$, $\eta^2_p = 0.55$
Dir.	**Future *vs* Present SK**	**Dir.**	**Future *vs* Present SK**
>	$F(1, 27) = 22.48$, $p < .001$, $\eta^2_p = 0.45$	<	$F(1, 27) = 18.59$, $p < .001$, $\eta^2_p = 0.41$
Dir.	**Past SK vs Present SK**	**Dir.**	**Past SK vs Present SK**
ns	$F(1, 27) = 2.24$, $p = .146$, $\eta^2_p = 0.08$	*ns*	$F(1, 27) = 3.2$, $p = .085$, $\eta^2_p = 0.11$

Dir.	SM vs Past SK	Dir.	SM vs Past SK
ns	$F(1, 27) = .16$, $p = .692$, $\eta^2_p = 0.01$	*ns*	$F(1, 27) = 2.36$, $p = .136$, $\eta^2_p = 0.08$
Dir.	**SM vs Present SK**	**Dir.**	**SM vs Present SK**
<	$F(1, 27) = 4.34$, $p = .047$, $\eta^2_p = 0.14$	*ns*	$F(1, 27) < .01$, $p = .955$, $\eta^2_p < 0.01$

Note: > = "higher percentage"; < = "lower percentage", *ns* = non-significant, SM = semantic memory, SK = self-knowledge

3.3.3 Behavioral data: recognition memory task. We compared the rapidity of the correct recognition responses (2 levels: hits and correct rejections) with Valence as an additional factor. Participants were slower to make correct rejections (M = 629.78ms ± 34.56 SE) compared to hits (M = 503ms ± 23.22 SE), $F(1, 27) = 25.04$, $p < .001$, $\eta^2_p = 0.48$. The interaction between the response time of Response Type and Valence approached the level of significance, $F(1, 27) = 4.13$, $p = .052$, $\eta^2_p = 0.13$. Participants were faster to make hits than correct rejections for both positive and negative words ($p \leq .001$), however this effect seemed stronger for positive words. The main effect of Valence was not significant, $F(1, 27) = .35$, $p = .56$, $\eta^2_p = 0.01$.

For recognition performance, we compared the percentage of correct responses between Response Type (2 levels: hits and correct rejections) and Valence. Participants were more accurate in their recognition of target words (M = 81.56 ± 1.93 SE) than new words overall (M = 66.79 ± 2.49 SE), $F(1, 27) = 17.65$, $p < .001$, $\eta^2_p = 0.4$. There was no effect of Valence, $F(1, 27) = .03$, $p = .862$, $\eta^2_p < 0.01$, but Memory and Valence interacted, $F(1,27) = 23.62$, $p < .001$, $\eta^2_p = 0.47$. Participants produced more hits when traits were positive (M = 83.93% ± 2.02 SE) than when they were negative (M = 79.2% ± 2.1SE), $F(1, 27) = 10.89$, $p = .003$, $\eta^2_p = 0.29$. Conversely, participants were more accurate to reject new items when traits where negative (M = 69.38% ± 2.5 SE) than positive (M = 64.2% ± 2.78 SE), $F(1, 27) = 8.28$, $p =.008$, $\eta^2_p = 0.24$.

Next, we considered whether differences between positive and negative traits were attributable to a change in sensitivity (*d'*) or to a bias towards a certain response (*c*). Positive and negative traits did not differ in sensitivity, $F(1, 27) = .35$, $p = .56$, $\eta^2_p = 0.01$. Participants were significantly more biased towards a *yes* response for positive traits ($M = -.37 \pm .07$ *SE*) than they were for negative traits ($M = -.15 \pm .06$ *SE*), $F(1, 27) = 28.68$, $p < .001$, $\eta^2_p = 0.52$.

4. Discussion

The goal of the present study was to compare the event-related potential (ERP) correlates of self-knowledge to both semantic and episodic memory, focusing on N400 and LPC as proxies for semantic and episodic processing, respectively. We also considered time perspective of the self-knowledge judgements (past, present, and future), because thinking about one's past and future selves may engage semantic and episodic memory to differing degrees (Irish & Piguet, 2013; Prebble et al., 2013).

Behavioral results revealed that participants endorsed more positive traits and fewer negative traits as reflecting their future selves, and did so faster, compared to their past and present selves (D'Argembeau et al., 2010; Wilson & Ross, 2001). The participants also rated themselves as "better-than-average": Their own current and future personalities were perceived as containing more positive traits than other people's personalities (similar to: Kanten and Teigen (2008)).

ERP results indicated that mean N400 amplitude at sagittal sites was larger for semantic memory than for all time perspectives of self-knowledge (note also that, as one might expect from the literature (Kutas & Federmeier, 2011), the *no* responses on the self-knowledge and semantic memory tasks were associated with a larger N400 compared to *yes* responses). Of note, we found a larger P200 for self-knowledge conditions relative to semantic memory at these same electrode sites. The N400 memory effect was in tandem with the preceding P200, thus the N400 effect may not be solely attributable to a difference in semantic processing (see 4.3 for a discussion of this finding). Also commensurate with the existing literature, on the recognition memory task the LPC was larger for high confidence hits compared to correct rejections at posterior parietal sites. On the self-knowledge task, the amplitude of the LPC associated with knowing one's current self fell intermediately between semantic and episodic memory, whereas the LPC for knowledge of past and future selves was closer to episodic memory. This modulation of the time perspective is noteworthy in that it is related to only a slight variation in the instructions (i.e., past vs. present vs. future).

4.1 Time perspective and self-knowledge

Some have considered that temporally distant selves are similar to other people (e.g., Pronin & Ross, 2006). Using a similar logic, D'Argembeau et al. (2010) reported that the neurocognitive processes involved in thinking about distant past or the future selves relative to the present self shares similarities with thinking of other people. Knowledge of unknown or a generic group of people belongs to the domain of semantic memory (Binder & Desai, 2011; Lambon Ralph et al., 2017), thus such perspectives and findings can be gathered as further support that past and future self-knowledge recruits semantic processing. Our study shows the value of including conditions of semantic and episodic memory rather than extrapolating relationships solely on the basis of neural correlates associated with semantic and episodic memory (and the self). Regarding the N400, we had considered the possibility of a closer relationship between semantic memory and present self-knowledge because of their conceptual similarity. This expectation was based on the idea that present self-knowledge implies awareness in the present, like semantic memory. Moreover, present self-knowledge might reflect mostly stable (atemporal) characteristics of one's personality (Anusic & Schimmack, 2016). A recent meta-analysis estimated the stable portion of our personality to be 83% (at *M* age = 32 years old; Anusic & Schimmack, 2016). Likewise, semantic memory is conceptualized as devoid of temporal context. Contrary to these expectations, we found that time perspective did not modulate the N400. In fact, when considering the P200/N400 and LPC, the current study suggests that present self-knowledge shares greater similarity with past and future self-knowledge than with semantic memory. As D'Argembeau et al. (2008) pointed out, the qualifier "present" in "present" self-knowledge might instead refer to an extended period (e.g., as a life chapter or "repeated/general" events). In addition, personality can change with context (Roberts, 2007), even within a single life period. Most participants in the present study were university students and the experimental context (i.e., at the University) might have reinstated the relevance of that context for the current self-identity (e.g., I am calm as a student, but wild when with friends). Awareness of oneself through different temporal contexts is a hallmark of episodic memory (Tulving, 2001, 2002). To investigate the neural correlates of the stable/atemporal aspects of self-knowledge, the instructions in a future study could insist on participants' processing the words according to whether they reflect stable characteristics of one's personality (e.g., I have always been independent).

The mean LPC of past and future self-knowledge was less positive than, but not significantly different from, episodic memory. The LPC is associated with recollection, and possibly also with self-relevance (Fields & Kuperberg, 2016; Rugg & Curran, 2007, Renoult et al., 2015). The trials from the three self-knowledge conditions were all judged to be self-relevant by our participants (i.e., we focused on the "yes" trials in the ERP analyses), therefore the LPC difference is unlikely to be explained by this factor. However, it will be interesting to disambiguate how self-relevance, demands on scene construction, and/or mental time travel (Palombo et al., in press) may each contribute to LPC differences across past, present, and future time perspectives. Alternatively, our findings suggest that self-knowledge could be conceptualized as falling on a continuum ranging from "experience-near" (e.g., I was very friendly as a salesperson) to the "experience-far" (e.g., I am always a cheerful person; Grilli & Verfaellie, 2016; Renoult et al., 2016). This distinction has proven to be useful for autobiographical facts, another type of personal semantics. For example, amnesic patients are more impaired when autobiographical facts are judged to be close to experience (e.g., I adopted my cat in a shelter in Ottawa) than they are for facts removed from experience (e.g., I speak French; Grilli & Verfaellie, 2016). Self-knowledge might similarly be organized in an experience-near versus experience-far manner.

On the basis of the self-construal account we can deduce that the requirements in semantic processing (i.e., the N400) of past and future self-knowledge will be closer to general semantics than to present self-knowledge, because distant events include more general facts and less episodic details (Trope & Liberman, 2010). If we extend this logic, past and future self-knowledge may require accessing general knowledge about typical life narratives and changes in personality to a greater extent than present self-knowledge. Temporal orientation of self-knowledge did not modulate the N400, contrary to this interpretation of the self-construal account. The alternative account highlights the role of events to define identity, as well as the close interrelationships between past or future thinking and episodic memory. This last account offers a better fit for our findings: the LPC of past and future self-knowledge was not significantly different from episodic memory, while present self-knowledge was intermediate, and differed from semantic and episodic memory. Our results support the perspective that recollection or simulation of personal events shape self-knowledge for all temporal orientation, although knowledge of past and future selves increases demands on episodic processing. This pattern of results for the LPC, with past and future self-knowledge being less similar to semantic memory relative to present self-knowledge was not mirrored in the N400. The N400 and LPC thus showed distinct modulations by time perspective and memory types. Time perspective produced a strong LPC effect, but weak (or absent) N400 effect. Similarly, in one of our previous studies, the LPC, but not the N400, distinguished high autobiographically significant concepts from concepts with low autobiographical significance (Renoult et al., 2015).

4.2 Self-knowledge and other types of personal semantics

Personal semantics have been argued by Renoult et al. (2012) to come in 4 types, all of which fall between semantic and episodic memory as "intermediate types of declarative memory", but are their neural and behavioral correlates all "intermediate" in the same way? The Renoult et al. (2012) review of the existing literature suggested that the answer is "no;" two of the 4 types of personal semantics (i.e., memory for repeated events, and autobiographically significant concepts) may be closer to episodic memory, one type (i.e., autobiographical facts) may be closer to semantic memory, and the last type (i.e., self-knowledge; see Figure 1; Renoult et al., 2012) may be relatively distinct from both – although as seen in the present paper self-knowledge's relation to semantic and episodic memory appears to vary as a function of time perspective. Yet, the question of how similar or dissimilar these 4 different types of personal semantics are to one another can only be answered tentatively at present, because most types of personal semantics have not been compared to one another, or to the same kind of semantic and episodic memory "control" conditions, within the same study. The ERP correlates of personal semantics appear to vary. For instance, a first study (Renoult et al., 2015) compared the ERP correlates of concepts from a single experimental condition by sorting them according to whether the concepts had high or low autobiographical significance (self-reported by each participant after the task). High autobiographically significant (AS) concepts were theorized to be personal semantics, whereas low autobiographical significance concepts were taken to predominantly reflect semantic memory. The N400 was not significantly different between these two kinds of concepts, but the mean LPC was more positive for the highly autobiographically significant concepts than for the less-autobiographically significant ones. Conversely, in a separate study on two other kinds of personal semantics – namely, autobiographical facts and memory for repeated events (Renoult et al., 2016) -- the N400 for autobiographical facts (e.g., I am vegetarian) and for repeated events (e.g., I remember cleaning the windows every spring) was less negative than for general facts at sagittal and posterior parietal sites. Other findings appear to be more consistent across various subtypes of personal semantics in this nascent literature. Across several recent publications, all types of personal semantics were associated with larger LPC amplitudes than semantic memory (Coronel & Federmeier, 2016; Renoult et al., 2015, 2016). In contrast, in the Renoult et al. (2016) report, autobiographical facts and repeated events were less distinguishable from episodic memory, similar to our findings in the present study regarding future and past self-knowledge (Renoult et al., 2016). The effect sizes that we have reported here can be used to generate the hypothesis that past self-knowledge (η^2_p = 0.03) and future self-knowledge (η^2_p = 0.1) are less different from episodic memory than are autobiographical facts (η^2_p = .18), memory for repeated events (η^2_p = 0.26), and present self-knowledge (η^2_p = 0.14). A unique characteristic of self-knowledge as compared to other types of personal semantics may be modulation of the

P200, as such modulation was not observed for memories of autobiographical facts, repeated events or for autobiographically significant concepts (Renoult et al., 2015, 2016).[2]

A main interest of Coronel and Federmeier (2016) and Choi et al. (2017) was to investigate the characteristics of the incongruency effect of personal semantics, if at all present (i.e., larger N400 for a word incongruent with its context vs. congruent). These researchers collected personal information prior to the experimental tasks to elaborate the stimuli, unlike Renoult et al. (2015; 2016), and this study. Thus, the statements were either consistent or inconsistent with the facts or the preferences the participants had shared. The N400 was larger for statements conflicting with one's preferences (i.e., self-knowledge) and for false autobiographical facts compared to congruent statements. Likewise, in our study, *no* responses, signifying that traits do not reflect oneself or other people, were associated with a larger N400 than *yes* responses at sagittal sites. The effect did not interact with memory type (i.e., personal semantics versus semantic memory). Visual inspection of the data suggests that the effect only

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[2] In other studies of this group the mean N400 was extracted 300-500 ms post-stimulus onset including centro-parietal sites, and the mean LPC was extracted from 500 to 700 ms post-stimulus onset, including posterior parietal sites. We selected a time window of 250 to 500 ms in this study. Each offers a comparable outcome. That is, when using a 300 to 500 ms time window, the main effect of Memory was significant over the sagittal site, $F(4, 108) = 2.61$, $p = .039$, $\eta^2_p = .09$, and it was not significant over the parasagittal site, $F(2.58, 69.75) = 1.62$, $p = .198$, $\eta^2_p = .06$. Pairwise comparisons showed that semantic memory was more negative compared to all other memory conditions over the sagittal site (past self-knowledge, $p = .04$; present self-knowledge, $p = .023$; future self-knowledge, $p = .01$; episodic memory, $p = .04$). All these effects were also significant from 250 to 500 ms, and no other effects were significant.

became evident when all memory conditions were considered together, and the effect was not significant at parasagittal sites. Contrary to Choi et al. (2017), and Coronel and Federmeier (2016), the stimuli in our personal semantics and semantic memory tasks do not possess a truth or false value *per se*. Rather, traits are likely to range on a continuum of how well they match one's personality or other people's personality (e.g., I have a moderate sense of humour, priests have a moderate sense of humour). Future studies could record responses on a scale from the *completely congruent* to the *completely incongruent* (instead of the dichotomous yes/no response) to investigate how the level of agreement modulates the N400.

4.3 Future directions

We found that the amplitude of the P200 was less positive for semantic memory than for the other conditions. The P200 is sometimes thought to index high order perceptual processes, as in visual feature analysis (Evans & Federmeier, 2007; Luck & Hillyard, 1994). However, we do not think that differences due to selective attention to visual features are likely to explain any P200 effects in our study. Indeed, our stimuli were matched in number of letters, frequency, familiarity, and likableness (similar to emotional valence). Moreover, stimulus presentation was identical across conditions (i.e., same duration, font, colour, location on the screen), and a similar yes/no response was required in all conditions. Interestingly, a large body of research links P200 to emotion via its possible effects on attention or early lexico-semantic processing (Hajcak, Weinberg, MacNamara, & Foti, 2012; Kotz & Paulmann, 2011; Trauer, Kotz, & Müller, 2015). In these studies, the P200 is larger for emotional than neutral stimuli (Carretié, Hinojosa, Martín-Loeches, Mercado, & Tapia, 2004; Kanske & Kotz, 2007; Kotz & Paulmann, 2011). Even though the stimuli of our memory conditions were matched in likableness (or emotional valence), thinking about the words in relation to oneself may have increased their emotional salience compared to thinking about a group of people. Our findings would thus be reminiscent of those of Trauer et al., (2015) who interpreted their larger P200 and smaller N400 for emotional words compared to neutral words as *"*enhanced lexico-meaning access" (P200) and "facilitate[d] (….) integrative semantic processing*"*. Other studies have found a larger P200 but smaller N400 for positive compared to neutral words (Kanske & Kotz, 2007), and smaller N400 for positive words about self relative to positive words about others (Fields & Kuperberg, 2015). Fields and Kuperberg (2015) interpreted their findings in the context of a positivity bias: the attribution of a positive outcome is more expected for oneself than for others, and we could add that it requires less semantic processing for oneself. Indeed, our "yes" responses include mostly positive words from each condition, and a positivity bias is observed in the behavioural data. The component process view of personal semantics proposes, among other things, that emotional valence would be increased for self-knowledge relative to semantic memory (Renoult et al., 2012). Therefore, processing words in relation to one's self rather than in relation to others might increase the emotional salience of the words in a way that transpires in the P200 (possibly via attentional processes).

It is worth noting that there may be qualitative gaps when comparing personal with general semantics, as typically operationalized. Self-knowledge is often more emotional than general knowledge (Renoult et al., 2012; Sui & Humphreys, 2015). Similarly, a general semantics judgement may be less specific or may rely on a smaller amount of information that a self-judgement (e.g., I know what the word student means *versus* I know that I am a student; Klein & Loftus, 1993). Moreover, general semantics is very often looked at with typicality judgements of culturally-shared knowledge (what most people think/do, what is true in general, as in semantic categorisation tasks); this by definition concerns a group, whereas the self by definition is specific to one individual. To try to circumvent these problems, one might consider instead contrasting knowledge of just one individual (e.g., a close family member) with self-knowledge, but the former would not be a typical semantic memory condition because semantic memory is most often defined as general, culturally-shared knowledge (and, thus, detailed knowledge of a close other may be instead another type of personal semantics; Binder & Desai, 2011; Hart et al., 2007; Martin, 2001). For these reasons, when we compared personal to general semantics, we chose to contrast judgements of one's own traits to judgements of a category of people. Nonetheless, because of these potential qualitative gaps between typical operationalizations of personal and general semantics, it will be worthwhile in future studies to study some of these factors further (e.g., investigate how emotional semantic knowledge compares to self-knowledge; compare the neural substrates of knowledge of groups to knowledge of individuals, etc.).

It is also important to note that, in the present study, episodic memory was operationalized as high confidence recognition memory hits (Diana, Yonelinas, & Ranganath, 2007) and not as rich episodic re-experiencing, as is commonly done in autobiographical memory studies (Cabeza & St Jacques, 2007). This is because such slow re-experiencing recollection experiences are typically associated with complex task demands and longer processing time (e.g., 5-10 s per trial, Conway, Pleydell-Pearce, Whitecross, & Sharpe, 2002; Svoboda, McKinnon, & Levine, 2006) as compared to semantic memory tasks (0.8-1.5s, Chang, 1986). High confidence recognition memory is thus a better comparison in this context as it relies on more comparable task demands (Renoult et al., 2016), yet is thought to derive from recollection (Daselaar, 2006; Diana & Ranganath, 2011; Yonelinas, 2002b). The present episodic memory condition may rely to a greater extent on the 1st recollection stage of the model of Moscovitch (2008), reflecting fast ecphory (i.e., automatic interaction between the word cue and a corresponding memory trace) than on the second stage reflecting conscious and effortful re-experiencing. It would be interesting in future studies to develop complex semantic memory tasks that could be used as comparison for these slower and more elaborative recollection processes.

Our design could be modified easily to compare the brain regions associated with self-knowledge, and semantic and episodic memory, and to investigate the effects of time perspective, with functional Magnetic Resonance Imaging (fMRI). fMRI would also allow to assess the component process view of personal semantics (Renoult et al., 2012). That is, the 4 putative types of personal semantics (along with semantic and episodic memory themselves) may involve different weightings of such components as self-reflection, spatial and temporal processing, executive functions, emotions, and so forth. Of foremost interest regarding personal semantics, and perhaps regarding self-knowledge in particular, is the mPFC. Lesion to it impairs traits knowledge (Marquine et al., 2016), consistent with multiple fMRI studies linking this region to self-referential processing (particularly the ventral mPFC; Denny, Kober, Wager, and Ochsner, (2012); Qin et al. (2012)). The mPFC is activated when judging one's own traits, but less so when the decision is made in relation to the past and to the future than in present (e.g., D'Argembeau et al., 2010). Instead, past and future self-knowledge are associated with more activation of the right inferior parietal cortex compared to present self-knowledge (D'Argembeau et al., 2010). Brain regions associated with semantic and episodic memory would also be of key interest [e.g. medial temporal, anterior and inferior temporal, lateral parietal, retrosplenial, and several prefrontal regions (Lambon Ralph et al., 2017; Renoult et al., 2012; Spaniol et al., 2009)]. Additionally, differential activation to semantic and episodic or time perspective could help to generate hypotheses about patterns of impairment/preservation in neurological disorders. fMRI would complement our findings with ERPs, but this does not imply that all possible questions have already been addressed with ERPs. Rather, the present study highlights ERPs' potential for studying the factors – or components – that make personal semantics appear closer to either semantic or episodic memory. We found that the frequent and classical operationalization of self-knowledge, knowledge of present traits, can be differentiated from semantic memory by the P200/N400 and the LPC. Interestingly, the LPC of present self-knowledge suggests that it is intermediate to semantic and episodic memory. Yet the simple distinction of thinking of past and future traits rather than present traits pushed the LPC to be closer to episodic memory. Some open questions would benefit from the use of ERPs, including the possible influences on the present paradigm of scene construction (Palombo et al., in press), the closeness and similarity of the "other" people being considered (Lee & Atance, 2016), and taking a first vs. a third person perspective on oneself (Grossmann & Kross, 2014). In the meantime, the ancient Greeks' invitation to "Know thyself" continues to resonate with us. The present study suggests that past, present, versus future time perspectives can influence the brain correlates of self-knowledge. Incorporating time perspective into our models may help us develop a more comprehensive understanding of personal semantics and perhaps, even more broadly, of declarative memory.

Acknowledgements

We thank Rachel Lambert for help with data collection and all those who participated in the study. This work was supported by grants from the British Academy [grant number SG142524] to Louis Renoult and from the Natural Sciences and Engineering Research Council (NSERC) of Canada to P.S.R.D, and a Canada Graduate Scholarship from NSERC to A.N.T. The funders played no role in the study design; in the collection, analysis and interpretation of data; in the writing of the report; or in the decision to submit the article for publication. A.N.T., Lorenza. R., P.S.R.D, Louis R. contributed to study design, A.N.T., L.B., Lorenza. R., and C.S to data collection; A.N.T, L.B. Louis R. and P.S.R.D. to data preprocessing and data analyses. A.N.T wrote the bulk of the manuscript and all other authors contributed to writing and reviewing the manuscript.

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Appendix A

The stimuli

Task	Word	Task	Word
Self-knowledge List 1	depressed	Self-knowledge List 2	soft-spoken
Self-knowledge List 1	bossy	Self-knowledge List 2	logical
Self-knowledge List 1	rash	Self-knowledge List 2	attentive
Self-knowledge List 1	irrational	Self-knowledge List 2	caring
Self-knowledge List 1	trustworthy	Self-knowledge List 2	lovable
Self-knowledge List 1	indifferent	Self-knowledge List 2	invincible
Self-knowledge List 1	flamboyant	Self-knowledge List 2	impulsive
Self-knowledge List 1	self-centered	Self-knowledge List 2	angry
Self-knowledge List 1	casual	Self-knowledge List 2	genuine
Self-knowledge List 1	easygoing	Self-knowledge List 2	terrible
Self-knowledge List 1	inquisitive	Self-knowledge List 2	joyful
Self-knowledge List 1	quick-witted	Self-knowledge List 2	resistant
Self-knowledge List 1	philosophical	Self-knowledge List 2	sluggish
Self-knowledge List 1	old-fashioned	Self-knowledge List 2	worried
Self-knowledge List 1	fashionable	Self-knowledge List 2	inefficient
Self-knowledge List 1	dishonest	Self-knowledge List 2	zestful
Self-knowledge List 1	discreet	Self-knowledge List 2	nasty
Self-knowledge List 1	driven	Self-knowledge List 2	dynamic
Self-knowledge List 1	robust	Self-knowledge List 2	blunt
Self-knowledge List 1	finicky	Self-knowledge List 2	sloppy
Self-knowledge List 1	sarcastic	Self-knowledge List 2	enterprising
Self-knowledge List 1	neat	Self-knowledge List 2	agreeable
Self-knowledge List 1	charming	Self-knowledge List 2	cultured
Self-knowledge List 1	cautious	Self-knowledge List 2	manipulative
Self-knowledge List 1	orderly	Self-knowledge List 2	alert
Self-knowledge List 1	gleeful	Self-knowledge List 2	inaccurate
Self-knowledge List 1	vigilant	Self-knowledge List 2	courteous
Self-knowledge List 1	modest	Self-knowledge List 2	spontaneous
Self-knowledge List 1	merry	Self-knowledge List 2	playful
Self-knowledge List 1	pretentious	Self-knowledge List 2	courageous
Self-knowledge List 1	vulgar	Self-knowledge List 2	oversensitive
Self-knowledge List 1	incompetent	Self-knowledge List 2	hasty
Self-knowledge List 1	demanding	Self-knowledge List 2	grim
Self-knowledge List 1	listless	Self-knowledge List 2	self-righteous
Self-knowledge List 1	anxious	Self-knowledge List 2	harsh
Self-knowledge List 1	persuasive	Self-knowledge List 2	excitable

Self-knowledge List 1	considerate	Self-knowledge List 2	jubilant
Self-knowledge List 1	neighborly	Self-knowledge List 2	candid
Self-knowledge List 1	bitter	Self-knowledge List 2	ultra-critical
Self-knowledge List 1	talkative	Self-knowledge List 2	disrespectful
Self-knowledge List 1	self-sufficient	Self-knowledge List 2	aggressive
Self-knowledge List 1	narrow-minded	Self-knowledge List 2	eccentric
Self-knowledge List 1	mathematical	Self-knowledge List 2	liar
Self-knowledge List 1	grave	Self-knowledge List 2	sympathetic
Self-knowledge List 1	suspicious	Self-knowledge List 2	rational
Self-knowledge List 1	discourteous	Self-knowledge List 2	sophisticated
Self-knowledge List 1	rebellious	Self-knowledge List 2	tense
Self-knowledge List 1	sexy	Self-knowledge List 2	brave
Self-knowledge List 1	assertive	Self-knowledge List 2	opinionated
Self-knowledge List 1	complaining	Self-knowledge List 2	brisk
Self-knowledge List 1	cynical	Self-knowledge List 2	broad-minded
Self-knowledge List 1	vengeful	Self-knowledge List 2	well-mannered
Self-knowledge List 1	regretful	Self-knowledge List 2	observant
Self-knowledge List 1	envious	Self-knowledge List 2	grateful
Self-knowledge List 1	offensive	Self-knowledge List 2	hard-hearted
Self-knowledge List 1	conceited	Self-knowledge List 2	combative
Self-knowledge List 1	subtle	Self-knowledge List 2	tidy
Self-knowledge List 1	overcritical	Self-knowledge List 2	self-conscious
Self-knowledge List 1	mediocre	Self-knowledge List 2	cheeky
Self-knowledge List 1	sentimental	Self-knowledge List 2	thoughtful
Self-knowledge List 1	self-assured	Self-knowledge List 2	reckless
Self-knowledge List 1	energetic	Self-knowledge List 2	greedy
Self-knowledge List 1	disruptive	Self-knowledge List 2	obnoxious
Self-knowledge List 1	tolerant	Self-knowledge List 2	idealistic
Self-knowledge List 1	possessive	Self-knowledge List 2	stupid
Self-knowledge List 1	violent	Self-knowledge List 2	pushy
Self-knowledge List 1	nosy	Self-knowledge List 2	mischievous
Self-knowledge List 1	humorless	Self-knowledge List 2	careless
Self-knowledge List 1	peaceful	Self-knowledge List 2	egotistical
Self-knowledge List 1	decent	Self-knowledge List 2	anguished
Self-knowledge List 1	polite	Self-knowledge List 2	smug
Self-knowledge List 1	restless	Self-knowledge List 2	dignified
Self-knowledge List 1	inconsistent	Self-knowledge List 2	bubbly
Self-knowledge List 1	fearful	Self-knowledge List 2	insolent
Self-knowledge List 1	peppy	Self-knowledge List 2	absentminded
Self-knowledge List 1	quarrelsome	Self-knowledge List 2	outspoken

Self-knowledge List 1	jealous	Self-knowledge List 2	stern
Self-knowledge List 1	industrious	Self-knowledge List 2	sad
Self-knowledge List 1	realistic	Self-knowledge List 2	quiet
Self-knowledge List 1	spirited	Self-knowledge List 2	touchy
Self-knowledge List 3	mean	Semantic Memory - Priest	amusing
Self-knowledge List 3	sneaky	Semantic Memory - Priest	informal
Self-knowledge List 3	impolite	Semantic Memory - Priest	hilarious
Self-knowledge List 3	punctual	Semantic Memory - Priest	versatile
Self-knowledge List 3	superficial	Semantic Memory - Priest	vigorous
Self-knowledge List 3	whiny	Semantic Memory - Priest	clumsy
Self-knowledge List 3	temperamental	Semantic Memory - Priest	snobbish
Self-knowledge List 3	apprehensive	Semantic Memory - Priest	immature
Self-knowledge List 3	hateful	Semantic Memory - Priest	lazy
Self-knowledge List 3	impractical	Semantic Memory - Priest	crude
Self-knowledge List 3	grouchy	Semantic Memory - Priest	overcautious
Self-knowledge List 3	prudent	Semantic Memory - Priest	solemn
Self-knowledge List 3	short-tempered	Semantic Memory - Priest	scornful
Self-knowledge List 3	comical	Semantic Memory - Priest	intolerant
Self-knowledge List 3	perceptive	Semantic Memory - Priest	meddlesome
Self-knowledge List 3	extravagant	Semantic Memory - Priest	dependable
Self-knowledge List 3	comforting	Semantic Memory - Priest	conscientious
Self-knowledge List 3	noisy	Semantic Memory - Priest	hopeful
Self-knowledge List 3	insincere	Semantic Memory - Priest	amiable
Self-knowledge List 3	wise	Semantic Memory - Priest	forgiving

Self-knowledge List 3	open-minded	Semantic Memory - Soldier	defenseless
Self-knowledge List 3	overconfident	Semantic Memory - Soldier	compulsive
Self-knowledge List 3	materialistic	Semantic Memory - Soldier	irresponsible
Self-knowledge List 3	cooperative	Semantic Memory - Soldier	helpless
Self-knowledge List 3	accurate	Semantic Memory - Soldier	weak
Self-knowledge List 3	tactless	Semantic Memory - Soldier	hot-headed
Self-knowledge List 3	cordial	Semantic Memory - Soldier	cruel
Self-knowledge List 3	resentful	Semantic Memory - Soldier	tormented
Self-knowledge List 3	troublesome	Semantic Memory - Soldier	inexperienced
Self-knowledge List 3	sensible	Semantic Memory - Soldier	cranky
Self-knowledge List 3	pompous	Semantic Memory - Soldier	giggly
Self-knowledge List 3	agitated	Semantic Memory - Soldier	entertaining
Self-knowledge List 3	loud	Semantic Memory - Soldier	loyal
Self-knowledge List 3	seductive	Semantic Memory - Soldier	studious
Self-knowledge List 3	optimistic	Semantic Memory - Soldier	inoffensive
Self-knowledge List 3	daring	Semantic Memory - Soldier	disciplined
Self-knowledge List 3	decisive	Semantic Memory - Soldier	fearless
Self-knowledge List 3	reliable	Semantic Memory - Soldier	vivacious
Self-knowledge List 3	cowardly	Semantic Memory - Soldier	responsive
Self-knowledge List 3	explosive	Semantic Memory - Soldier	level-headed
Self-knowledge List 3	hesitant	Semantic Memory - Lawyer	confused
Self-knowledge List 3	innocent	Semantic Memory - Lawyer	indecisive
Self-knowledge List 3	clownish	Semantic Memory - Lawyer	inattentive

Self-knowledge List 3	cheerful	Semantic Memory - Lawyer	dull
Self-knowledge List 3	progressive	Semantic Memory - Lawyer	hypochondriac
Self-knowledge List 3	pessimistic	Semantic Memory - Lawyer	wordy
Self-knowledge List 3	high-spirited	Semantic Memory - Lawyer	boastful
Self-knowledge List 3	sparkling	Semantic Memory - Lawyer	hostile
Self-knowledge List 3	cool-headed	Semantic Memory - Lawyer	deceitful
Self-knowledge List 3	likable	Semantic Memory - Lawyer	malicious
Self-knowledge List 3	contented	Semantic Memory - Lawyer	humble
Self-knowledge List 3	ethical	Semantic Memory - Lawyer	generous
Self-knowledge List 3	naive	Semantic Memory - Lawyer	truthful
Self-knowledge List 3	crafty	Semantic Memory - Lawyer	daydreamer
Self-knowledge List 3	pleasant	Semantic Memory - Lawyer	tactful
Self-knowledge List 3	congenial	Semantic Memory - Lawyer	ambitious
Self-knowledge List 3	opportunist	Semantic Memory - Lawyer	witty
Self-knowledge List 3	thrifty	Semantic Memory - Lawyer	intelligent
Self-knowledge List 3	affectionate	Semantic Memory - Lawyer	theatrical
Self-knowledge List 3	rude	Semantic Memory - Lawyer	bold
Self-knowledge List 3	tiresome	Semantic Memory - Scientist	foolish
Self-knowledge List 3	mellow	Semantic Memory - Scientist	negligent
Self-knowledge List 3	strict	Semantic Memory - Scientist	gullible
Self-knowledge List 3	ingenious	Semantic Memory - Scientist	frantic
Self-knowledge List 3	submissive	Semantic Memory - Scientist	tearful
Self-knowledge List 3	hot-tempered	Semantic Memory - Scientist	downcast

Self-knowledge List 3	efficient	Semantic Memory - Scientist	wasteful
Self-knowledge List 3	timid	Semantic Memory - Scientist	thoughtless
Self-knowledge List 3	outgoing	Semantic Memory - Scientist	bleak
Self-knowledge List 3	obstinate	Semantic Memory - Scientist	antisocial
Self-knowledge List 3	exuberant	Semantic Memory - Scientist	frisky
Self-knowledge List 3	artistic	Semantic Memory - Scientist	fortunate
Self-knowledge List 3	critical	Semantic Memory - Scientist	sociable
Self-knowledge List 3	neurotic	Semantic Memory - Scientist	expressive
Self-knowledge List 3	vain	Semantic Memory - Scientist	humorous
Self-knowledge List 3	moody	Semantic Memory - Scientist	inventive
Self-knowledge List 3	soft-hearted	Semantic Memory - Scientist	competent
Self-knowledge List 3	argumentative	Semantic Memory - Scientist	meticulous
Self-knowledge List 3	disobedient	Semantic Memory - Scientist	persistent
Self-knowledge List 3	imaginative	Semantic Memory - Scientist	precise
Episodic Memory - New	coercive	Episodic Memory - Old	depressed
Episodic Memory - New	foolhardy	Episodic Memory - Old	bossy
Episodic Memory - New	frivolous	Episodic Memory - Old	rash
Episodic Memory - New	defiant	Episodic Memory - Old	irrational
Episodic Memory - New	deceptive	Episodic Memory - Old	indifferent
Episodic Memory - New	stingy	Episodic Memory - Old	self-centered
Episodic Memory - New	radical	Episodic Memory - Old	old-fashioned
Episodic Memory - New	spiteful	Episodic Memory - Old	dishonest

Episodic Memory - New	overbearing	Episodic Memory - Old	finicky
Episodic Memory - New	fidgety	Episodic Memory - Old	sarcastic
Episodic Memory - New	fault-finding	Episodic Memory - Old	flamboyant
Episodic Memory - New	fussy	Episodic Memory - Old	casual
Episodic Memory - New	gloomy	Episodic Memory - Old	easygoing
Episodic Memory - New	preoccupied	Episodic Memory - Old	inquisitive
Episodic Memory - New	distrustful	Episodic Memory - Old	quick-witted
Episodic Memory - New	insecure	Episodic Memory - Old	philosophical
Episodic Memory - New	shallow	Episodic Memory - Old	fashionable
Episodic Memory - New	disagreeable	Episodic Memory - Old	discreet
Episodic Memory - New	dissatisfied	Episodic Memory - Old	driven
Episodic Memory - New	uptight	Episodic Memory - Old	robust
Episodic Memory - New	skeptical	Episodic Memory - Old	impulsive
Episodic Memory - New	crabby	Episodic Memory - Old	stern
Episodic Memory - New	desperate	Episodic Memory - Old	angry
Episodic Memory - New	hyperactive	Episodic Memory - Old	terrible
Episodic Memory - New	withdrawn	Episodic Memory - Old	touchy
Episodic Memory - New	arrogant	Episodic Memory - Old	resistant
Episodic Memory - New	gossipy	Episodic Memory - Old	sluggish
Episodic Memory - New	irritable	Episodic Memory - Old	worried
Episodic Memory - New	cold	Episodic Memory - Old	nasty
Episodic Memory - New	messy	Episodic Memory - Old	enterprising
Episodic Memory - New	selfish	Episodic Memory - Old	agreeable

Episodic Memory - New	threatening	Episodic Memory - Old	attentive
Episodic Memory - New	boring	Episodic Memory - Old	caring
Episodic Memory - New	impatient	Episodic Memory - Old	lovable
Episodic Memory - New	nervous	Episodic Memory - Old	invincible
Episodic Memory - New	forgetful	Episodic Memory - Old	genuine
Episodic Memory - New	jovial	Episodic Memory - Old	joyful
Episodic Memory - New	prosocial	Episodic Memory - Old	zestful
Episodic Memory - New	methodical	Episodic Memory - Old	dynamic
Episodic Memory - New	upright	Episodic Memory - Old	careless
Episodic Memory - New	diligent	Episodic Memory - Old	whiny
Episodic Memory - New	maternal	Episodic Memory - Old	temperamental
Episodic Memory - New	ecstatic	Episodic Memory - Old	apprehensive
Episodic Memory - New	cunning	Episodic Memory - Old	hateful
Episodic Memory - New	refined	Episodic Memory - Old	impractical
Episodic Memory - New	righteous	Episodic Memory - Old	grouchy
Episodic Memory - New	moderate	Episodic Memory - Old	short-tempered
Episodic Memory - New	sharp-witted	Episodic Memory - Old	noisy
Episodic Memory - New	glowing	Episodic Memory - Old	insincere
Episodic Memory - New	resourceful	Episodic Memory - Old	overconfident
Episodic Memory - New	perfectionist	Episodic Memory - Old	cordial
Episodic Memory - New	heroic	Episodic Memory - Old	prudent
Episodic Memory - New	constructive	Episodic Memory - Old	comical
Episodic Memory - New	prompt	Episodic Memory - Old	perceptive

Episodic Memory - New	glorious	Episodic Memory - Old	extravagant
Episodic Memory - New	carefree	Episodic Memory - Old	comforting
Episodic Memory - New	inspired	Episodic Memory - Old	wise
Episodic Memory - New	gifted	Episodic Memory - Old	open-minded
Episodic Memory - New	outstanding	Episodic Memory - Old	cooperative
Episodic Memory - New	tender	Episodic Memory - Old	accurate
Episodic Memory - New	calm	Episodic Memory - Old	foolish
Episodic Memory - New	obedient	Episodic Memory - Old	hot-headed
Episodic Memory - New	respectful	Episodic Memory - Old	confused
Episodic Memory - New	gentle	Episodic Memory - Old	cruel
Episodic Memory - New	protective	Episodic Memory - Old	downcast
Episodic Memory - New	passionate	Episodic Memory - Old	negligent
Episodic Memory - New	lively	Episodic Memory - Old	tormented
Episodic Memory - New	supportive	Episodic Memory - Old	defenseless
Episodic Memory - New	talented	Episodic Memory - Old	clumsy
Episodic Memory - New	sincere	Episodic Memory - Old	inexperienced
Episodic Memory - New	lucky	Episodic Memory - Old	entertaining
Episodic Memory - New	adventurous	Episodic Memory - Old	humble
Episodic Memory - New	confident	Episodic Memory - Old	frisky
Episodic Memory - New	helpful	Episodic Memory - Old	inventive
Episodic Memory - New	belligerent	Episodic Memory - Old	witty
Episodic Memory - New	stubborn	Episodic Memory - Old	fortunate
Episodic Memory - New	exceptional	Episodic Memory - Old	dependable

Episodic Memory - New	romantic	Episodic Memory - Old	disciplined
Episodic Memory - New	ill-tempered	Episodic Memory - Old	sociable
Episodic Memory - New	hopeless	Episodic Memory - Old	competent

Scrutinizing the grey zones of declarative memory: Does the Late Positive Component (LPC) reflect mental time travel, self-relevance, or proximity to self?

Annick N. Tanguay[a], Daniela J. Palombo[b], Cristina M. Atance[a], Louis Renoult[c], Patrick S. R. Davidson[a]

[a] School of Psychology, University of Ottawa, Ottawa, Canada.

[b] Department of Psychology, University of British Columbia, Vancouver, Canada

[c] School of Psychology, University of East Anglia, Norwich, UK.

Abstract

In the cognitive neuroscience of memory, knowledge of the world (i.e., semantic memory) is often contrasted with the vivid recollection of personal events (i.e., episodic memory). Behavioural and ERP data have dissociated these two forms of declarative memory from self-knowledge (Renoult, Davidson, Palombo, Moscovitch, & Levine, 2012; Tanguay et al., 2018). In addition, the temporal orientation of self-knowledge appeared to influence the Late Positive Component (LPC), an ERP correlate of recollection (Rugg & Curran, 2007). Thinking about present traits produced a LPC amplitude that was intermediate between semantic and episodic memory, whereas thinking of future selves did not differ from episodic memory (Tanguay et al., 2018). In this study, participants thought about their own traits in the present and in the future, and did the same task for other people. Thus, the atemporal "semantic memory" condition became "temporal" to match the self-knowledge conditions. Theoretical and empirical reasons motivated this modification. From a theoretical standpoint, little is known regarding whether mental time travel or recollection depends on self-relevance. Hence, we investigated whether we would find a temporal orientation effect on the LPC amplitude when thinking about other people's traits as well as personal traits. From an empirical standpoint, some researchers attributed LPC effects to self-relevance instead of recollection (e.g., Kotlewska and Nowicka, 2016), but both factors had not been manipulated systematically. As a second major goal, we further manipulated the proximity of other people between subject: some thought of the traits of their age group (group other, *n* = 35), or of a stranger (generic other, n = 28), or of a close friend (close other, *n* = 31). Thinking of a close friend should increase self-relevance and possibly also recollection, thus decreasing the LPC difference between self and other. We extracted the mean

LPC amplitude from 500 to 800 ms post-stimulus onset, averaged parietal sites (P3/Pz/P4). The LPC amplitude was entered in a mixed ANOVA with knowledge type (self, other), and temporal perspective (present, future) as within subject factors, and proximity to others (group other, generic other, close other) as a between subject factor. The LPC amplitude for self-knowledge was more positive than for other-knowledge, and more positive for future- than present thinking, as expected, and these did not interact with proximity to self. Hence, the LPC when thinking of close friends differs from self in a similar fashion to thinking of a group of people or a generic other. The interaction between self-relevance and temporal orientation approached significance, because the temporal orientation effect was larger when thinking about the self than others. Our study shows that the LPC amplitude is sensitive to the temporal perspective and self-relevance of semantic aspects of declarative memory, and might not be solely a signature of episodic memory.

Keywords: Late Positive Component (LPC), ERPs, self-knowledge, self-relevance, future thinking, semantic memory, traits

"I will be adventurous and active when I retire." How does one create a prediction like this about one's future? In many situations, our culturally-shared knowledge of the world (i.e., semantic memory) and our ability to reconstruct events from our personal past (i.e., episodic memory) can shape our imagination of the future (Atance & O'Neill, 2001; Irish & Piguet, 2013; Schacter, Benoit, & Szpunar, 2017). Self-knowledge, for example knowledge of one's own personality (e.g., I am adventurous) and preferences, is a type of personal semantics (i.e., personal, yet abstract; Renoult et al., 2012). Knowledge of one's *present* personality traits can be resilient to brain lesions that impair either semantic or episodic memory (reviewed in Klein & Lax, 2010). Yet, might self-knowledge become more dependent on semantic or episodic memory when one imagines a *future* self? For instance, being able to draw on semantic knowledge to say "I know that staying active is key to healthy aging" or refer back to an episodic memory to say "I dream of one day volunteering in schools in Africa" might inform one's vision of future and possible selves. To investigate this question, recently we leveraged two extensively-studied ERPs (Tanguay et al., 2018): The N400, which is sensitive to semantic memory (Kutas & Federmeier, 2011), and the Late Positive Component (LPC), which is associated with episodic memory (Rugg & Curran, 2007). In our study, people had to decide whether traits reflected their own personality five years ago, currently, and five years from now (for the past, present, and future self-knowledge tasks), or the personality of people holding an occupation (e.g., soldiers - courageous; for the semantic memory task). The participants also completed a recognition task with old and new traits (for the episodic recognition memory task). The amplitude of the N400 was greatest for semantic memory, and not modulated by temporal perspective. In contrast, the amplitude of the LPC was minimal for semantic memory, maximal for episodic memory, and intermediate for the knowledge of one's current traits. The LPC amplitude for thinking about one's past and future selves fell between thinking about one's present self and episodic memory, and did not differ significantly from them.

For theoretical reasons, it seemed reasonable to take the LPC effects in Tanguay et al. (2018) as provisional indicators of recollection [i.e., a high-confidence judgment involving retrieval of item and context; Daselaar, Fleck, & Cabeza, 2006; Rugg & Curran, 2007; Yonelinas, 2002)], a process associated with episodic memory. The LPC (also known as the parietal old/new effect) is an ERP component of positive amplitude that peaks approximately 500 to 800 ms after stimulus onset, and is typically maximal over left parietal electrode sites (Rugg & Curran, 2007; Wilding & Ranganath, 2012). The LPC's relationship with recollection, which can be evoked in a classical recognition memory task, is reasonably well-established: Subjective "Remember" responses produce a larger LPC amplitude than subjective "Know" responses, and the LPC is also contingent on the actual occurrence of the (experimental) event (i.e., false alarms do not elicit a comparable LPC amplitude; Rugg & Curran, 2007; Wilding & Ranganath, 2012). Amnesia abolishes the LPC effect even if the items are correctly recognized based on familiarity (Addante, Ranganath, Olichney, & Yonelinas, 2012). The recollection of autobiographical events can also produce a larger LPC compared to semantic memory (Renoult, Tanguay, et al., 2016). On an old/new recognition task with healthy people, the LPC correlated with fMRI activation in the medial temporal lobe (MTL; in right hippocampus and parahippocampal gyrus), along with bilateral middle cingulate cortex and some frontal regions (Hoppstädter, Baeuchl, Diener, Flor, & Meyer, 2015).

Yet, future thinking and episodic processing need not always go together. Recent fMRI studies have suggested that future thinking does not engage necessarily the medial temporal lobes (MTL, which are classically associated with episodic memory), but rather does so only when a great number of episodic details are involved (Addis, Cheng, P. Roberts, & Schacter, 2011; Palombo, Hayes, Peterson, Keane, & Verfaellie, 2016). Similarly, thinking about past and future traits did not increase MTL activity relative to present traits in another fMRI study, although it did increase inferior parietal cortex (IPC) activity (D'Argembeau, Stawarczyk, et al., 2010b). The authors linked their IPC finding to its previously found relationship with perspective taking and dissociating the self from others. In another study, participants reported recalling slightly more events when thinking about traits as true in general (e.g., in general, I am shy) rather than relative to a context (e.g., at work, I am outspoken; Martial, Stawarczyk, & D'Argembeau, 2018). Hypothetically, the future could be a "context" to which traits become attached. Nonetheless, the higher recall of events did not translate into greater MTL activity for traits that were true in general (Martial et al., 2018). According to Lieberman, Jarcho, and Satpute, (2004) traits can be judged intuitively, or based on evidence (e.g., episodic memory) as indicated by slower reaction times in people with a lot of relevant experience. Only the latter case may be related to MTL activity (Lieberman et al., 2004). Episodic processing could become necessary when an "intuitive" or "abstracted" form of trait knowledge is inaccessible (Klein & Lax, 2010). Considerable data suggest the possibility of a dissociation between episodic processing and thinking about one's traits in the future, specifically.

Part of the challenge may be that future thinking involves several processes: not only episodic processing (at least, under certain conditions), but also self-referential processing, a change in temporal perspective, emotional valence, and other factors (similar to a component process view of episodic memory or personal semantics; (Cabeza & Moscovitch, 2013; D'Argembeau, Ortoleva, Jumentier, & Van der Linden, 2010; Moscovitch, 1992; Renoult et al., 2012). In this present study we focused on three factors that might play a significant role in the

LPC amplitude’s relation with future thinking: temporal orientation (“mental time travel”; Schacter et al., 2012), self-relevance, and proximity to self.

Is it temporal orientation? Prior literature offers limited evidence regarding a temporal orientation account of the LPC effect. In Tanguay et al. (2018), the amplitudes of the LPC for thinking about the self five years ago or five years from now were larger than for thinking about the present self. The amplitudes of the LPC for each of these were larger compared to thinking about people in general (semantic memory condition). To our knowledge, no other studies have found such a temporal orientation effect for thinking about past or future traits (but see Kotlewska & Nowicka, 2015, 2016; Luo, Jackson, Wang, & Huang, 2013). Hence, an important goal of this study is to replicate our finding of a larger LPC amplitude when thinking about the future self than the present self.

Is it self-relevance? The LPC is associated with self-relevance, for example it is larger for stimuli associated with the self than others, like one’s own name [Kotlewska & Nowicka, (2016); Magno & Allan (2007); Tamura, Mizuba, & Iramina, (2016); reviewed in Renoult, Tanguay, et al. (2016)]. As a pertinent application of this interpretation: A smaller LPC difference in amplitude for thinking about past traits compared to the present traits has been attributed to the decreased self-relevance of the past self (note that this was not a significant difference; [Kotlewska and Nowicka (2016) based on D’Argembeau et al., (2008); D’Argembeau, Stawarczyk, Majerus, Collette, Van der Linden, and Salmon (2010)]. Self-relevance could contribute to the effects reported in Tanguay et al. (2018), but only in part. The LPC amplitudes of self-knowledge—no matter the temporal perspective—were always more positive than semantic memory (i.e., other-knowledge). However, an increased self-relevance is unlikely to explain the larger LPC for past and future self-knowledge compared to present self-knowledge. In Tanguay et al. (2018), temporal orientation and self-relevance were confounded when considering the past and future selves. Little research has aimed to disentangle effects of self-relevance and temporal orientation.

Does the temporal orientation effect depend on self-relevance? Prior studies suggest that the neural correlates of thinking about the self and others at different times do not overlap fully. To our knowledge, the few relevant studies recorded brain activity with fMRI. D'Argembeau, Stawarczyk, Majerus, Collette, Van der Linden, & Salmon (2010) found reduced medial prefrontal cortex (mPFC) and increased IPC activity for thinking about past and future traits relative to present traits. The mPFC (particularly ventral) relates to self-referential processing, and the retrieval of schemas (Denny, Kober, Wager, & Ochsner, 2012; Ghosh & Gilboa, 2014; Gilboa & Marlatte, 2017). In another fMRI study, thinking about the present self was associated with more activity in the mPFC and posterior cingulate cortex (PCC) than thinking about the past self or a friend in the past or in the present, which did not differ from one another (D'Argembeau et al., 2008). The PCC supports "internally directed thoughts", as in future thinking and autobiographical memory, and shows a relationship with attentional processes and arousal (Leech & Sharp, 2014). Hence, distant selves could be like "other" people (D'Argembeau, Stawarczyk, et al., 2010b). In another rare study of self-relevance and temporal orientation, the imagination of future events that connected to personal goals recruited more mPFC and PCC than those with low self-relevance (D'Argembeau, Stawarczyk, et al., 2010a). In sum, the difference in neural correlates between the present and the future might not be identical when considering the self and others, with the future being most distinct from the present for the self.

Proximity to self. Instead of a dichotomous category (me/others), self-relevance could range on a continuum from self-irrelevant/abstract (e.g., a group) to self-relevant/episodic-like (e.g., friends, family, significant others). Across studies, the "other" has varied somewhat, from a close other (i.e., significant other, friend, family member; D'Argembeau et al., 2008; Kotlewska & Nowicka, 2016) to a famous person (Kotlewska & Nowicka, 2016) to a group of people (Tanguay et al., 2018)**.** The other's similarity or proximity to self might determine the difference between the knowledge of self and other. That is, the knowledge of close others might entail the retrieval of past events (e.g., I remember when Thomas reviewed a text despite being busy; he is generous), emotional valence (e.g., I don't want to paint my friend in a negative light), self-relevance (e.g., Thomas is "my" friend, or he is similar to me), etc. (Renoult et al., 2012). Further, the close "other" could be included within the self-concept (Aron, Aron, Tudor, & Nelson, 1991). Therefore, a simple and global distinction between self- and other- knowledge conceal several similarities – and differences – between these memory types**.** In accordance with these ideas, in Kotlewska & Nowicka (2016), the LPC of thinking about the traits of a close other was intermediate between the maximum effect (which was for the present self) and the minimum effect (which was for a famous person; akin to the vmPFC effect in fMRI research; Murray, Schaer, & Debbané, 2012).

Does the temporal orientation effect depend on proximity to self? Many behavioural studies suggest that we consider other people's future differently based on their proximity to the self. For example, people predict greater stability in their preferences compared to other people (Bauckham et al., 2018; Renoult, Kopp, Davidson, Taler, & Atance, 2016). Adults envision smaller changes in their activities from younger to older age relative to a generic person of the same age (Renoult, Kopp, et al., 2016). Thus, one's relative "eternal youth" is not a shared destiny. In comparison, adults predict similar changes in adopting stereotypical activities of the young and greater changes in activities stereotypical of the older adults for a close other compared to the self (Bauckham et al., 2018). In any case, people expect a generic other to change the most, in a way that reflects better the preferences of current older adults (Bauckham et al., 2018). Lee & Atance (2016) speak of a “beneficial other effect” in which taking the perspective of another person can provide one with the psychological distance to ponder one’s future rationally. Thinking about the future of another person, particularly a generic person, might depend more on semantic memory and less on episodic processing than one’s own future. Episodic processing can also follow a gradation from self to close other to unknown: The events that are imagined from one’s own future possessed higher episodic richness than those imagined for close others, and both are richer than those for an acquaintance (Grysman, Prabhakar, Anglin, & Hudson, 2013). Therefore, even if we can ponder other people’s future—not just our own—this might be associated with reduced mental time travel or episodic processing and correspondingly, a reduced LPC amplitude. However, as mentioned above, the closeness of the relationship with the “other” might modulate this effect.

The Current Study

a) The four tasks. Within-subject factors

	Self-relevance (self vs. other)	
Time (present vs. future)	Present self	Present other
	Future self	Future other

b) Who is the other? Between-subject factor

Group other: "(…) people belonging to your age group in this country (…)"
Close other: "(…) your closest friend. It should not be a family member or a romantic partner."
Generic other: "(…) Amy (or John), a (age of participant) year old (usually same gender as the participant)"

c) Trial structure and durations

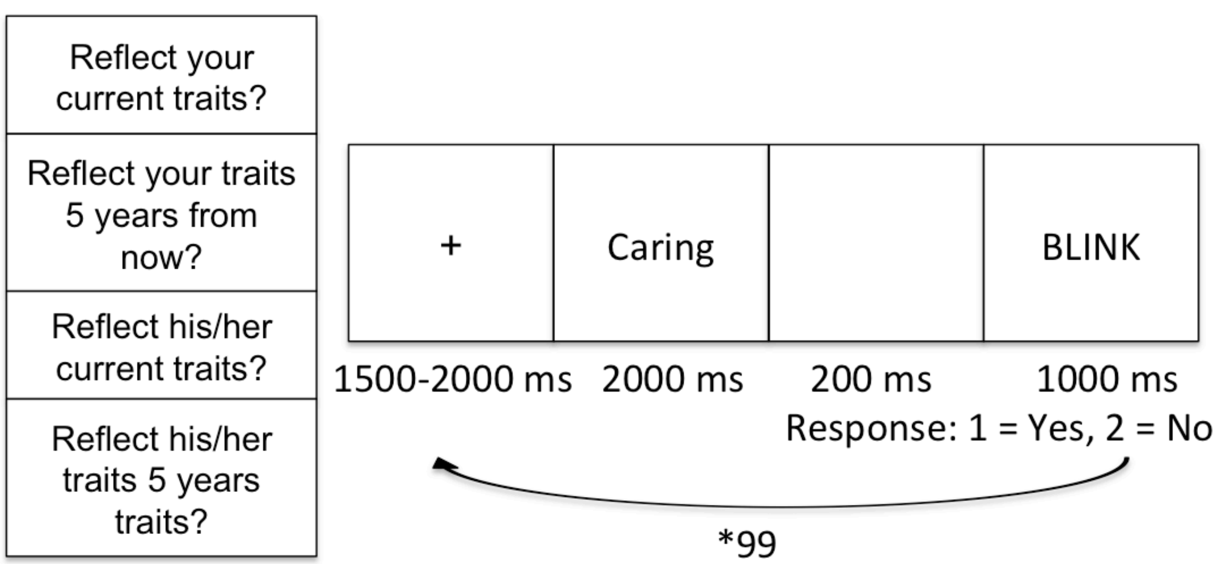

Figure 1. Overview of the study. a) All participants thought about their traits and those of another person in the present and the future. b) The "other" was defined in three ways that varied in proximity to self, i.e., close (friend) to remote/abstract (generic person, group of people). c) After the instructions (see Appendix A for the full instructions), the participants saw 100 trials per condition, and responded to each trait as instructed.

For the reasons outlined above, here we investigate how self-relevance and temporal orientation (present versus future) might modulate the LPC amplitude, in a present- and future-thinking task nearly identical to Tanguay et al. (2018), see Figure 1. Accordingly, we expected to replicate our previous finding of a larger LPC amplitude for thinking about the future self than the present self. We modified the condition regarding people in general (i.e., semantic memory) to accommodate a manipulation of temporal perspective. In the previous study, the participants thought about the typical (present) traits of people holding a certain occupation. Here, participants thought about the commonalities of people in the same age group (as the participant) currently and in the future (i.e., 5 years from now). Overall, we expected a temporal orientation effect irrespective of self-relevance (i.e., larger LPC amplitude for future than present), and a self-relevance effect irrespective of temporal orientation (i.e., larger LPC amplitude for self than other). Thinking about the future of a group might rely less on mental time travel, or the recollection or imagination of events; thus, the temporal orientation effect might be reduced for others. Semantic knowledge of time could underlie the orientation to other people's future rather than mental time travel, *per se* (e.g., Craver, Kwan, Steindam, & Rosenbaum, 2014). We selected the same age group to ensure that participants could orient to the present and the future of others, and to reduce group membership effects [social group membership modulates vmPFC activity, with greater vmPFC activity for one's own age group; Ebner et al. (2011)]. However, the task retained a certain self-relevance and our findings might not be perfectly applicable to the atemporal and self-irrelevant semantic memory. We added two additional conceptualizations of "others" to manipulate proximity to self: generic other and close other. The close other was the participants' closest friend. This condition is the most self-relevant of the Other conditions. The generic other was a stranger of the same age, and we matched the gender membership (same or different) to the close other condition. We included generic other to represent the processing of a single unknown person, which we assumed to recruit semantic memory and to be minimally relevant to the self.

To further elucidate the cognitive correlates of the LPC amplitude, we included self-report questions about self-relevance, episodic processing, and future thinking after each task. Furthermore, participants rated the perceived similarity between: 1) the present self and the future self, 2) the self and the other(s), 3) and the present other and the future other. We also administered the task in four orders to investigate their potential effect. In particular, when self came first, we expected that the difference between self and other would be reduced, because this could prime participants to perceive others as more similar to self. Lastly, we included a measure of empathy traits for exploratory analyses. People with a greater tendency to take the perspective of others might be better able to disengage from their own perspective to think of other people or distant times (Böckler, Herrmann, Trautwein, Holmes, & Singer, 2017; O'Connell, Hsu, Christakou, & Chakrabarti, 2018). If that is so, the LPC difference in amplitude between self and other would greater in people who endorse empathy traits.

Methods

Participants

From the 118 participants, the data of 94 participants was retained for the analyses. Of these 94, 71 were women (1 non-binary, 22 male), and they had a *M* age = 19.88 years (*SE* = .26) and a *M* education = 13.17 years (*SE* = .16). The participants were randomly assigned to one of the three experimental groups (see Table 1 for the characteristics of each group). Some participants signed up to take part in the study for credits towards their course on psychology or research methods. Some responded to online ads or to posters put on the campus of the University of Ottawa. These participants received a $30 compensation. The inclusion criteria were: native English speaker, or having learned English early, right-handed, no psychiatric or neurological disorder, no head injury with loss of consciousness over 5 minutes, no substance abuse, aged between 18 and 35 years, and good or corrected-to-normal vision. We excluded 24 participants (before running statistical analyses) because they did not meet the eligibility criteria (n = 18), because of technological failure or excessively poor EEG (n = 5) or failure to follow instructions (n = 1). The exclusion rate was a by-product of the recruitment strategy (i.e., the student pool) in part. We planned for sample sizes slightly bigger than Tanguay et al. (2018), that is, 30 participants per condition (vs. 28). This number corresponds approximately to the necessary sample size to obtain a significant LPC difference in amplitude between present self and future self within each group assuming the original 80 trials (instead of the current 100 trials) and a repeated measures ANOVA with only those 2 measurements ($n = 33$, $\eta^2_p = 0.06$, $\alpha = 0.05$, $\beta = 0.8$, 2 measurements, correlation among measures = 0.5 and nonsphericity correction = 1, computed in G*Power; (Faul, Erdfelder, Lang, & Buchner, 2007). In particular, our Group Other condition—the most similar to the original semantic memory—included enough participants to detect the effect, and the full sample (N = 94) provides ample power (0.998). The Health

Sciences and Science Research Ethics Board reviewed the ethical aspects of the study (H10-16-20) and all participants provided informed consent before beginning.

Table 1

Demographic characteristics of the experimental groups

	Group other	Generic other	Close other	Statistical tests
n	35	28	31	N/A
Gender	23 W/ 11 M / 1 non-binary	22 W/ 6 M	26 W/ 5 M	X^2 (4, N = 94) = 4.16, p = .384
Age in years	20.06 (SE = .4)	19.64 (SE = .44)	19.9 (SE = .53)	$F(2, 91) = .21, p = .814$
Years of education	13.29 (SE = .28)	12.96 (SE = .22)	13.21 (SE = .29)	$F(2, 91) = .37, p = .694$

Stimuli

We selected the same 400 words as (Tanguay et al., 2018) from (Dumas, Johnson, & Lynch, 2002), except that “competitive” replaced “complaining”. Each list consisted of 50 positive and 50 negative traits. The four lists did not differ in familiarity, number of letters, frequency (Kučera & Francis, 1967), or likableness, $p \geq .868$. The correlation between valence (Warriner, Kuperman, & Brysbaert, 2013) and likableness for a subset of words was $r = .932, p < .001$, confirming the overlap between these constructs. The positive words’ likableness was significantly higher than negative words within every list, $t(98) \geq 20.06, p < .001$.

Design

We assigned the participants to one of the three experimental Other conditions (group other, generic other, close other). Further, the order of the word lists was pseudo-randomized using the Latin Square method (i.e., each list was shown once in every position: first, second, third, fourth). We crossed the order of temporal orientation (present, future) and self-relevance (self, other), which led to four orders (i.e., self first/present first; self first/future first; other first/present first; other first/future first). The "self" conditions were presented consecutively; the "other" conditions likewise. The experimental conditions, with their associated list and task order, were randomized across all participants with an excel function to avoid temporal autocorrelation. After exclusion, 1 to 3 (median = 2) participants completed the study in a given list and task order and experimental condition.

Self-report questionnaires

Interpersonal questionnaire. The questionnaire was adapted from (Aron et al., 1991; Ersner-Hershfield, Garton, Ballard, Samanez-Larkin, & Knutson, 2009; Liviatan, Trope, & Liberman, 2008). We collected information on the close friend or the generic person (contingent on the experimental condition): age, sex, number of years they had known the person, and number of years they had been close. Moreover, on a scale from 1 (not at all) to 9 (very much), the participants rated how close and how similar they felt to the other person, and how much they liked him/her. Interestingly, the "generic other" participants became so immersed in the task that they often responded to those questions as if they knew the person. The experimenter verified that the instructions had been understood and followed throughout the task. These participants confirmed that they were "pretending" to know the person. Although we compare Close Other and Generic Other on these measures, the outcome must be interpreted with caution because of the ambiguity (e.g., what does it mean to feel close to a person that we pretend to know?).

All the participants, "group other" included, filled out the following questions. The participants rated the effort they invested in the task about the other person/people their age, and task difficulty for self and for other(s). Lastly, participants selected the circles that best represented 1) how similar they felt to the other person/people their age; 2) how similar the other person's present self was to their future self; 3) how similar they felt to their own self in 5 years from now (see Figure 1).

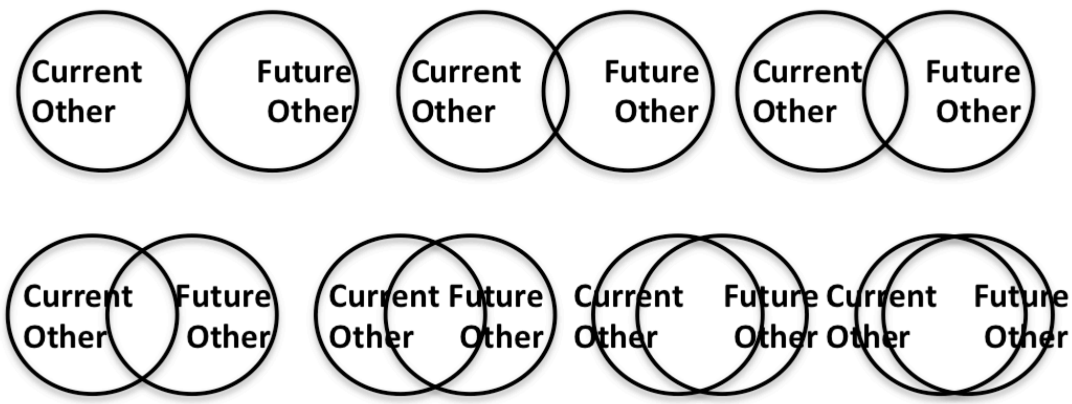

Figure 1. Ratings of similarity. Adapted from (Ersner-Hershfield et al., 2009). Additional similarity ratings showed "Current self" and "Future self" or "Self" and "Other" instead of "Current other" and "Future other".

Interpersonal reactivity index (Davis, 1983). The questionnaire examines various facets of empathy traits, of which we only included perspective taking and empathic concern. The perspective-taking scale assesses the tendency to put oneself in the shoes of another person (cognitively). The empathic concern pertains to feeling for other people, in particular in negative situations. Each scale comprises 7 items that were averaged together. The options ranged from 0 (does not describe me well) to 4 (describes me very well).

Procedure

The tasks were programmed in E-Prime 2.0 (Psychology Software Tools, Inc, 2012). Only the instructions and the subject of the two pre-experimental questions (i.e., self/other, present/future) distinguished the four tasks. Participants decided whether the words reflected (or not) their present traits for the present self condition, or in five years from now for the future self condition (Tanguay et al., 2018). The full sample completed these two tasks. The instructions for the "other" condition depended on the experimental condition (i.e., group other, generic other, close other). In group other, participants decided whether the traits were representative of the current and future traits (5 years from now) of people in their own age group in Canada. The instructions emphasized the commonalities of the age group. In the generic other condition, participants decided whether the traits reflected the personality of a John or Amy currently and in 5 years from now. This other person typically had the same gender, and always the same age. Lastly, in the Close Other condition, participants selected their closest friend that was not a family member or romantic partner. The participants decided whether the traits reflected their friend's current or future traits. The friends were known for a M of 7.22 years (SE = .92), and they entertained a close relationship since a M of 5.9 years (SE = .96). The relationship was judged to be near the maximum on closeness (i.e., 9; M = 8.08, SE = .23). The age of the chosen friend correlated almost perfectly with the participants' own age, $r = .967$, $p < .001$. The generic other and close other conditions were matched in gender membership of the "other" person. One participant in each group chose or was given a person from another gender (number of same vs other gender, $p = .728$, tested with Fisher's exact test).

Each task began with two questions about the self or the other(s) in the present or the future; one pertained to activities and the other to housing situation. The participants had 60 seconds to type their response, which was recorded for analyses (D'Argembeau, Stawarczyk, et al., 2010b; Tanguay et al., 2018). Subsequently, the participants viewed the 50 positive and 50 negative words in a randomized order using E-Prime, and made the decisions as instructed. The stimuli were shown over a white screen in a courier new font with a 24 size. Each trial started with fixation cross lasting from 1500 to 2000 (randomly; see Figure 2). The words were displayed for 2000 ms, and the participants had up to 3000 ms to respond. The trial ended with a 1000 ms screen to allow participants to blink between trials. At the end of each task, participants evaluated: 1) how much they thought about the future (about five years from now); 2) how much did details of imagined or real events came to mind; 3) how much they thought about themselves (e.g., their own personality and preferences). The scale ranged from 1 (not at all) to 9 (very much).

The study ended with a series of questionnaires, which were administered in a fixed order (see Appendix B): 1) the interpersonal questionnaire (Aron et al., 1991; Ersner-Hershfield et al., 2009; Liviatan et al., 2008); 2) a demographic and medication questionnaire; 3) health questionnaire; 4) the Centre for Epidemiologic Studies Depression Scale (Radloff, 1977); 5) the Pittsburgh Sleep Quality Index (PSQI; (Buysse, Reynolds, Monk, Berman, & Kupfer, 1989) ; 6) part of the IRI (Davis, 1983). This order was chosen to maximize the accuracy of the responses on the interpersonal questionnaire by minimizing priming effects or memory distortions. The other questionnaires were included for screening purposes or for secondary analyses. The experimenters debriefed the participants to verify that the instructions were implemented as expected (this step was omitted for a few participants).

EEG acquisition and preprocessing

The EEG was recorded with a 31-channel active electrode system (Brain Products GmbH) embedded in a nylon cap (10/10 system extended). An additional electrode under the left eye monitored vertical eye movements (lower EOG). The continuous EEG signal was sampled at 500 Hz using an FCz reference. A 250 Hz high filter and a time constant of 10 s were implemented. We kept the impedance below 25 kΩ. A vertical EOG was reconstructed offline as the difference between the lower EOG and FP1 activity. We constructed the horizontal EOG by subtracting F7 from F8 activity.

The data was preprocessed and extracted with Brain Vision Analyzer 2.1. High and low band-pass filter half-amplitude cutoffs were set at 0.1 and 30 Hz (second order), respectively. Next, semi-automatic visual inspection was performed to remove excessive artifacts. FP1/FP2 were omitted at this stage, because the blinks distort these channels particularly and we implemented ICA ocular correction in a later stage. The criteria for rejection were: 1) an absolute difference of two contiguous sampling points was larger than 75 µV; 2) a difference between the minimal and maximal voltage was larger than 150 µV within a 200 ms interval. We removed bad channels. Subsequently, we removed components representing eye movement and blinks with an automatic ICA ocular correction (Jung et al., 2000). We interpolated the bad channels using spherical interpolation. A mastoid reference (TP9/TP10) was computed offline and used for all analyses. The epochs of interest started at -200 prior to the word onset and ended 800 ms after the onset of the words. We rejected the trials, after a 200 ms baseline correction, (now, with all channels): 1) if the absolute difference of two contiguous sampling points was larger than 75 µV; 2) if the difference between the minimal and maximal voltage was larger than 150 µV within a 200 ms interval; 3) if the voltage was above 100 µV or below -100 µV; 4) if the difference between the minimum and maximum voltage was less than 0.5 µV for 100 ms. The 31-channel acquisition (instead of 63) signified that a somewhat different subset of electrodes were selected for the parietal region of interest (ROI), i.e., P3/Pz/P4 (vs. P1/P2, P3/P4, PO3/PO4). The mean Late Positive Component was defined as the mean amplitude from 500 to 800 ms over the parietal ROI (Tanguay et al., 2018). Other regions and time windows are included in Appendix C.

The mean number of trials included in the average and the mean percentage of retained trials after artifact rejection are shown in Table 2. Note that differences in the number of trials do not introduce a confound when mean amplitudes are used, because noise does not bias towards an effect [e.g., which would happen if only the highest peak was considered; Luck (2014)].

Table 2.

The mean number of trials included in the ERP averages and mean % of retained trials after artifact rejection, SE in parenthesis.

		Self – Present	Self- Future	Other – Present	Other – future
Group other					
	Yes – Included in average	49.94 (±1.43)	43.74 (±1.1)	52.71 (±1.45)	49.34 (±1.38)
	Yes – % retained	94.55 (±0.94)	94.18 (± 1.08)	92.91 (± 1.34)	93.72 (± 1.31)
	No – Included in average	48.83 (±1.55)	49.14 (±1.28)	39.66 (±1.39)	42.86 (±1.4)
	No – % retained	93.39 (± 1.21)	94.25 (± 0.99)	93.66 (±1.82)	93.03 (± 1.22)
Generic other	Yes – Included in average	43.36 (±1.84)	44.61 (±1.28)	47.61 (±2.23)	44.89 (±1.7)
	Yes – % retained	94.01 (± 2.1)	95.99 (± 0.8)	94.36 (±2.28)	94.14 (± 1)
	No – Included in average	49.79 (±2.16)	50.29 (±1.55)	45.71 (±2.47)	48.5 (±1.78)
	No – % retained	93.88 (±1.74)	96.03 (± 0.86)	93.93 (±2.55)	94.77 (±1.16)

Close other	Yes – Included in average	46.45 (±1.78)	44.13 (±1.43)	41.42 (±1.18)	42.29 (±1.13)
	Yes – % retained	93.65 (±1.19)	95.26 (±1.02)	92.68 (±1.03)	92.34 (±0.97)
	No – Included in average	45.48 (±1.76)	49.81 (±1.45)	50.32 (±1.22)	48.84 (±1.09)
	No – % retained	92.96 (±1.24)	94.85 (±0.92)	92.69 (±1.01)	92.31 (±1.08)

Statistical Analyses

In a first step, we verified whether the instructions produced the expected effects. That is: 1) participants should report thinking more about the future for the future tasks compared to the present tasks; 2) participants should report thinking more about themselves (their own personality and preferences) for the self tasks than the other tasks; 3) the participants might report that they recalled or imagined more events for the future tasks than the present tasks. We ran a mixed ANOVA for each of these ratings (i.e., future thinking, self, events) with Self-relevance (self, other) and Time (present, future) as within-subject factors, and Proximity to self (group other, generic other, close other) as a between-subject factor. Moreover, we tested whether the perceived similarity between self and other, present self and future self, and present other and future other differed between Experimental conditions using a factorial ANOVA. The same analysis was conducted for task difficulty and effort. Finally, the characteristics of the relationship with the friend and the generic person (e.g., age known, closeness) were compared with factorial ANOVAs (to get the η^2_p as the measure of effect size).

Secondly, we evaluated whether self-relevance and temporal orientation resulted in a LPC effect, and if these interacted with one another or with Proximity to self. The mean LPC amplitude was entered in a mixed ANOVA with Self-relevance (self, other) and Time (present, future). and Proximity to self (group other, generic other, close other).

Lastly, we considered factors that could influence the self-relevance or temporal orientation effects. To test the effects of orders on the LPC amplitude, we performed at a 2 (Self-relevance: self, other) x 2 (Time: present, future) x 2 (Memory order: self first, other first) x 2 (Time order: present first, future first) x 3 (Proximity to self: group other, generic other, close other) mixed ANOVA. We conducted a set of correlational analyses to investigate whether the LPC differences between self and other, and present and future (as appropriate) related with perceived similarity, empathy traits, and the episodic ratings.

The analyses of the responses, reaction times, P200, N400 and other regions of interest (central, frontal) are included in the Appendix C.

Results

Part 1. Behavioral

We ran a 2 x 2 x 3 mixed ANOVA with Self-relevance (self, other) and Time (present, future) as within-subject factors, and Proximity to self (group other, generic other, close other) as a between-subject factor with each of the ratings: thinking about the future, imagined or real events that came to mind, thinking about the self.

Thinking about the future. Participants thought more about the future during the future tasks (M = 7.49, SE = .14) than in the present tasks (M = 3.29, SE = .19), $F(1, 90) = 305.62$, $p < .001$, $\eta^2_p = .77$. An interaction between Self-relevance and Time approached significance, $F(1, 90) = 3.67$, $p = .06$, $\eta^2_p = .04$. That was because participants gave a higher rating on future thinking to the future self (M = 7.7, SE = .16) than to future others (M = 7.28, SE = .19), qualitatively (p = .06).

The imagined or real events that came to mind. Self-relevance and Proximity to self interacted, $F(2, 90) = 7.42$, $p = .001$, $\eta^2_p = .14$. More imagined or real events came to mind during the self tasks ($M = 7.18$, $SE = .28$) than the other tasks ($M = 6.21$, $SE = .33$) for Generic Other, $p = .002$. On the contrary, more imagined or real events came to mind during the other tasks ($M = 7.08$, $SE = .31$) than the self tasks ($M = 6.42$, $SE = .27$) for Close Other, $p = .025$. The self ($M = 6.62$, $SE = .25$) and other ($M = 6.46$, $SE = .3$) conditions did not differ for the Group Other condition, $p = .562$. Importantly, the main effect of Time and interactions with it did not reach significance, $p \geq .114$, thus the future was not associated with more episodic processing than the present. In all tasks, self or other, present or future, the ratings were significantly higher than the neutral point, indicating that events came to mind, $p < .001$ (tested with a one sample t-test with 5 as a neutral point).

Thinking about the self. Participants thought more about their own self during the self tasks ($M = 8.34$, $SE = .11$) than the tasks about others ($M = 4.8$, $SE = .22$), $F(1,90) = 215.09$, $p < .001$, $\eta^2_p = .71$. This effect interacted with the Proximity to self, $F(2,90) = 4.4$, $p = .015$, $\eta^2_p = .09$. When completing the tasks about other people, those in the Generic Other condition ($M = 5.84$, $SE = .4$) thought more about themselves than Group Other ($M = 4.62$, $SE = .36$; $p = .026$) or Close Other ($M = 3.94$, $SE = 38$; $p = .001$). The ratings did not differ for the tasks about the self across experimental conditions, $p \geq .214$.

Perceived similarity. We tested whether the perceived similarity between self and other, present self and future self, and present other and future other differed depending on Proximity to self. We used a 3-way factorial ANOVA with Proximity to self as a between-subject factor (group other, generic other, close other). First, the perceived similarity between self and others differed between experimental conditions, $F(2, 91) = 8.21$, $p = .001$, $\eta^2_p = .15$. Participants perceived greater similarity with the other in the Close Other (*M* = 5.52, *SE* = .24) than Generic Other (*M* = 4.32, *SE* = .26, *p* = .001) and Group Other (*M* = 4.31, *SE* = .23; $p < .001$) conditions. Second, the perceived similarity between the present and future self (*M* = 4.89, *SD* = 1.41), and the perceived similarity between the present and future other (*M* = 4.84, *SD* = 1.38), did not differ across experimental conditions, $p \geq .821$. Maximal similarity is 7, thus participants perceived some differences between the present and the future, for both the self and others.

Task difficulty and effort. We tested whether the task difficulty changed according to Self-relevance and Proximity to self. We used a 2 x 3 mixed ANOVA with Self-relevance (self, other) as a within-subject factor and Proximity to self as a between-subject factor (group other, generic other, close other). Self-relevance and Proximity to self interacted to modulate task difficulty, $F(2, 91) = 3.76$, $p = .027$, $\eta^2_p = .08$. The task difficulty was higher for self (*M* = 3.8, *SE* = .35) than others (*M* = 2.63, *SE* = .33), *p* = .002, for Group Other. Task difficulty did not differ between the self and other tasks for Close Other (*p* = .62) or Generic Other (*p* = .487). Additionally, the task difficulty did not differ between experimental conditions for the self tasks, $p \geq .103$. For the task about other people, the task was judged more difficult for Generic Other than Group Other or Close Other, $p \leq .008$. Group other and close other didn't differ, *p* = .326. A 3-way factorial ANOVA tested whether the effort invested in the task about others differed across experimental conditions (group other, generic other, close other), and it did not, $F(1, 91) = .75$, $p = .476$, $\eta^2_p = .02$. The participants did not rate their effort for the self tasks.

Generic other vs. Close other. The Close Other participants reported knowing their "other" and feeling close to them for longer (know: *M* = 7.22 years, *SE* = .92, close: *M* = 5.9 years, *SE* = .87) than the Generic Other (know: *M* = 3.5 years, *SE* = .81; close: *M* = 2.56 years, *SE* = .93), [know: $F(1, 57) = 8.99$, $p = .004$, $\eta^2_p = .14$; close: $F(1, 57) = 29.08$, $p < .001$, $\eta^2_p =$

.34]. The Close Other also liked their "other" more (*M* = 8.32, *SE* = .24) than the Generic other (*M* = 6.71, *SE* = .26), $F(1, 57) = 20.76$, $p < .001$, $\eta^2_p = .27$. In accordance with the similarity rating with circles, the Close other (*M* = 7.1, *SE* = .28) felt more similar to their "other" than the Generic other (*M* = 5.54, *SE* = .29), $F(1, 57) = 15.29$, $p < .001$, $\eta^2_p = .21$. As noted above, the researcher verified that the Generic Other participants "pretended" to know the person.

Part 2. EEG

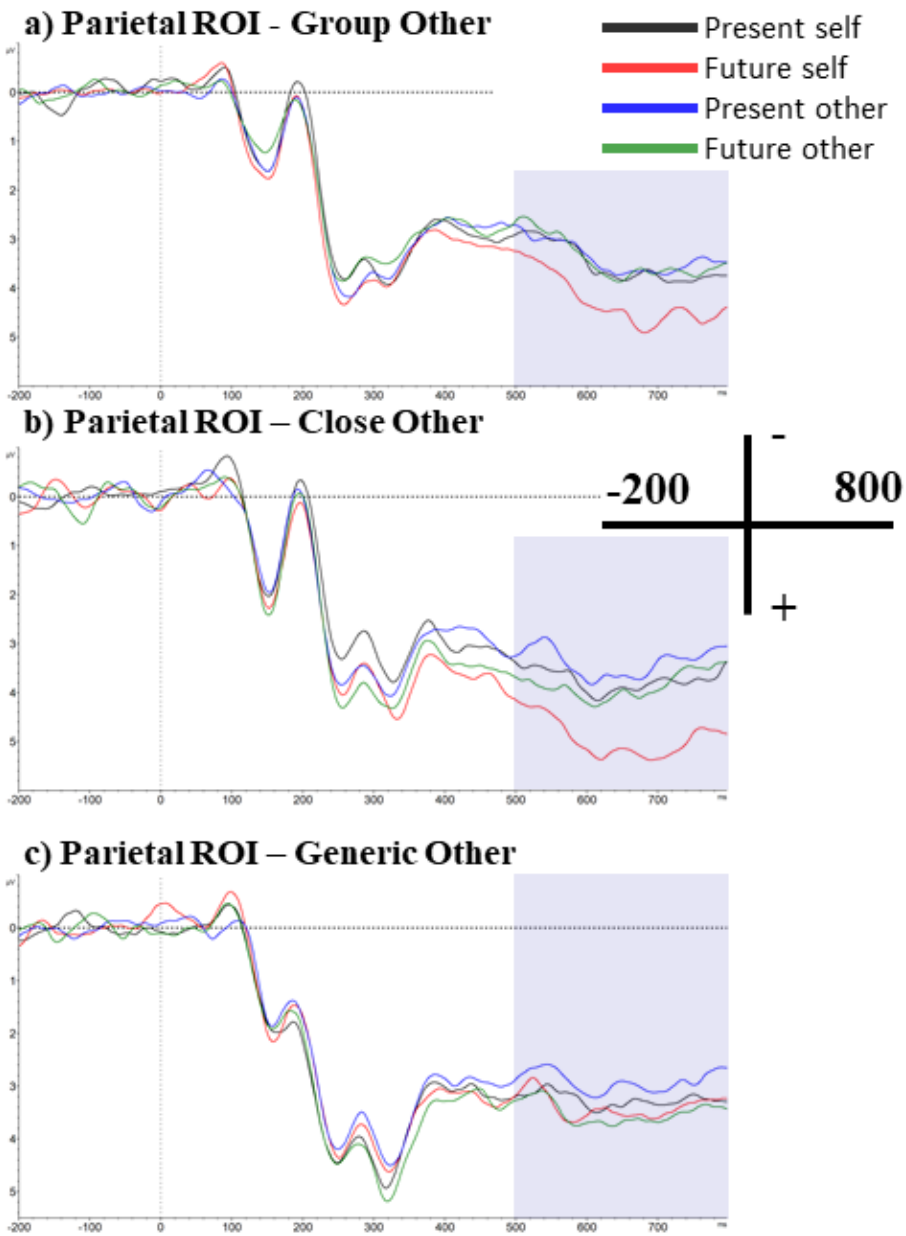

Figure 3. Grand mean average (Group other = 35; Generic other = 28; Close other = 31) over the parietal ROI (mean of P3, Pz, P4). The LPC time-window, 500 to 800 ms, is colored in light blue.

Dissociating between self-relevance, temporal orientation, and proximity to self.

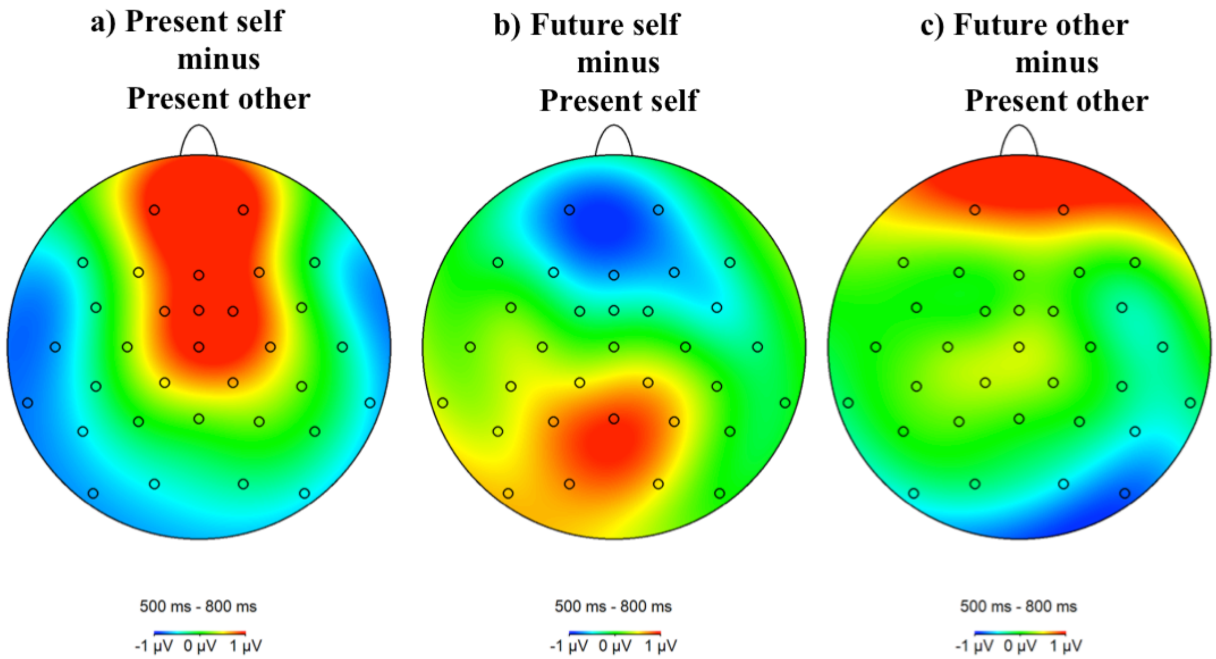

Figure 4.: Scalp distribution of Group Other for: a) present self minus present other, b) future self minus present self, c) future other minus present other from 500 to 800 ms.

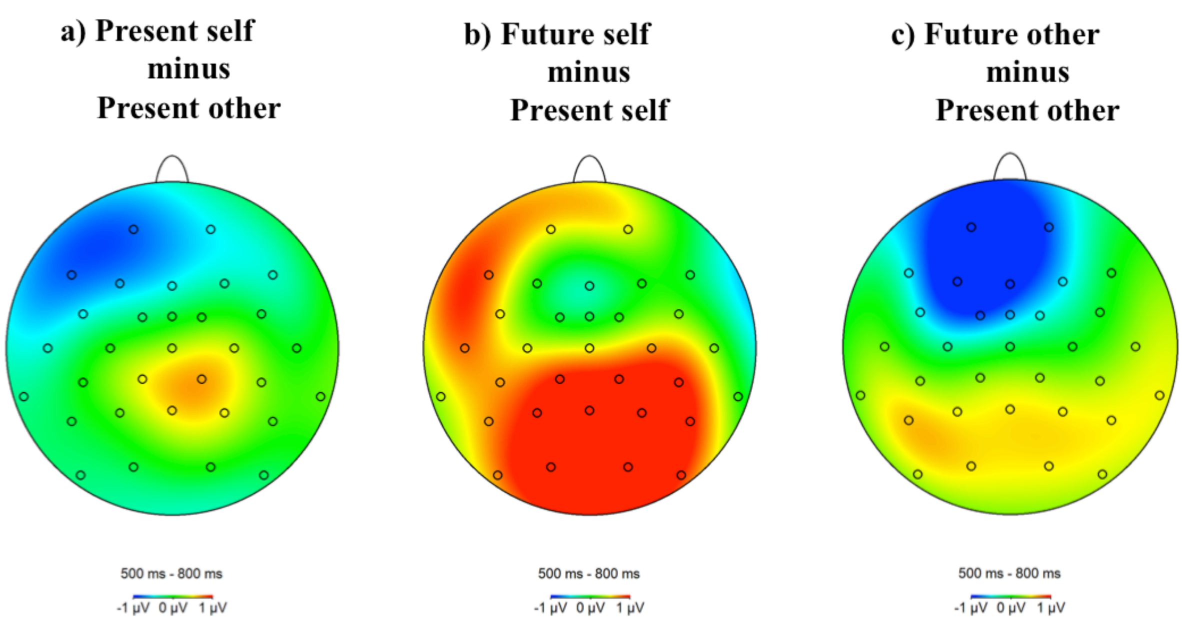

Figure 5.: Scalp distribution of Close Other for: a) present self minus present other, b) future self minus present self, c) future other minus present other from 500 to 800 ms.

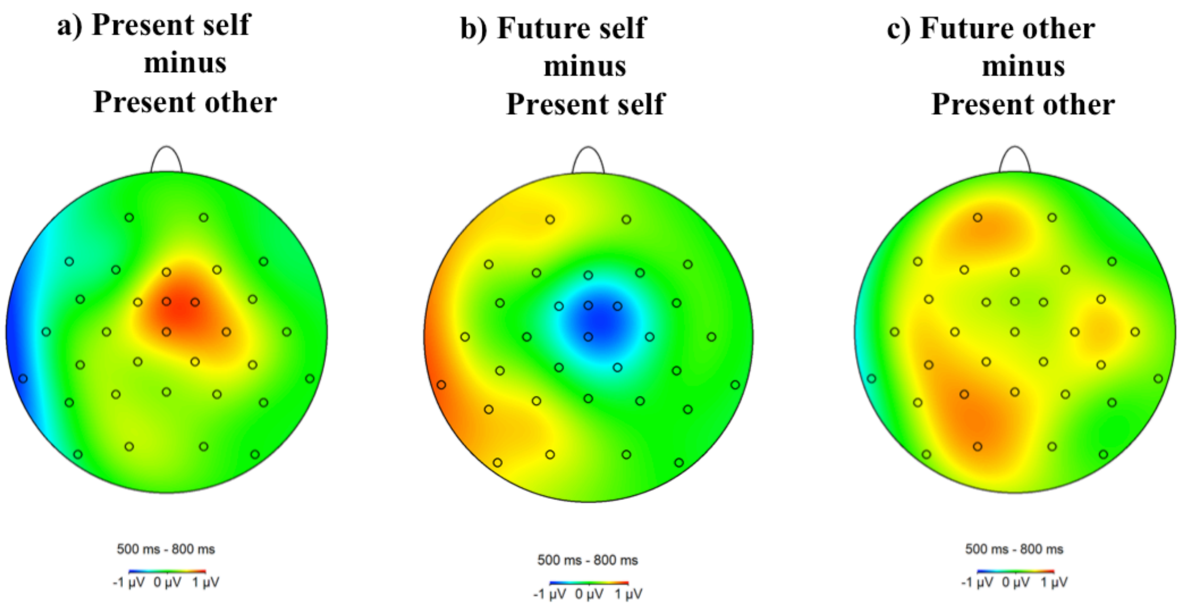

Figure 6.: Scalp distribution of Generic Other for: a) present self minus present other, b) future self minus present self, c) future other minus present other from 500 to 800 ms.

We tested whether Self-relevance, Time, and Proximity to self modulate the LPC amplitude. We included all participants in these analyses with experimental condition as a between subject factor. Therefore, the 2 x 2 x 3 mixed ANOVA included Self-relevance (self, other) and Time (present, future), and Proximity to self (group other, generic other, close other; see figure 3-6). The amplitude of the LPC was larger for self than others, $F(1, 91) = 6.79$, $p = .011$, $\eta^2_p = .07$ (see Figure 3). The LPC amplitude was also larger for the future than for the present, $F(1, 91) = 11.42$, $p = .001$, $\eta^2_p = .11$. These two factors did not interact with one another, or with Proximity to self (see Table 3). Although the three-way interaction between Self-relevance, Time and Proximity to self did not reach significance [$F(2, 91) = 2.48$, $p = .089$, $\eta^2_p =$

.05], we followed-up with a separate 2 x 2 repeated-measures ANOVA with Self-relevance and Time for Group Other, Close other, and Generic other given the centrality of that research question. Additionally, Figure 3 show patterns that are consistent with the results described above only for Group other and Close other. Debriefing data indicated that participants in the Generic Other did not complete the task as intended, that is, based primarily on semantic processing. Thus, we considered whether statistical analyses replicated the above findings in each experimental group.

Group Other. This condition shares the greatest similarity with the prior study conceptually. Here, we expected to replicate the larger LPC amplitude for future self than present self. The mean LPC amplitude was entered in a repeated-measures ANOVA with Self-Relevance (self, other) and Time (present, future; see Figure 3a and 4). The main effects and interaction were statistical trends [Self-relevance: $F(1, 34) = 3.51$, $p = .07$, $\eta^2_p = .09$; Time: $F(1,34) = 2.74$, $p = .107$, $\eta^2_p = .075$; Self-relevance*Time: $F(1,34) = 2.64$, $p = .113$, $\eta^2_p = .072$]. In agreement with our hypothesis, the LPC amplitude of future self was larger than present self, $p = .025$, $\eta^2_p = .14$. That was not the case for future other relative to present other, $p = .605$, $\eta^2_p = .01$. Only future self was more positive than future other, $p = .008$, $\eta^2_p = .19$, and no difference was found between present self and present other, $p = .406$, $\eta^2_p = .02$.

Table 3.

Interactions of the Self-relevance x Time x Proximity to self mixed ANOVA.

Interaction	***df***	***F***	η^2_p	***p***
Self-relevance * Proximity to self	2, 91	1.06	.02	.35
Time * Proximity to self	2, 91	.5	.01	.609

Self-relevance * Time	1,91	1.72	.02	.193

Close others. The amplitude of the LPC was larger for self than others, $F(1, 30) = 6.02$, $p = .02$, $\eta^2_p = 17$ (see Figure 3b and 5). Likewise, the LPC amplitude for the future was larger than the present, $F(1, 30) = 8.52$, $p = .007$, $\eta^2_p = .22$. The interaction between Self-relevance and Time did not reach significance, $F(1, 30) = 3.07$, $p = .09$, $\eta^2_p = .09$. This statistical trend occurred because the LPC difference between future self and future other was significant ($p = .003$, $\eta^2_p = .26$), but not for present self and present other ($p = .396$, $\eta^2_p = .02$). Future self had a larger LPC amplitude than present self, $p = .002$, $\eta^2_p = .27$, but this was not significant for others, $p = .392$, $\eta^2_p = .03$. In sum, the effects are similar to group other.

Generic other. None of the effects were significant [see Figure 3c and 6; Self-relevance: $F(1, 27) = .1$, $p = .755$, $\eta^2_p = .004$; Time $F(1, 27) = 2.05$, $p = .164$, $\eta^2_p = .07$; Self-relevance*Time: $F(1, 27) = 1.1$, $p = .303$, $\eta^2_p = .04$]. Upon close inspection, the future was always more positive than the present on average. This difference approached significance for others ($p = .053$, $\eta^2_p = .13$), but not the self ($p = .724$, $\eta^2_p = .01$). Self and Other did not differ in the present ($p = .45$, $\eta^2_p = .02$) or in the future ($p = .763$, $\eta^2_p = .003$).

Because of the ambiguity in the interpretation of any effect (or lack thereof) for Generic Other, we also repeated the analyses with only Close Other and Group Other. As could be expected from the previous analyses and the Grand Averages (see Figure 3), Self-relevance and Time interacted, $F(1, 64) = 5.81$, $p = .019$, $\eta^2_p = .08$. Future self ($M = 4.6$, $SE = .48$) was more positive than present self ($M = 3.63$, $SE = .46$), $p < .001$, $\eta^2_p = .2$, but not for future other ($M = 3.53$, $SE = .42$) than present other ($M = 3.29$, $SE = .38$), $p = .329$, $\eta^2_p = .02$. None of these effects interacted with Proximity to self [*Self-relevance, $F(1, 64) = .243$, $p = .624$, $\eta^2_p = .004$; *Time,

F(1, 64) = .497, p = .483, η^2_p = .01; Self-relevance*Time, F(1, 64) = .231, p = .632, η^2_p = .004]. The scalp distribution of the difference between future self and present self was maximally positive over the bilateral centro-parietal sites for Group Other. The distribution was larger for Close Other, which extended over bilateral central, parietal, and occipital sites, and left frontal electrodes (see Figure 4, 5, 6). The distribution of a Self-relevance effect (self minus other) depended somewhat on the experimental group, but was mostly maximally positive over frontal and central sites (rather than parietal sites; see Figure 4, 5, 6).

Part 3. Follow-up analyses.

Order effects. To test the effects of orders on the LPC amplitude, we performed at a 2 (Self-relevance: self, other) x 2 (Time: present, future) x 2 (Memory order: self first, other first) x 2 (Time order: present first, future first) x 3 (Proximity to self: group other, generic other, close other) mixed ANOVA. The inclusion of the Memory order and Time order lowered the significance level and increased the effect sizes of the main effects [ANOVA with Sum of Squares III; Self-Relevance: F(1, 82) = 9.04, p = .004, η^2_p = .1; Time: F(1, 82) = 14.85, p < .001, η^2_p = .15; but not Self-relevance * Time, F(1, 82) = 2.17, p = .145, η^2_p = .03]. By itself, this suggests that task order introduces a confound relative the self-relevance and temporal orientation effects. Thereafter, we focused on any interaction with Memory order or Time order or both.

The orders of the memory and of the temporal orientation tasks interacted with the Self-relevance effect, F(1, 82) = 4.53, p = .036, η^2_p = .05. The LPC amplitude of self was more positive than other when other came first only: For this order, the mean difference was larger when the present came first (p < .001, η^2_p = .28) than when future came first (p = .051, η^2_p = 05).

When self came first, self and other did not differ, neither when present came first (p = .294, η^2_p = .01) nor when future came first (p = .745, η^2_p = .001).

The Time order and Proximity to self also interacted with the Self-relevance effect, F(2, 82) = 3.14, p = .048, η^2_p = .07. In Group Other, self was more positive than other when present came first, p = .001 η^2_p = .13. On the contrary, in close other, self was more positive than other when future came first, p = .013, η^2_p = .07. There were no other differences (see Table 4).

Table 4. Self and Other comparison according to Proximity to self and Time order.

	df	***F***	η^2_p	***p***
Group other – Future first	1,82	.07	.001	.795
Generic other – Present first	1,82	.27	.003	.605
Generic other – Future first	1,82	.2	.002	.655
Close other – Present first	1,82	2.31	.03	.133
Nb. Significant effects are discussed in text.				

Lastly, the Time order interacted with Self-relevance and Time, F(1, 82) = 4.16, p = .045, η^2_p = .05. Future self had a larger LPC than future other when present came first, p > .001, η^2_p = .19, but there was no difference between present self and present other, p = .327, η^2_p = .01. Present self and present other (p = .29, η^2_p = .01), as well as future self and future other (p = .449, η^2_p = .01) did not differ when future came first. Both for self and other, future was more positive than present when present came first (self: p < .001, η^2_p = .31; other: p = .015, η^2_p = .07), but not when future came first (self: p = .745, η^2_p = .001; other: p = .842, η^2_p < .001).

We hypothesized that the Other would appear more similar to the self when the self tasks came first. Although the LPC effect was coherent with this, the two orders (i.e., self first, other first) did not differ in their self-reported similarity between self and other, F(1,92) = .677, p =

.413, $\eta^2_p = .01$ (tested with a factorial ANOVA). Instead, the task order could have modified thoughts related to the self, possibly because of an increased comparison of the other to the self, if self came first. We compared those in the "self first" and in the "other first" orders in terms of their self related thoughts. During the other tasks, the self-related thoughts were higher if other came first than self came first [present task: $F(1, 91)$, $p = .002$, $\eta^2_p = .1$; future task: $F(1, 91) = 25.18$, $p < .001$, $\eta^2_p = .22$]. The self tasks were not significantly different [present task: $F(1, 91) = 1.65$, $p = .202$, $\eta^2_p = 02$; future task: $F(1, 91) = 1.57$, $p = .214$, $\eta^2_p = .02$].

Correlational analyses. Lastly, a set of Pearson correlations tested whether the LPC differences in mean amplitude between self and other (in the present and the future), and the future and present self related with perceived similarity, empathy traits, and the mean episodic rating (i.e., events that came to mind). We removed univariate outliers at $z \pm 2.58$, and bivariate outliers with a Mahalanobis distance of $p \leq .01$. Only the correlation of the perceived similarity between self and other(s) and the difference of the LPC amplitude of future self and present self reached significance ($r = .243$, $p = .018$; see Figure 7). Those who perceived greater similarity with others tended to have a larger LPC in the future than the present. This needs to be interpreted with caution because we did not correct for multiple comparisons. None of the other correlations reached significance (see Table 5).

Table 5.

Correlations between the LPC differences for Self-relevance and Time, and factors that could explain interindividual differences.

	Perspective Taking Traits	Empathic Concern Traits	Perceived similarity between self and other	Perceived similarity between present and future (self)	Perceived similarity between present and future (other)	Mean rating of episodic richness

LPC Present Self Minus Present other	r = -.071 p = .506 n = 89	r = .021 p = .843 n = 89	r = .010 p = .921 n = 92	r = .077 p = .469 n = 91	r = .016 p = .877 n = 92	r = .124 p = .252 n = 87
LPC Future Self Minus Future other	r = .077 p = .472 n = 90	r = .019 p = .860 n = 90	r = .2 p = .056 n = 92	r = .185 p = .079 n = 91	r = .116 p = .272 n = 92	r = .065 p = .547 n = 87
LPC Future Self Minus Present Self	r = .130 p = .219 n = 91	r = -.031 p = .774 n = 91	r = .243* p = .018 n = 94	r = .178 p = .088 n = 93	r = .086 p = .407 n = 94	r = -.114 p = .289 n = 89

Nb. We excluded univariate and bivariate outliers prior to correlational analyses, and kept the maximum available data (i.e., pairwise), thus the *n* varies somewhat. Threshold for statistical significance was set at p = .05.

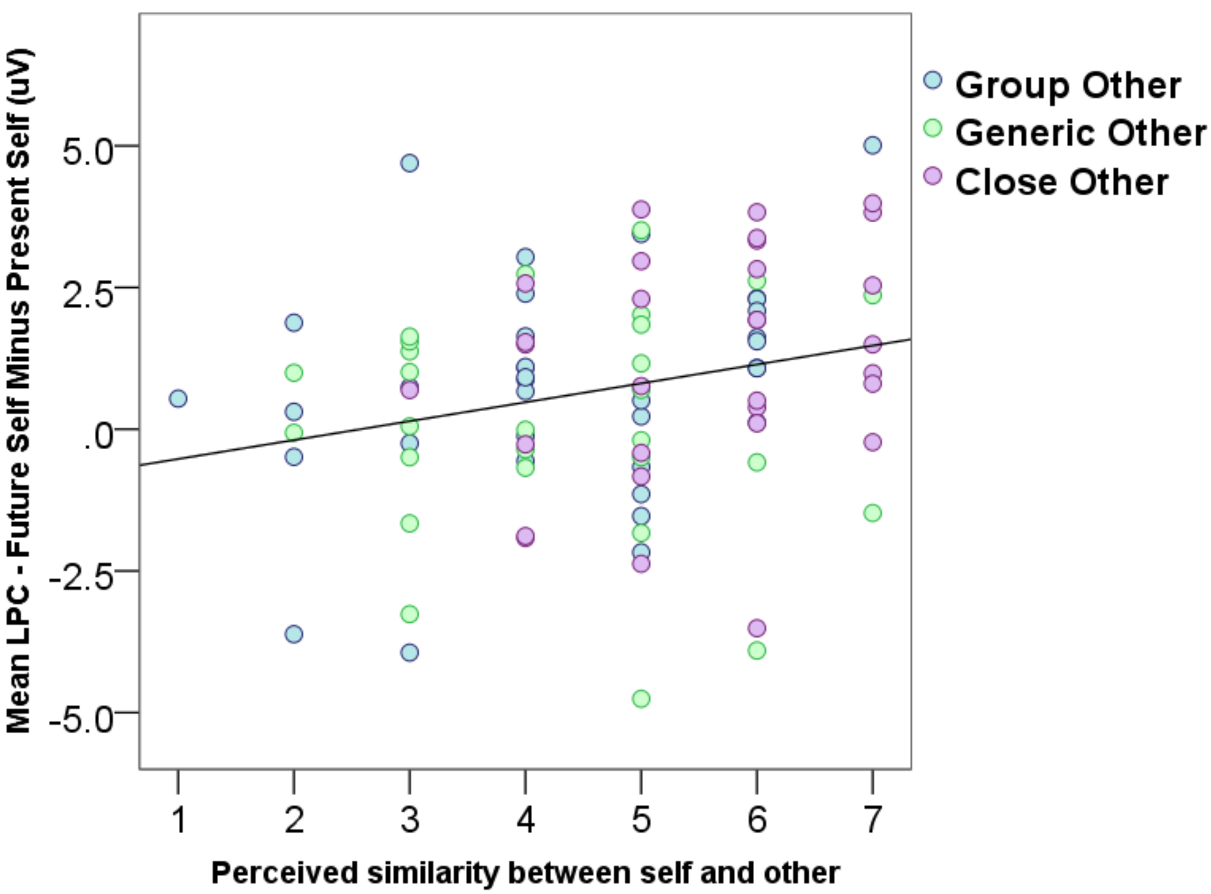

Figure 7. The correlation between perceived similarity between self and other(s) and the mean LPC difference between the future and present self.

Discussion

In this study, we aimed to investigate the relative contribution of self-relevance and temporal orientation to the LPC effect when judging one's own traits or the traits of another person (or a group of people). In coherence with our previous study (Tanguay et al., 2018) and other research, the amplitude of the LPC was larger for the self than others, and for the future than the present. Rather than relying on a purely semantic processing, most of the participants of Generic Other appeared to have imagined a specific person. This seemed to reduce the LPC difference between self and other, and to produce a larger LPC amplitude for the future than the present for both self and other (on average). In contrast, a clear interaction emerged when Group Other and Close other were compared: future elicited a larger LPC amplitude than the present only for the self, and not for the Other. The results for the most self-relevant close other were similar to the least self-relevant group other.

Orientation to our own and other people's future. The projection to a personal future, like Tanguay et al. (2018), produced a larger LPC amplitude compared to the present. On average, we found this effect for thinking about other people's future (relative to their respective present) as well, but diminished (and not significant in post-hoc analyses). Accordingly, the participants gave higher ratings on future thinking for the self than others after the tasks. The processing of information in a more general or atemporal manner coincides with people's prediction that generic peers will adopt stereotypical preferences in the future (Bauckham et al., 2018; Renoult, Kopp, et al., 2016). On the one hand, taking the perspective of another person to think about our own future can improve the realism of predictions (Lee & Atance, 2016). On the other hand, predictions about other people's future—as doctors, parents, managers, mentors—are necessary, and this reduced temporal orientation might bias decisions towards normative behaviour and cultural scripts. Could this generate decisions that are insensitive to a personal history and to idiosyncratic preferences? Further research could explore the practical implications of our findings (e.g., in surrogate decision making; Tunney & Ziegler, 2015), and whether interventions could increase the LPC effect when pondering other people's future (e.g., specificity induction; Schacter & Madore, 2016). Moreover, research could examine the influence of the type of relationship. For instance, it could be easier to project to the future (e.g., the retirement) of a close family member or a significant other because of a partly shared autobiographical narrative. This question highlights an avenue to investigate the interrelationship between self-relevance, episodic processing, and temporal orientation.

The knowledge of people. Knowledge about people appears to be a distinct category in semantic memory (Mitchell, Heatherton, & Macrae, 2002; Zahn et al., 2007). Person knowledge could be unique in the amount and diversity of its content: physical appearance, personality, preferences, autobiographical facts, episodic memory, and general cultural scripts (Olson, McCoy, Klobusicky, & Ross, 2013; Wang et al., 2017). The anterior temporal lobe (ATL) may be like the "hub" to the "spokes" of person knowledge; it integrates multiple types of information, including autobiographical facts and traits about other people (Wang et al., 2017). The processing of traits increases ATL's connectivity to the PCC, whereas roles increase ATL's connectivity to the inferior parietal lobe (IFL; (Wang et al., 2017). The putative "person identity node" (PIN) links all relevant facts about a person, according to a model (Burton, Bruce, & Johnston, 1990). Injury to anterior temporal lobes (ATL) produce an "associative prosopognosia" that impairs the ability to encode or recollect information in relation to a face (Olson et al., 2013). However, the ATL does not decode a unique node for a person, at least for information acquired in the laboratory (Wang et al., 2017). "Person knowledge" appears to hold a special place in semantic memory, but how about the knowledge of close relationships?

The knowledge of close others: general or personal semantics? Personal semantics could be a catchall term for anything that does not meet the definition of either semantic or episodic memory. Semantic memory refers to culturally-shared knowledge, including vocabulary, e.g., I know that shoes cover feet. Episodic memory entails the recollection of a personal event as if we were reliving them, e.g., I remember going to the Bata Shoe Museum in Toronto last weekend (Tulving, 2002). Personal semantics refers to self-knowledge (e.g., traits or preferences), autobiographical facts, and summaries of repeated events, e.g., my shoe size is 9 (Renoult et al., 2012). Where does knowledge of people in one's unique network fit, e.g., my friend often wears high heels, my father is a good problem-solver? In this study, the LPC effects of self-relevance and temporal perspective did not interact with the other's proximity to self. In fact, if anything, close friends displayed the largest effect size associated with the self vs other difference in LPC amplitude. A few possibilities could explain this surprising finding: 1) the age group subsumes the self, thus maybe one's own traits and preferences are projected onto other people, making this task more "self-relevant"; 2) a few participants explained that they considered the generic person as an ideal version of the self. Somewhat in accordance with this, the participants reported thinking more about themselves during the generic other condition than Close Other or Group Other; close other were associated with the least self-oriented thoughts on average. On the contrary, perceived similarity was the greatest for the close others. Prior research suggests that present self is associated with the greatest self-relevance (D'Argembeau et al., 2008; D'Argembeau, Stawarczyk, et al., 2010b). The LPC findings do not follow a pattern that reflects self-relevance. Perhaps the LPC responds to introspection (i.e., thinking about oneself or episodic processing) rather than similarity to self or self-relevance.

The participants could have thought more about events that substantiate their decision for a trait of friend relative to a stranger or people in general, e.g., "Is Martha assertive? I remember how she dealt with an unsatisfactory meal at a restaurant." This decision would be "evidence-based" rather than "intuition" or semantic based (Lieberman et al., 2004). Indeed, more imagined and real events came to mind during the other than self tasks for the close other tasks. However, overall, the small differences in ratings on episodic recall/imagination do not mirror the LPC effect. If that were so, these episodic ratings would be highest for the future self. Although the dissociation in self-relevance and temporal orientation could have produced differences in episodic processing, it did not. Future ERP research would be helpful to examine when episodic processing contributes to self-knowledge. In the intermediate, the self-report rating of recalled or imagined events deserves to be qualified. First, the LPC amplitude can be modulated even if a task does not demand explicit recollection (Renoult et al., 2015). Possibly, a mere association with an event or contextual processing suffice. Second, the self-report rating requires good meta-memory, thus they might not be perfectly reflective of the episodic processing.

In conjunction with other research, we can safely conclude to a special status of personal semantics in declarative memory (Grilli & Verfaellie, 2016; Marquine et al., 2016; Renoult et al., 2012; Renoult, Tanguay, et al., 2016). On the sole basis of this study, we could speculate that knowledge of our friends resembles knowledge of people in general. However, previous research indicates that the LPC amplitude can distinguish between close others and a famous person in a within-subject design (Kotlewska & Nowicka, 2016). The close other was a person of the participants' choosing, and most often a significant other (Kotlewska & Nowicka, 2016).

Moreover, a meta-analysis on fMRI data about processing traits suggests that the knowledge of close others could be intermediate between the self and unknown people (e.g., in the mPFC, Murray et al., 2012). We would benefit from a conceptual replication of this EEG study with a self-irrelevant condition [e.g., a creative use of occupations and a longer temporal distance (Tanguay et al., 2018), or a famous person (Kotlewska & Nowicka, 2016), or a use of preferences instead of traits (Bauckham et al., 2018; Renoult, Kopp, et al., 2016)]. In addition, we should include other types of relationships such as romantic or familial, which might be closer to the self-concept. Other analyses [e.g., oscillations or MVPA; Mu & Han, (2013)] or neuroscience technique (e.g., fMRI, TMS; Pobric, Lambon Ralph, & Zahn, 2016) could provide complementary findings. In sum, further research is required to clarify whether the knowledge of close others is another "shade of grey" within a continuum from semantic to episodic memory.

Imagining a stranger. The Generic other condition did not replicate the Group other or Close other patterns: future other was maximally positive in the LPC time window, followed with future self, present self, and the least positive was present other on average. It appears that most participants constructed a person in a lot of details instead of simply responding based on the stereotypical characteristics of a person of that age and sex. The two questions prior to each task (about activities and housing) could have encouraged this interpretation of the task. The experimenters did not provide further precision on how to complete the task, except to indicate the person was unknown (i.e., not a Amy or John they knew). Additionally, as described previously, some participants mentioned thinking of an ideal self. The "future other" might have been an alternative version of the "future self." Hence, this data does not help to provide a straightforward interpretation to the close other vs. group other data. However, the Generic other could assist in the generation of hypotheses about the creative mind and how we can imagine a person with little information. Such task could lend credence to the assumption that authors project their self in their creations. Our findings might not generalize to another domain, for example a task about a person's preferences might not require to construct or imagine a person in as much detail (e.g., Bauckham et al., 2018; Renoult, Kopp, et al., 2016). Moreover, our findings on self-relevance and temporal orientation might not generalize to other types of knowledge, like autobiographical facts (Renoult et al., 2012).

Self-knowledge in context. Traits are largely stable characteristics of a person, but the effects of the order of the tasks suggest that context plays a key role in the perception of self and others. In the study, the LPC amplitude dissociated self from others only when thinking about the others came first. Oddly, this was neither explained through the increased perceived similarity of the other or the increased thoughts about the self during the other task. On the contrary, the participants in the "other first" order reported thinking more about the self during the "other" tasks than those who did the self tasks first. The first tasks might act like "anchoring" for the subsequent judgments (and ratings; Chambers & Windschitl, 2004). In this study, participants also displayed the "self-enhancement effect" in their behavioural responses (see Appendix C; Kanten & Teigen, 2008; Wilson & Ross, 2001); that is, they perceived having a better personality than their peers (in the Group other condition). Thus, if the responses about the self came first, participants might relate more their others' judgment to themselves (implicitly or not). Even though self- and other-knowledge are considered as "absolutes" for the purposes of cognitive neuroscience, future research should evaluate their malleable and interrelated nature (if only for experimental reasons). For example, the distinction between self and others could depend in part on culture (Zhu, Zhang, Fan, & Han, 2007).

Conclusion. Now with 94 participants, and in a Canadian sample (vs. British), we replicated our finding that the LPC amplitude is larger when thinking about one's own future traits compared to current traits. The effect clearly emerged in two of three experimental groups, and only in average in the generic other condition. In the present study we found that the temporal orientation effect interacts with self-relevance. Whereas thinking about the future self elicited a larger LPC amplitude than present self, this effect was smaller (and not significant) when thinking about others. The LPC effect mirrored the subjective rating of thinking about the future: These were higher for thinking about the future self than the future other. Comparatively, the rating of remembering or imagining events did not follow the LPC effect. That is, our participants did report remembering or imagining events, but that was similar across perspectives (self vs. other, present vs. future). In sum, this study replicates Tanguay et al. (2018) and suggests that the LPC is sensitive to temporal orientation, in addition to episodic processing (as demonstrated by other studies; Rugg & Curran, 2007). This LPC could provide a measure to investigate interventions to improve our imagination of our own future and that of our loved ones.

Acknowledgements

We thank the 118 patient and generous participants who took part in the study. Warm thanks to the research team who helped with data collection and data entry: Petar Vidjen, Anndee Hoover, Galit Karpov, Imaan Handulle, Eléa Knobloch, Marie Huc, and Talia Chin. All the authors (ANT, DJP, CMA, LR, PSRD) contributed to the design of the study. ANT collected the data, analyzed the data, wrote the current manuscript, and is responsible for the current interpretation of the data, with critical input from PSRD. LR also contributed to the current manuscript. The work was supported by funds from the Natural Sciences and Engineering Research Council (NSERC) of Canada to PSRD and an Ontario Graduate Scholarship to ANT.

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Appendix A - Task Instructions

	Present	**Future**
Self ***(identical for all participants)***	In this next task, we will ask you to think about yourself, and what may be some of your characteristics CURRENTLY. *** 1) What are some of your current activities? Please type your answer. You have a maximum of one minute to respond. Please press the "z" key when you are ready. *** 2) What is your current housing situation? Please type your answer. You have a maximum of one minute to respond. Please press the "z" key when you are ready. *** Your task is to assess whether or not each of the words describe your CURRENT character traits, by pressing one of two buttons: -- If you think the word reflects your PRESENT traits, please press button 1. -- If you think the word does NOT reflect your PRESENT traits, please press button 2. In between stimuli, there will be a fixation cross: Please stay focused on the center of the screen. After each stimulus, the word "Blink" will appear. It is very important to only blink when this word appears and not	In this next task, we will ask you to think about yourself, and what may be some of your characteristics 5 YEARS FROM NOW. *** 1) What will some of your activities be? Please type your answer. You have a maximum of one minute to respond. Please press the "z" key when you are ready. *** 2) What do you think will be your housing situation? Please type your answer. You have a maximum of one minute to respond. Please press the "z" key when you are ready. *** Your task is to assess whether or not each of the words describe the character traits you might have 5 YEARS FROM NOW, by pressing one of two buttons: --If you think the word reflects your FUTURE traits, please press button 1. --If you think the word does NOT reflect your FUTURE traits, please press button 2. In between stimuli, there will be a fixation cross: Please stay focused on the center of the screen. After

	at any other point. Press the "z" key to proceed.	each stimulus, the word "Blink" will appear. It is very important to only blink when this word appears and not at any other point. Press the "z" key to proceed.
Group other	In this next task, we will ask you to think about people belonging to your age group in this country, and what might be some of their characteristics CURRENTLY. *** 1) What do you think are some of their typical activities CURRENTLY? Please type your answer. You have a maximum of one minute to respond. Please press the "z" key when you are ready. *** 2) What do you think is their typical housing situation CURRENTLY? Please type your answer. You have a maximum of one minute to respond. Please press the "z" key when you are ready. *** Think about representative people of your age group in this country. Try to think about the commonalities of people in your age group. Your task is to assess whether or not each of the words describe their CURRENT character traits, by pressing one of two buttons: --If you think the word reflects their CURRENT traits, please press button 1. --If you think the word does NOT reflect their CURRENT traits, please press button 2.	In this next task, we will ask you to think about people belonging to your age group in this country, and what might be some of their characteristics 5 YEARS FROM NOW. *** 1) What do you think will be some of their typical activities? Please type your answer. You have a maximum of one minute to respond. Please press the "z" key when you are ready. *** 2) What do you think will be their typical housing situation? Please type your answer. You have a maximum of one minute to respond. Please press the "z" key when you are ready. *** Think about representative people of your age group in this country. Try to think about the commonalities of people in your age group. Your task is to assess whether or not each of the words describe the character traits they might have 5 YEARS FROM NOW, by pressing one of two buttons: --If you think the word reflects their FUTURE traits,

	In between stimuli, there will be a fixation cross: Please stay focused on the center of the screen. After each stimulus, the word "Blink" will appear. It is very important to only blink when this word appears and not at any other point. Press the "z" key to proceed.	please press button 1. --If you think the word does NOT reflect their FUTURE traits, please press button 2. In between stimuli, there will be a fixation cross: Please stay focused on the center of the screen. After each stimulus, the word "Blink" will appear. It is very important to only blink when this word appears and not at any other point. Press the "z" key to proceed.
Generic other	In this next task, we will ask you to think about [Name], a [Age] year old [Sex], and what may be some of [Pronoun] characteristics CURRENTLY. *** 1) What do you think are some of [Pronoun] typical activities CURRENTLY? Please type your answer. You have a maximum of one minute to respond. Please press the "z" key when you are ready. *** 2) What do you think is [Pronoun] housing situation CURRENTLY? Please type your answer. You have a maximum of one minute to respond. Please press the "z" key when you are ready. *** Think about [Name], a [Age] year old [Sex]. Your task is to assess whether or not each of the words describe [Pronoun] CURRENT character traits,	In this next task, we will ask you to think about [Name], a [Age] year old [Sex], and what may be some of [Pronoun] characteristics 5 YEARS FROM NOW. *** 1) What do you think will be some of [Pronoun] typical activities? Please type your answer. You have a maximum of one minute to respond. Please press the "z" key when you are ready. *** 2) What do you think will be [Pronoun] housing situation? Please type your answer. You have a maximum of one minute to respond. Please press the "z" key when you are ready. *** Think about [Name], a [Age] year old [Sex]. Your task is to assess whether or not each of the words describe the character traits

	by pressing one of two buttons: --If you think the word reflects [Pronoun] CURRENT traits, please press button 1. --If you think the word does NOT reflect [Pronoun] CURRENT traits, please press button 2. In between stimuli, there will be a fixation cross: Please stay focused on the center of the screen. After each stimulus, the word "Blink" will appear. It is very important to only blink when this word appears and not at any other point. Press the "z" key to proceed. NB. [Name] [Pronoun] [Age] was based on the gender and age of the participant (usually, see main text for a full description)	[Pronoun2] might have 5 YEARS FROM NOW, by pressing one of two buttons: --If you think the word reflects [Pronoun] FUTURE traits, please press button 1. --If you think the word does NOT reflect [Pronoun] FUTURE traits, please press button 2. In between stimuli, there will be a fixation cross: Please stay focused on the center of the screen. After each stimulus, the word "Blink" will appear. It is very important to only blink when this word appears and not at any other point. Press the "z" key to proceed. NB. [Name] [Pronoun] [Age] was based on the gender and age of the participant (usually, see main text for a full description)
Close other	In this next task, we will ask you to think about your closest friend, and what may be some of his/her characteristics CURRENTLY. It should not be a family member or a romantic partner. Please select that person now (if not done already) and complete the task in relation to that person. *** 1) What are some his/her current activities? Please type your answer. You have a maximum of one minute to respond. Please press the "z" key when you are ready. *** 2) What is his/her current housing	In this next task, we will ask you to think about your closest friend, and what may be some of his/her characteristics 5 YEARS FROM NOW. It should not be a family member or a romantic partner. Please select that person now (if not done already) and complete the task in relation to that person. *** 1) What will be some of his/her activities? Please type your answer. You have a maximum of one minute to respond. Please press the "z" key when you are ready. *** 2) What do you think will be

	situation? Please type your answer. You have a maximum of one minute to respond. Please press the "z" key when you are ready. *** Think about your closest friend. Your task is to assess whether or not each of the words describe the CURRENT character traits of your friend, by pressing one of two buttons:--If you think the word reflects his/her CURRENT traits, please press button 1. --If you think the word does NOT reflect his/her CURRENT traits, please press button 2. In between stimuli, there will be a fixation cross: Please stay focused on the center of the screen. After each stimulus, the word "Blink" will appear. It is very important to only blink when this word appears and not at any other point. Press the "z" key to proceed.	his/her housing situation? Please type your answer. You have a maximum of one minute to respond. Please press the "z" key when you are ready. *** Think about your closest friend. Your task is to assess whether or not each of the words describe the character traits your friend might have 5 YEARS FROM NOW, by pressing one of two buttons: --If you think the word reflects his/her FUTURE traits, please press button 1. --If you think the word does NOT reflect his/her FUTURE traits, please press button 2. In between stimuli, there will be a fixation cross: Please stay focused on the center of the screen. After each stimulus, the word "Blink" will appear. It is very important to only blink when this word appears and not at any other point. Press the "z" key to proceed.

Appendix B - Questionnaires

Interpersonal Questionnaire

Participant ID:_______________

Date:______________________

Time:____________________

We asked you to complete two tasks about someone else. The next questions concern this other person and your perception of your relationship. Please answer these questions – like all others – as truthfully as possible. If you do not know the person well or at all, please answer accordingly.

1. Initial of the person: ______

2. The person's sex is (please circle): Male Female Other

2. The person's age is: ______

3. Since how long have you known this person? __________years.months

4. Since how long have you been close friends (if applicable)? ____________ years.months

3. How close to you feel with him/her?

Not at all Very much

1 2 3 4 5 6 7 8 9

4. How similar is this person to you?

Not at all Very much

1 2 3 4 5 6 7 8 9

5. How much do you like him/her?

Not at all Very much

1 2 3 4 5 6 7 8 9

6. How difficult were the tasks about this person?

Not at all Very much

1 2 3 4 5 6 7 8 9

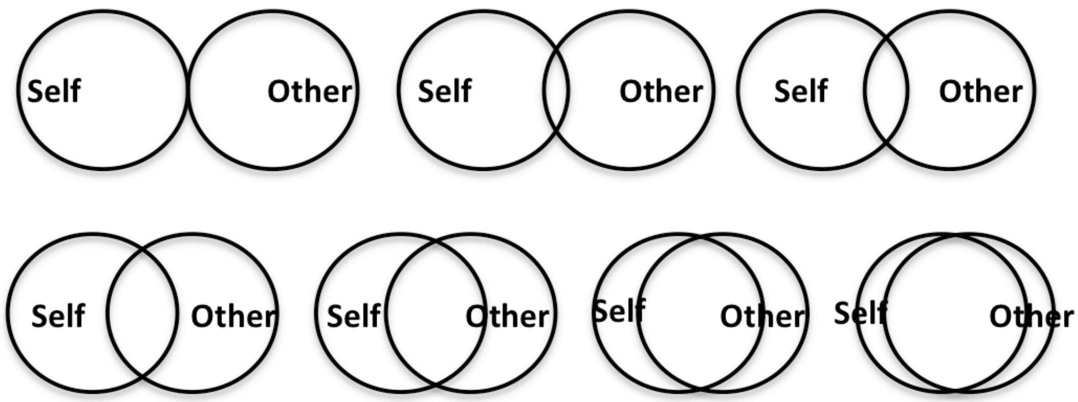
7. How much effort did you invest in the tasks about this person?

Not at all Very much

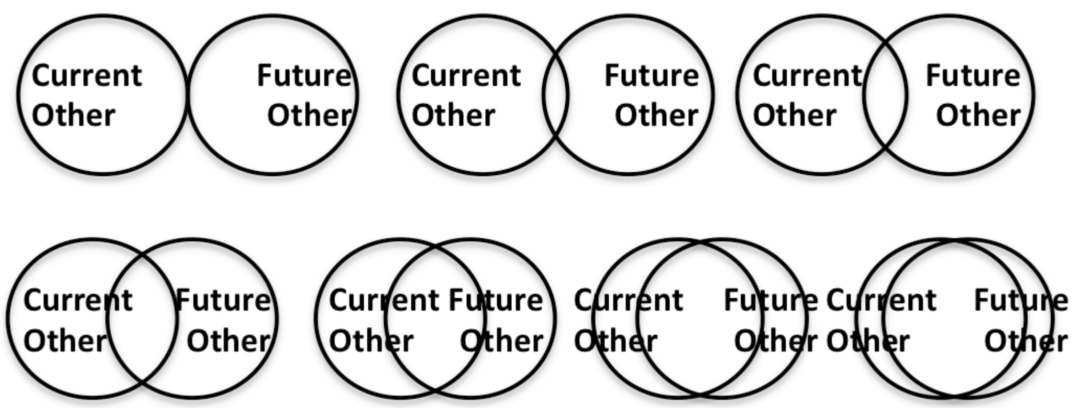
1 2 3 4 5 6 7 8 9

8. How difficult were the other tasks about you?
Not at all Very much
1 2 3 4 5 6 7 8 9

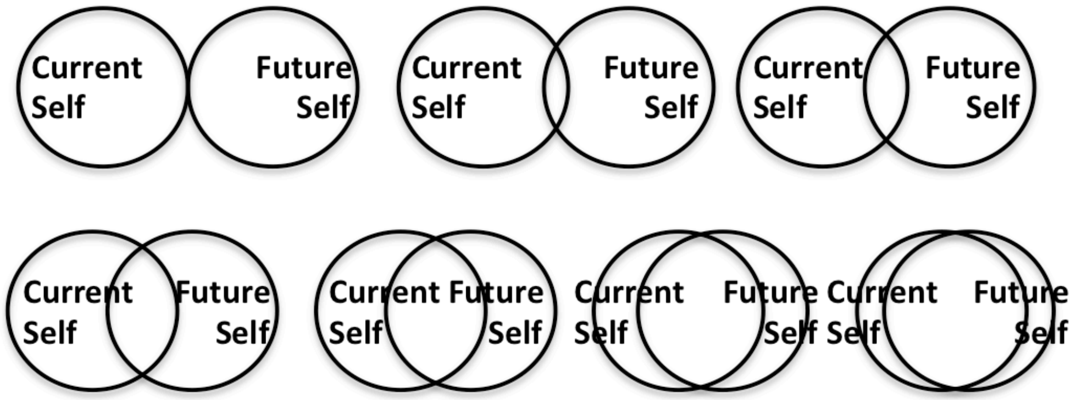
9. In the picture below, please circle the option that best describes how similar you feel to this person.



10. In the picture below, please circle the option that best describe how similar you think this person's present self will be to their future self.



11. The next question is about yourself. In the picture below, please circle the option that best describes how similar you think you may feel to your self in 5 years from now.



Personal Data Sheet

Participant ID:______________

Date:_____________________

Time:____________________

In order to better understand the results of our study, we need to know a few things about you and your background. We will use this information for research purposes only, and it will be kept strictly confidential. You will note that we do not ask for your name on the form. Please respond to the following items completely.

1. My sex is (please circle): Male Female Other, I identify as (please specify) ____

2. My age is: ______

3. My native language is: English: _____ Other (please specify):_____________

If English is not your first language, how old were you when you began learning it? ______

4. Handedness (please circle):Left Right Ambidextrous

5. Is your vision normal or corrected-to-normal (please circle)? Yes No

6. Which academic diplomas or degrees or certificates have you obtained?

a) Please circle ALL that apply	*For those you circled:* *How many full-time years did you take to*

	complete them?
no degree/diploma/certificate	
high school diploma	
technical/trade school or community college	
Bachelor’s (e.g., BA, BSc, BComm.)	
Master’s (e.g., MA, MSc, MEd, LLM)	
Bachelor’s of Law (LLB)	
Medical degree (MD	
PhD or other doctoral degree	
other or additional degrees/diplomas/certificates (*please specify*)	
incomplete degree (*please specify how many years completed*)	
Additional degrees: If you completed more than one degree of one type (e.g., community college, bachelor), please indicate this clearly.	

7. Are you presently taking any drugs or medications (prescription or other)? Did you drink coffee or alcohol? Smoke cigarette or pot? Please list:

Yes ______ No _______

____
____
____
____
____
____
____

Health Questionnaire

Participant ID:_______________

Date:______________________

Time:_____________________

Questions	Please indicate Y/N
1. Have you ever had a stroke or T.I.A (transient ischemic attack)?	
2. a. Have you been seen by a neurologist or neurosurgeon? b. (If yes) Was this for a back or neck problem? c. (If yes) Was this for a tension headache?	
3. Have you had a cancer other than skin cancer diagnosed within the last 3 years?	
4. Do you have shortness of breath while sitting still?	
5. Do you use home oxygen?	
6. Do you have difficulty understanding conversations because of your hearing even if you wear a hearing aid?	
7. Do you have trouble with your vision that prevents you from reading ordinary print even when you have glasses on?	
8. Have you had heart surgery?	
9. Have you ever been resuscitated?	
10. a. Do you drink beer, wine, or other alcoholic beverages every day? b. (If daily) How many drinks do you have each day?	
11. a. Have you ever had a problem due to abuse of drugs or medications? b. (If yes) Was this within the past 5 years or is it ongoing?	
12. a. Have you been treated for alcohol or drug abuse? b. (If yes) Was this within the past 5 years?	
13. Do you have diabetes that requires insulin to control?	
14. Do you have hypertension that is not well controlled?	
15. Have you had a head injury with loss of consciousness greater than 5 minutes?	
16. Have you ever been unconscious for more than 1 hour other than during surgery?	
17. Have you ever required overnight hospitalization because of a head injury?	
18. Have you ever had encephalitis or meningitis? If yes, which one?	
19. a. Have you ever had heart attack? b. (If yes) Did you have any change in your memory, ability to talk or solve problems 24 hours after your heart attack?	
20. Are you currently taking medications for mental or emotional problems?	
21. Have you been hospitalized for mental or emotional problems in the past 5 years?	
22. Have you ever had seizures?	
23. Do you have Parkinson's Disease?	
24. Have you ever had brain surgery?	
25. Have you ever undergone surgery to clear arteries to the brain?	
26. Have you ever had any illness that caused a permanent decrease in memory or other mental functions?	
27. Have you ever received electroshock therapy?	
28. Have you ever been diagnosed as learning disabled?	
29. Were you placed in special classes in school because of learning problems?	

30. Have you ever been diagnosed as having a brain tumor?	
31. Do you have difficulty using your hands?	
32. a. Have you ever had major surgery with general anesthesia? b. (If yes) Did you have any change in your memory, ability to talk or solve problems 1 week after surgery?	
33. Do you have multiple sclerosis, cerebral palsy, or Huntington's disease?	
34. Are you receiving kidney dialysis?	
35. Do you have liver disease?	
36. Do you have lupus?	
37. Are you able to write your name?	

CES-D

Participant ID:_______________

Date:_____________________

Time:___________________

During the past week

	Below is a list of the ways you might have felt or behaved. Please tell me how often you have felt this way during the past week. Please be sure to add your response in the right row.	Rarely or none of the time (less than 1 day)	Some or a little of the time (1-2 days)	Occasionally or a moderate amount of time (3-4 days)	Most or all of the time (5-7 days)
1.	I was bothered by things that usually don't bother me.				
2.	I did not feel like eating; my appetite was poor.				
3.	I felt that I could not shake off the blues even with help from my family or friends.				
4.	I felt I was just as good as other people.				
5.	I had trouble keeping my mind on what I was doing.				
6.	I felt depressed.				
7.	I felt that everything I did was an effort.				
8.	I felt ho.peful about the future.				
9.	I thought my life had been a failure.				

10.	I felt fearful.				
11.	My sleep was restless.				
12.	I was happy.				
13.	I talked less than usual.				
14.	I felt lonely.				
15.	People were unfriendly.				
16.	I enjoyed life.				
17.	I had crying spells.				
18.	I felt sad.				
19.	I felt that people dislike me.				
20.	I could not "get going".				

PSQI

Participant ID:_______________

Date:______________________

Time:____________________

Instructions: The following questions relate to your usual sleep habits during the past month only. Your answers should indicate the most accurate reply for the majority of days and nights in the past month. Please answer all questions. During the past month,

1. When have you usually gone to bed? ____________________

2. How long (in minutes) has it taken you to fall asleep each night? ____________________

3. When have you usually gotten up in the morning? ____________________

4. How many hours of actual sleep do you get at night? (This may be different than the number of hours you spend in bed) ____________________

5. During the past month, how often have you had trouble sleeping because you…	Not during the past	Less than once a	Once or twice a	Three or more times a

	month (0)	week (1)	week (2)	week (3)
a. Cannot get to sleep within 30 minutes				
b. Wake up in the middle of the night or early morning				
c. Have to get up to use the bathroom				
d. Cannot breathe comfortably				
e. Cough or snore loudly				
f. Feel too cold				
g. Feel too hot				
h. Have bad dreams				
i. Have pain				
j. Other reason(s), please describe, including how often you have had trouble sleeping because of this reason(s):				
6. During the past month, how often have you taken medicine (prescribed or "over the counter") to help you sleep?				
7. During the past month, how often have you had trouble staying awake driving, eating meals, or engaging in social activity?				
8. During the past month, how much of a problem has it been for you to keep up enthusiasm to get things done?				
	Very good (0)	Fairly good (1)	Fairly bad (2)	Very bad (3)
9. During the past month, how would you rate your sleep quality overall?				

IRI

Participant ID:_______________

Date:______________________

Time:____________________

Please circle the number that most applies to your view of yourself.

Does not describe me well 0	1	2	3	Describes me very well 4

1.	I often have tender, concerned feelings for people less fortunate than me.	0 1 2 3 4
2.	I sometimes find it difficult to see things from the "other person's" point of view.	0 1 2 3 4
3.	Sometimes I don't feel very sorry for other people when they are having problems.	0 1 2 3 4
4.	I try to look at everybody's side of a disagreement before I make a decision.	0 1 2 3 4
5.	When I see someone being taken advantage of, I feel kind of protective towards them.	0 1 2 3 4
6.	I sometimes try to understand my friends better by imagining how things look from their perspective.	0 1 2 3 4
7.	Other people's misfortunes do not usually disturb me a great deal.	0 1 2 3 4
8.	If I'm sure I'm right about something, I don't waste much time listening to other people's arguments.	0 1 2 3 4
9.	When I see someone being treated unfairly, I sometimes don't feel very much pity for them.	0 1 2 3 4
10.	I am often quite touched by things that I see happen.	0 1 2 3 4
11.	I believe that there are two sides to every question and try to look at them both.	0 1 2 3 4
12.	I would describe myself as a pretty soft-hearted person.	0 1 2 3 4
13.	When I'm upset at someone, I usually try to "put myself in his/her shoes" for a while.	0 1 2 3 4
14.	Before criticizing somebody, I try to imagine how I would feel if I were in their place.	0 1 2 3 4

Appendix C – Supplementary analyses

Reaction Times (RT)

The RTs were entered in a mixed ANOVA with Self-relevance (self, other), Time (present, future), Valence (positive, negative), Response (yes, no), Time (present, future), and Proximity to self (group other, generic other, close other; see means and SE in Figure 1 below). Note that for RT and response analyses, the data of one Close other participant was lost due to technological failure.

Self-relevance, Valence, Response and Condition interacted, $F(2, 90) = 7.69$, $p = .001$, $\eta^2_p = .15$. Time also produced interactions with other factors, but we forgo a description of these to test the effects within each condition.

Group other. Self-relevance, Valence, and Response interacted: $F(1, 34) = 16.81$, $p < .001$, $\eta^2_p = .331$. Participants were faster to endorse positive traits ($p < .001$, $\eta^2_p = .55$) and to reject negative traits for themselves ($p < .001$, $\eta^2_p = .66$) than others. The participants were also slower to reject a positive trait for themselves than others, $p = .027$, $\eta^2_p = .14$, The rapidity of responding "yes" to negative traits for self and other did not differ between self and other, $p = .462$, $\eta^2_p = .02$.

Time and Response interacted as well, $F(1,34) = 9.09$, $p = .005$, $\eta^2_p = .21$. The "no" responses were slower than "yes" responses in the present ($p < .001$, $\eta^2_p = .33$), and this was not the case for the future ($p = .275$, $\eta^2_p = .04$).

Generic other. Valence and response interacted, $F(1,27) = 76.93$, $p < .001$, $\eta^2_p = .74$. The yes responses were faster than no responses, $p < .001$, $\eta^2_p = .66$, for positive traits. On the contrary, the yes responses were slower than no responses for negative traits, $p < .001$, $\eta^2_p = .49$.

Time and Response also interacted, $F(1, 27) = 4.81$, $p = .037$, $\eta^2_p = .151$. Although not significant, the "no" responses were slower than "yes" responses, $p = .108$, $\eta^2_p = .09$, in the present. The difference between "yes" and "no" was smaller for the future tasks and not significant, $p = .786$, $\eta^2_p = .003$. Lastly, Self-relevance and Time interacted, $F(1, 27) = 6.04$, $p = .021$, $\eta^2_p = .18$. The responses to the self tasks were faster than the other tasks in the future, $p = .016$, $\eta^2_p = .2$, but not the present, $p = .885$, $\eta^2_p = .001$. No three-way or four-way was significant.

Close other. Time, Valence, and Response interacted: $F(1, 29) = 4.54$, $p = .042$, $\eta^2_p = .14$. The "yes" responses for the positive words were somewhat slower in the present than in the future, $p = .015$, $\eta^2_p = .19$. The "no" responses to negative words were slower in the present than in the future on average, but not significantly so, $p = .139$, $\eta^2_p = .08$. The RTs of no responses to positive words ($p = .505$, $\eta^2_p = .02$) and yes responses to negative words ($p = .527$, $\eta^2_p = .01$) did not differ between time perspectives.

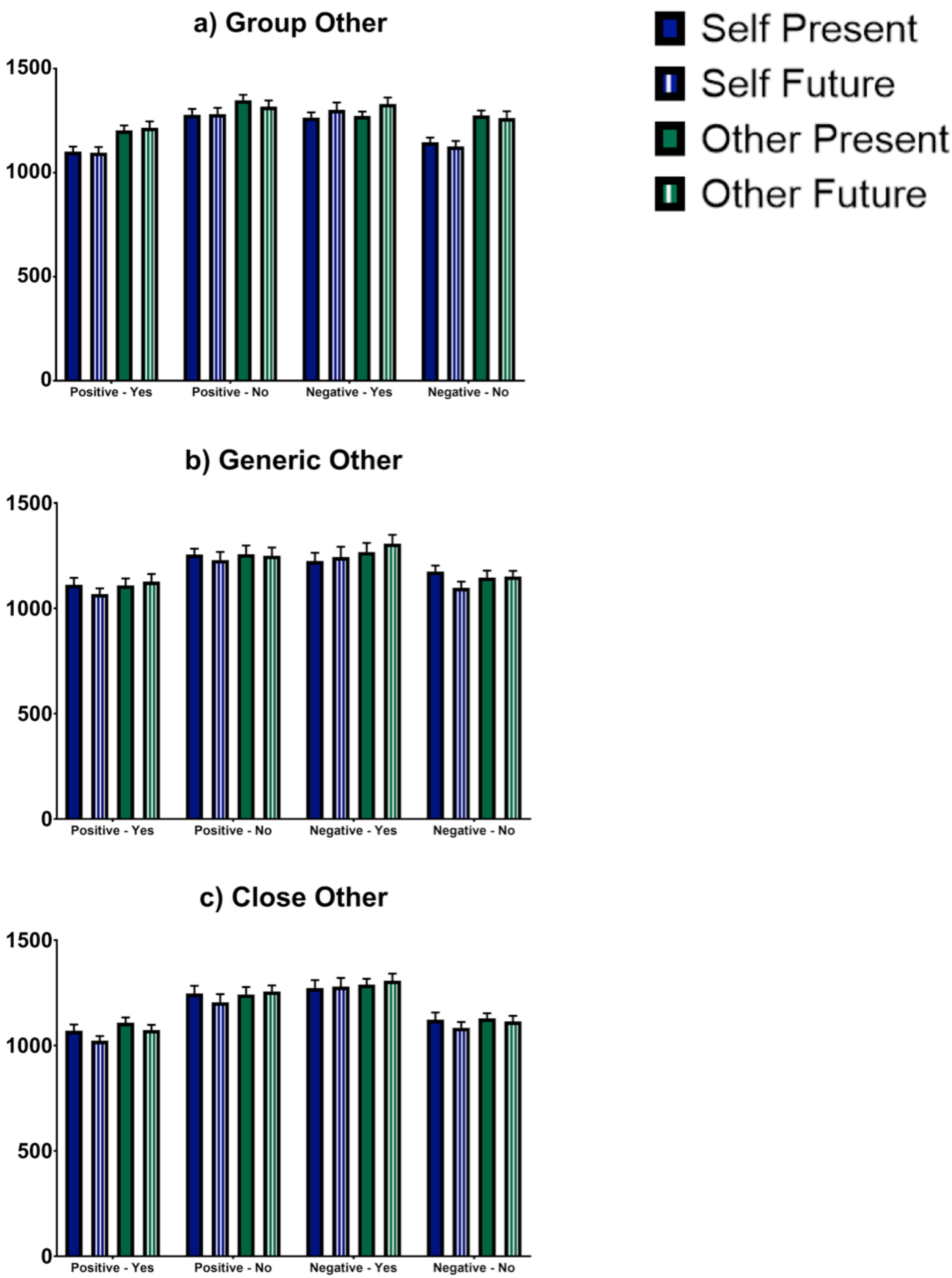

a) Group Other
b) Generic Other
c) Close Other
1500
1000
500
0
Positive - Yes
Positive - No
Negative - Yes
Negative - No
Self Present
Self Future
Other Present
Other Future

Figure 1. RTs are displayed in milliseconds for participants in a) the group other condition, b) the generic other, c) the close other condition.

Response

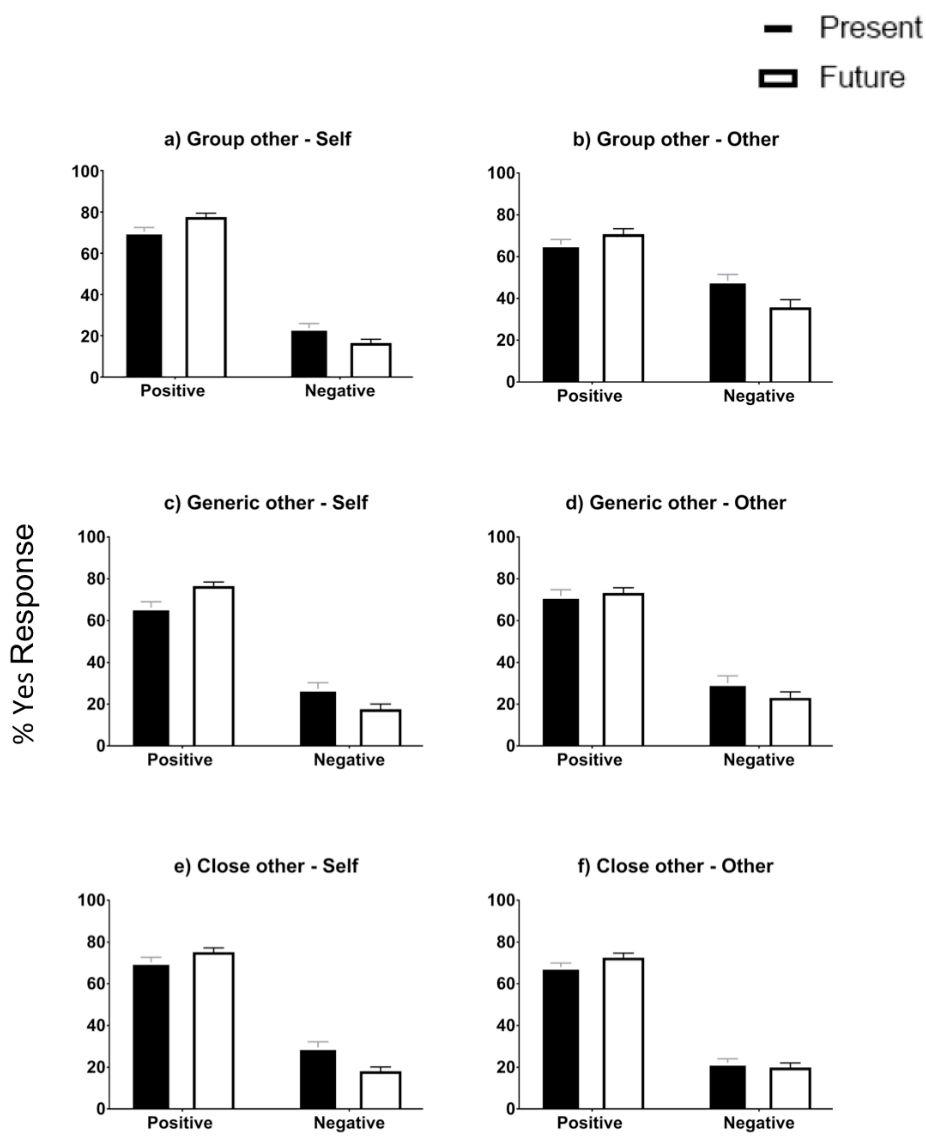


Figure 2. The percentage of yes responses is shown for each condition, divided by traits endorsed for self (a, c, e) and others (b, d, f). *SE* ± 1.

The percentage of yes responses was entered in a mixed ANOVA with Self-relevance (self, other), Time (present, future), Valence (positive, negative), Time (present, future), and Proximity to self (group other, generic other, close other; see means and SE in Figure 2 above). These four factors interacted, $F(2, 90) = 5.33$, $p = .007$, $\eta^2_p = .11$. To follow-up on this interaction, a repeated-measures ANOVA was run for each Proximity to self condition.

Group other. There were three two-way interactions, but the three way interaction was not significant, $F(1,34) = 1.03$, $p = .318$, $\eta^2_p = .03$. Firstly, Time and Valence interacted, $F(1, 34) = 53.82$, $p < .001$, $\eta^2_p = .61$. The participants envisioned more positive traits ($p < .001$, $\eta^2_p = .41$) and less negative traits ($p < .001$, $\eta^2_p = .54$) in the future than in the present. Secondly, Self-relevance and Valence interacted, $F(1,34) = 36.41$, $p < .001$, $\eta^2_p = .52$. The percentage of "yes" responses to positive words was higher for the self than for other, $p = .021$, $\eta^2_p = .15$. Inversely, for negative words, the percentage of "yes" responses was lower for the self than for other, $p < .001$, $\eta^2_p = .65$. Thirdly, Self-relevance and Time also interacted $F(1,34) = 5.87$, $p = .021$, $\eta^2_p = .15$. The percentage of "yes" responses was higher in the present than in the future for the Other, $p = .002$, $\eta^2_p = .24$, and this was not found for the Self, $p = .982$, $\eta^2_p < .001$.

Generic other. In this case, Self-relevance, Time, and Valence interacted, $F(1,27) = 11.51$, $p = .002$, $\eta^2_p = .3$. The participants attributed more positive traits to the other than to the self in the present, $p = .038$, $\eta^2_p = .15$, but other and self did not differ in the future, $p = .132$, $\eta^2_p = .08$. The

Other had more negative traits than the self in the future, p = .039, η^2_p = .15, but did not differ in the present, p = .328, η^2_p = .04.

Close other. In this case as well, Self-relevance, Time and Valence interacted, $F(1,29)$ = 5.19, p = .03, η^2_p = .15. The self and the other differed only in the present and as pertains to negative traits: The percentage of "yes" responses was *higher* for the self than the other, p = .005, η^2_p = .24. The self and the friend did not differ for the current (p = .331, η^2_p = .03) or future (p = .379, η^2_p = .03) positive traits, or the future negative traits (p = .567, η^2_p = .01)

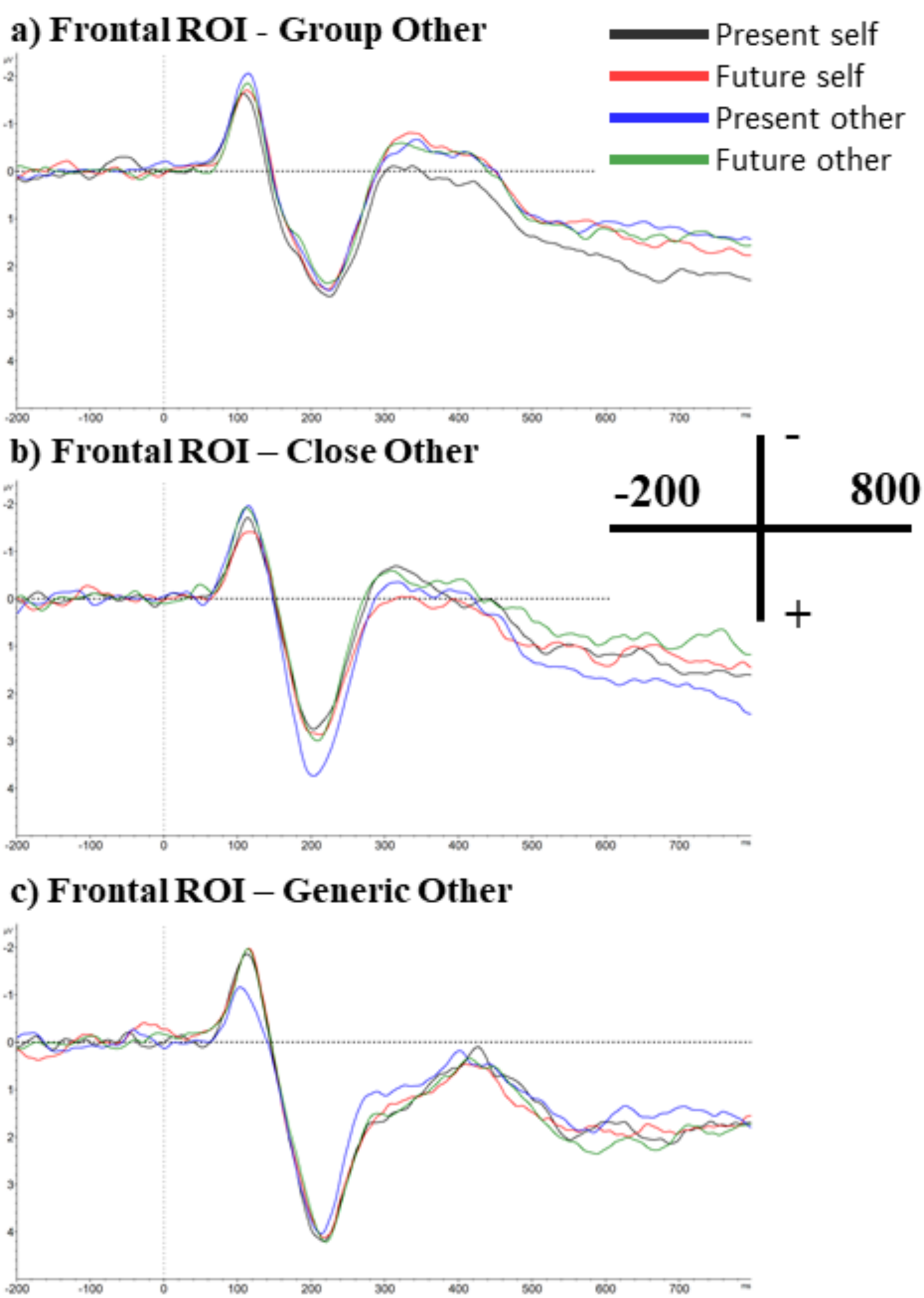


Figure 3. Grand mean average (Group other = 35; Generic other = 28; Close other = 31) over the frontal ROI (F3, Fz, F4).

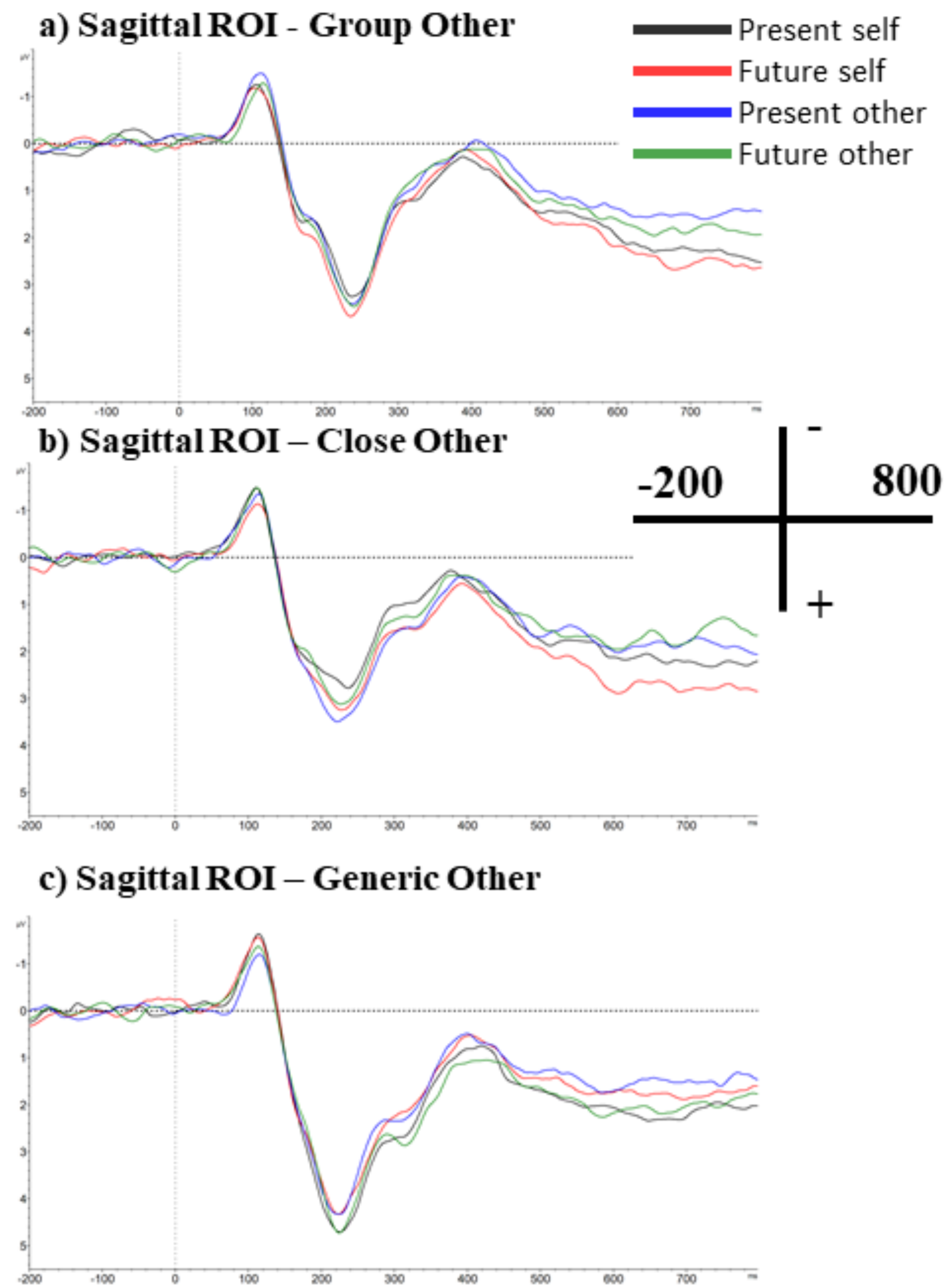


Figure 4. Grand mean average (Group other, n = 35; Generic other, n = 28; Close other, n = 31) over the Sagittal/Central ROI (C3, Cz, C4). The LPC time-window, 500 to 800 ms, is colored in light blue.

P200 time-window

We extracted the mean amplitudes from 150 to 250 ms (the P200 time window) over frontal (F3, Fz, F4), sagittal/central (C3, Cz, C4), and parietal (P3, Pz, P4) sites. We conducted a mixed ANOVA for each ROI with Self-relevance (self, other), Time (present, future) and Proximity to self (group other, generic other, close other) with the mean of the three ROI electrodes. None of the effects reached significance over frontal, central, or parietal sites (see Table 1 for details on these analyses).

Table 1. ANOVA table for main effects of Self-relevance, Time, and Proximity, and their interactions for the P200 time window.

	df	*F*	*p*	η^2_p
Frontal				
Self-relevance	1,91	.001	.971	0
Self-relevance*Proximity to self	2,91	1.1	.338	.024
Time	1, 91	1.35	.249	.02
Time*Proximity to self	2, 91	.36	.705	.01
Self-relevance*Time	1, 91	.50	.481	.005
Self-relevance*Time*Proximity to self	2, 91	1.49	.23	.03
Central				
Self-relevance	1, 91	.01	.936	0
Self-relevance*Proximity	2, 91	.51	.601	.01

to self				
Time	1, 91	.12	.731	.001
Time*Proximity to self	2, 91	1.06	.35	.02
Self-relevance*Time	1, 91	.90	.345	.01
Self-relevance*Time*Proximity to self	2, 91	1.94	.15	.04
Parietal				
Self-relevance	1,91	0	.992	0
Self-relevance*Proximity to self	2,91	.23	.794	.005
Time	1, 91	2.3	.133	.03
Time*Proximity to self	2, 91	.77	.465	.02
Self-relevance*Time	1, 91	.33	.568	.004
Self-relevance*Time*Proximity to self	2, 91	2.61	.079	.054

N400 time-window

We extracted the mean amplitudes from 250 to 500 ms (the N400 time window) over frontal (F3, Fz, F4), sagittal/central (C3, Cz, C4), and parietal (P3, Pz, P4) sites. We conducted a mixed ANOVA for each ROI with Self-relevance (self, other), Time (present, future) and

Proximity to self (group other, generic other, close other) with the mean of the three ROI electrodes. None of the effects were significant for the mean of the frontal ROI (see Table 2).

Over the central site, Self-relevance, Time, and Proximity to self interacted, $F(2, 91) = 3.24$, $p = .044$, $\eta^2_p = .07$. However, none of any pairwise comparisons reached significance (M and SE shown in Figure 5, see also Figure 4). On average, for Group other, the amplitude of the N400 was less positive for other than self in the present and the future (as was expected, i.e., more negative amplitude for others than self). Still on average, for Close other, the other was also less positive than the self on average, but this reserved for the future. Finally, on average, for the Generic other: on the contrary, self was less positive than other in the present, but more positive than other in the future (like Group other). See Table 3 for the statistical tests of these comparisons.

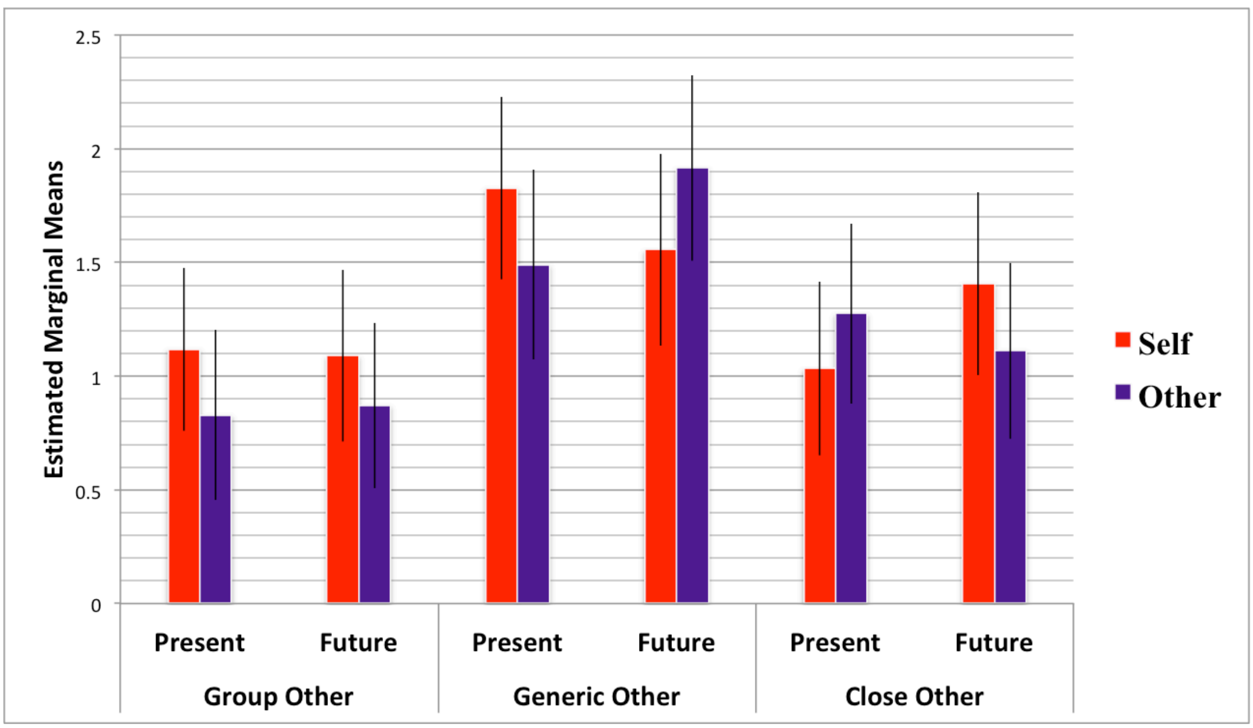


Figure 5. The estimated marginal means of the mean amplitudes of C3, Cz, C4 averaged together per Self-relevance, Time, and Proximity to self. $SE \pm 1$.

Over the parietal site, present was less positive (*M* = 3.29, *SE* = .26) than future (*M* = 3.56, *SE* = .27), $F(1, 91) = 5.49$, $p = .021$, $\eta^2_p = .06$.

Table 2. ANOVA table for main effects of Self-relevance, Time, and Proximity, and their interactions for the N400 time window.

	df	*F*	*p*	η^2_p
Frontal				
Self-relevance	1,91	1.09	.3	.01
Self-relevance*Proximity to self	2,91	.02	.978	0
Time	1, 91	.03	.862	0
Time*Proximity to self	2, 91	.704	.497	.02
Self-relevance*Time	1, 91	0	.995	0
Self-relevance*Time*Proximity to self	2, 91	2.32	.104	.05
Central				
Self-relevance	1,91	.535	.467	.01
Self-relevance*Proximity to self	2,91	.482	.619	.01
Time	1, 91	.375	.542	.004
Time*Proximity to self	2, 91	.087	.917	.002
Self-relevance*Time	1, 91	.158	.692	.002

Self-relevance*Time*Proximity to self	2, 91	3.24	.044*	.07
Parietal				
Self-relevance	1,91	.208	.649	.002
Self-relevance*Proximity to self	2,91	.241	.786	.01
Time	1, 91	5.49	.021*	.06
Time*Proximity to self	2, 91	1.79	.172	.04
Self-relevance*Time	1, 91	.01	.906	0
Self-relevance*Time*Proximity to self	2, 91	1.17	.315	.03

Table 3. Multiple comparisons of self versus other per Time and Proximity to self for the central site during the N400 time window.

		df	*F*	*p*	η^2_p
Group other					
Present	Self vs Other	1, 91	1.32	.253	.01
Future	Self vs Other	1, 91	.73	.395	.01
Generic other					
Present	Self vs Other	1, 91	1.42	.237	.02
Future	Self vs Other	1, 91	1.56	.215	.02

Close other					
Present	Self vs Other	1, 91	.82	.368	.01
Future	Self vs Other	1, 91	1.16	.284	.01

LPC time-window

We extracted the mean amplitudes from 500 to 800 ms (the LPC time window) over frontal (F3, Fz, F4) and sagittal/central (C3, Cz, C4) site. We report the analyses of the parietal site in the main text. We conducted a mixed ANOVA for each ROI with Self-relevance (self, other), Time (present, future) and Proximity to self (group other, generic other, close other) with the mean of the three ROI electrodes as the dependent variable.

None of the effects were significant over the frontal ROI (see Table 4). Over the central site, Self-relevance, Time, and Proximity to self interacted, $F(2, 91) = 4.02$, $p = .021$, $\eta^2_p = .08$. For group other, self was more positive than other in the future, $p = .043$, $\eta^2_p = .04$, and this was a statistical trend in the present, $p = .052$, $\eta^2_p = .04$. For Close other, future self was more positive than future other, $p < .001$, $\eta^2_p = .13$, but present self and present other did not differ, $p = .416$, $\eta^2_p = .01$. When it comes to Generic other, self and other did not differ in the present, $p = .108$, $\eta^2_p = .03$, and in the future, $p = .335$, $\eta^2_p = .01$.

Table 4. ANOVA table for main effects of Self-relevance, Time, and Proximity, and their interactions for the LPC time window.

	df	*F*	*p*	η^2_p
Frontal				
Self-relevance	1,91	.61	.437	.01

Self-relevance*Proximity to self	2,91	.82	.445	.02
Time	1, 91	.92	.34	.01
Time*Proximity to self	2, 91	1.28	.282	.03
Self-relevance*Time	1, 91	.11	.743	.03
Self-relevance*Time*Proximity to self	2, 91	2.38	.098	.05
Central				
Self-relevance	1,91	11.1	.001*	.11
Self-relevance*Proximity to self	2,91	1.2	.307	.03
Time	1, 91	1.72	.193	.02
Time*Proximity to self	2, 91	.24	.786	.01
Self-relevance*Time	1, 91	.11	.745	.001
Self-relevance*Time*Proximity to self	2, 91	4.02	.021*	.08

CHAPTER III. GENERAL DISCUSSION AND CONCLUSION

3.1 Summary of findings

The taxonomy of personal semantics exposed what could be perplexing issues both for the unitarian and dualist (is declarative memory one? two? it can't be more assuredly?). Tulving (2007) humorously asked, "Are there 256 different kinds of memory?" The feat of this thesis is not to add three kinds of memory to this excessively long list. However, across the studies including Renoult et al. (2016), I have shown that the neural correlates of self-knowledge, autobiographical facts, and repeated events can be distinct from general semantics and episodic memory. In a previous ERP study (Renoult et al., 2016), we had shown that autobiographical facts and repeated events were associated with an intermediate N400/LPC amplitude when compared between semantic and episodic memory (before correction for multiple comparisons). In the fMRI study, we found a small graded increase in activity from general facts to autobiographical facts to repeated events to unique events in the left posterior hippocampus (mostly on average, with a significant linear trend). Moreover, autobiographical facts shared greater similarity with general facts than unique events (overall), and repeated events shared greater similarity with unique events than repeated events (overall). These findings are consistent with the continuum perspective on personal semantics, but must be replicated [using the original stimuli of Renoult et al. (2016)] Further, the LPC amplitude associated with present self-knowledge was intermediate between semantic and episodic memory. Thinking about past and future selves increased the LPC amplitude, which was not significantly different from present self-knowledge or episodic memory. The temporal orientation effect was mostly specific to thinking about the self, and the LPC effects were not modified when the operationalization of the "other" changed from "group other" to "close other".

In subsequent sections, I discuss some key contemporary issues about personal semantics and I propose future directions.

3.2 Experience-near vs. experience-far

The continuum perspective on personal semantics posits that they could be organized from the abstract to the experience-near (Renoult et al., 2012). If that were so, the continuum would range from the most abstract self-knowledge, to autobiographical facts, to repeated events, and to the most experience-near autobiographically significant concepts (according to Renoult et al., 2012). This perspective aligns with hierarchical models of autobiographical memory (Barsalou, 1988; Conway, 2009; Conway & Pleydell-Pearce, 2000). Additionally, we could possibly represent each subtype of personal semantic on a continuum from the abstract to the experience-near (Grilli & Verfaellie, 2016; Tanguay et al., 2018). In particular, proximity to events (or a temporal and spatial context) and temporal orientation appear to modify a personal semantics' relationship with semantic or episodic memory (Grilli & Verfaellie, 2016; Tanguay et al., 2018). For parsimony, we could translate these ideas into a component process view on the basis of neuroimaging and neuropsychological data. For instance, we could theorize that the posterior HPC relates to the perceptual details of a memory (including personal semantics; Sekeres, Winocur, & Moscovitch, 2018). In which case, *any* personal semantics that has a higher probability of generating those processes, [as nicely outlined for experience-near autobiographical facts; (Grilli & Verfaellie, 2016)], should also engage the posterior HPC (study 1). I conceptualized the ERP study (study 3) within that logic of component process view on personal semantics. I aimed to dissociate self-relevance, proximity to self, mental time travel, and to infer on the contribution of episodic processing. From this study, I speculate that temporal orientation—in the absence of an explicit event or period—does not appear to increase the reliance on processes that we could ascribe to the HPC. Of course, these are only a few of many component processes, and a single type of personal semantics (i.e., self-knowledge). The vast area of activation in all types of declarative memory (study 1; Addis, Moloney, Tippett, P. Roberts, & Hach, 2016; Svoboda et al., 2006) can be regarded as another indication of how ambitious it would be to elaborate component process view on personal semantics.

The operationalization of autobiographically significant concepts could offer another opportunity for parsimony. Autobiographically significant concepts are: semantic concepts associated with personal events [e.g., naan bread + my wife prepared naan bread for a special meal (Renoult et al., 2015; Westmacott, Black, Freedman, & Moscovitch, 2003; Westmacott, Leach, Freedman, & Moscovitch, 2001)]. Could this principle apply to *any* type of semantics, including personal semantics, rather than constitute a subtype of personal semantics? According to this proposal, personal semantics would be more likely to elicit the recollection of events than general semantics because of their greater proximity with personal events. Moreover, the concepts or facts would also vary in the strength of their association to events within a category of personal semantics. As implied previously, Study 2 and 3 highlight the necessity of a clear theory regarding when this process should be engaged. Study 3 and Martial, Stawarczyk, & D'Argembeau (2018) suggest that future thinking (or a possible temporal context) and the context of a social role do not relate to an increased self-reported episodic thoughts. Therefore, the presence of "contextual" processing might not suffice to predict a closer relationship to episodic memory. Another possibility is that an "autobiographically significant" effect is not uniform across types of personal semantics (e.g., when comparing the most abstract self-knowledge to the most concrete autobiographical facts). Lastly, I intend to verify whether an "autobiographically significant" effect *must* involve an explicit recollection of a unique event or whether it could reflect other processes (e.g., relational processes, retrieval of other types of personal semantics; Duss et al., 2014). In other words, must the events associated with a trait (or other concepts) be explicitly recalled, or could their mere association with events suffice to create an "autobiographically significant" effect (on a neural level)? Maybe a type of implicit "episodic richness" (e.g., number of associated autobiographical events) could be the counterpart to "semantic richness" effects (López Zunini, Renoult, & Taler, 2017; Vilberg, & Rugg, 2009; Wilding, 2000)? The last proposal diverges from the operationalization of autobiographically significant concepts. (The general idea of this paragraph comes from a discussion with Dr. Patrick S. R. Davidson.)

3.3 Is personal semantics equivalent to a "know" response or overgeneral autobiographical memory?

A challenge of studying personal semantics comes from their operationalization as a "know" response (Brown et al., 2018), or their putative association with any recollection (Sreekumar, Nielson, Smith, Dennis, & Sederberg, 2017) or any self-relevance effect (Schöne et al., 2018). Moreover, another field of research evolves under the name of overgeneral autobiographical memory (OGM); it echoes somewhat the operationalization of personal semantics. OGM refers to a tendency to retrieve extended/repeated events instead of a specific event, a phenomenon that can be observed in older adults or Major Depressive Disorder (Sumner, 2012). The proposal of equivalence between a subjective judgment or OGM to personal semantics is not trivial. The quality of recollection is undeniably linked to the contrast between personal semantics and episodic memory. Indeed, personal semantics are less detailed than the memory of a unique event or are associated with a "know" instead of recollection. Nevertheless, the equation of a "know" response with personal semantics does not fully capture the conceptualization of personal semantics (Renoult et al., 2012). That is, general semantics also produces a "know" response. Moreover, repeated events can also generate a sense of recollection or remember responses (Renoult et al., 2012). Additionally, in a preliminary manner, ERP studies on personal semantics argue against equating personal semantics with a know response for personal information. Two ERPs can dissociate a recollection and a familiarity/know response (Rugg & Curran, 2007). The first, a correlate of recollection, has already been discussed extensively. The LPC is a positive amplitude that peaks approximately from 500 to 800 ms over parietal sites, and it is more positive for a hits (correct recognition) than a correct rejection (Rugg & Curran, 2007). The second ERP is associated with a familiarity response, or a recognition without recollection, and is called a "mid-frontal old/new effect" (FN400) in contrast to the "left parietal old/new effect" (LPC; Rugg & Curran, 2007; Wilding & Ranganath, 2012). The FN400 peaks within the N400 time-window (about 250–500 ms) over fronto-central sites; it is more positive for hits (even without recollection) than correction rejection (Rugg & Curran, 2007). If personal semantics were simply a "know" response in contrast to a "remember" response for personal memories, we would expect a reduced LPC amplitude and larger FN400 amplitude for personal semantics relative to episodic memory. To my knowledge, no ERP studies on personal semantics have suggested such a pattern (Renoult et al., 2015, 2016; Tanguay et al., 2018). Although the FN400's privileged relationship to familiarity is debatable (Kwon, Rugg, Booth, Wiegand, & Morcom, 2018), our ERP studies tentatively suggest that a "know" response does not fully capture the construct of personal semantics. To conclude on this delicate question, we could assess the usefulness of any approach to studying personal semantics through this benchmark: Does it contribute to further elucidate the relationships and distinctions between semantic and episodic aspects of declarative memory?

Some researchers could turn the question on its head to ask: Considering the large literature of subjective memory and OGM, is personal semantics a useful construct? In the absence of a taxonomy of personal semantics, all types of semantics become amalgamated. However, neuropsychological studies argue against an indivisibility of general and personal semantics (Cermak & O'Connor, 1983; Grilli & Verfaellie, 2014; Renoult et al., 2012; Warrington & McCarthy, 1988). Moreover, the categories of semantic and episodic memory can dissimulate distinctions that could mislead us into predicting the wrong patterns of preservation and impairment in patients and in aging. For example, we could speculate that patients with Alzheimer's disease would generate fewer extended events compared to controls, but the opposite was found using a modified coding of the AI (Strikwerda-Brown et al., 2018). Therefore, from my standpoint, an invaluable contribution of personal semantics is the ability to provide a nuanced portrait of memory function, and to recognize areas of preservation.

However, an ongoing challenge is to categorize a useful and meaningful number of personal semantics (on behavioural and neural levels). Researchers have suggested additional distinctions: lifetime/autobiographical periods (Ford et al., 2011a; Thomsen, 2015), extended events (Ford et al., 2011; Holland et al., 2011), thoughts and beliefs (Strikwerda-Brown et al., 2018) [examined in (Grilli, 2017)]. In addition, role is sometimes distinguished from autobiographical facts or self-knowledge (Grilli, 2017; Strikwerda-Brown et al., 2018), and traits and preferences (part of self-knowledge) do not appear entirely identical across studies [when comparing generic other of study 3 to (Bauckham et al., 2018)]. Many of these proposals precede the taxonomy of personal semantics, for example in the work of Barsalou (1988) and Conway & Pleydell-Pearce (2000). An update to the personal semantics taxonomy could be desirable to minimize divergences between researchers (for greater comparability across studies).

3.4 Is a hierarchy of autobiographical memory crucial to understanding the neural correlates of personal semantics?

Hierarchical models of autobiographical memory emphasize the nested structure of memory. In study 1, we found a small graded increase in the posterior HPC activity from general facts to autobiographical facts to repeated events to unique events (on average). General facts and autobiographical facts were never more active than repeated or unique events in any ROI analyses. Together, this is coherent with the idea that events are nested under more abstract forms of memory, and they recruit semantic processing, but entail greater episodic processing (Barsalou, 1988; Cabeza & St Jacques, 2007b; Conway, 2009; Conway & Pleydell-Pearce, 2000). Nevertheless, the sentence verification task (study 1) offers limited insights about the interactions between types of personal semantics. In particular, could we structure the analyses in a way that preserves the relationship between the items? In such a scenario, we could relate the retrieval across types of memory for a common theme, but still consider the memory type (maybe with hierarchical modelling). For example, 1) I ate chicken today (unique event), 2) I rarely eat chicken (autobiographical fact); 3) when I went to Swiss Chalet, I have ordered chicken a few times (repeated events); 4) during undergraduate studies, I was vegetarian (autobiographical fact derived from a lifetime period; Grilli & Verfaellie, 2016); 5) I strongly value pro-environmental behaviour (self-knowledge). Ideally, we would assume a greater similarity of the neural correlates within a memory type (e.g., self-knowledge), and also within the nested structure (see Figure 1). That is, unique events that are instances of the same repeated events should be more similar to one another. Additionally, going to the pub with Joe and taking books at the library should be more similar to one another than to archiving files after a study, because the first two are nested under “undergrad”, and so on (see Figure 1). Moreover, the recency of lifetime periods could modify the neural correlates of the personal semantics, and would need to be taken into account (Grilli, 2017). Even in part, these proposals cannot be examined with the current version of the sentence verification design.

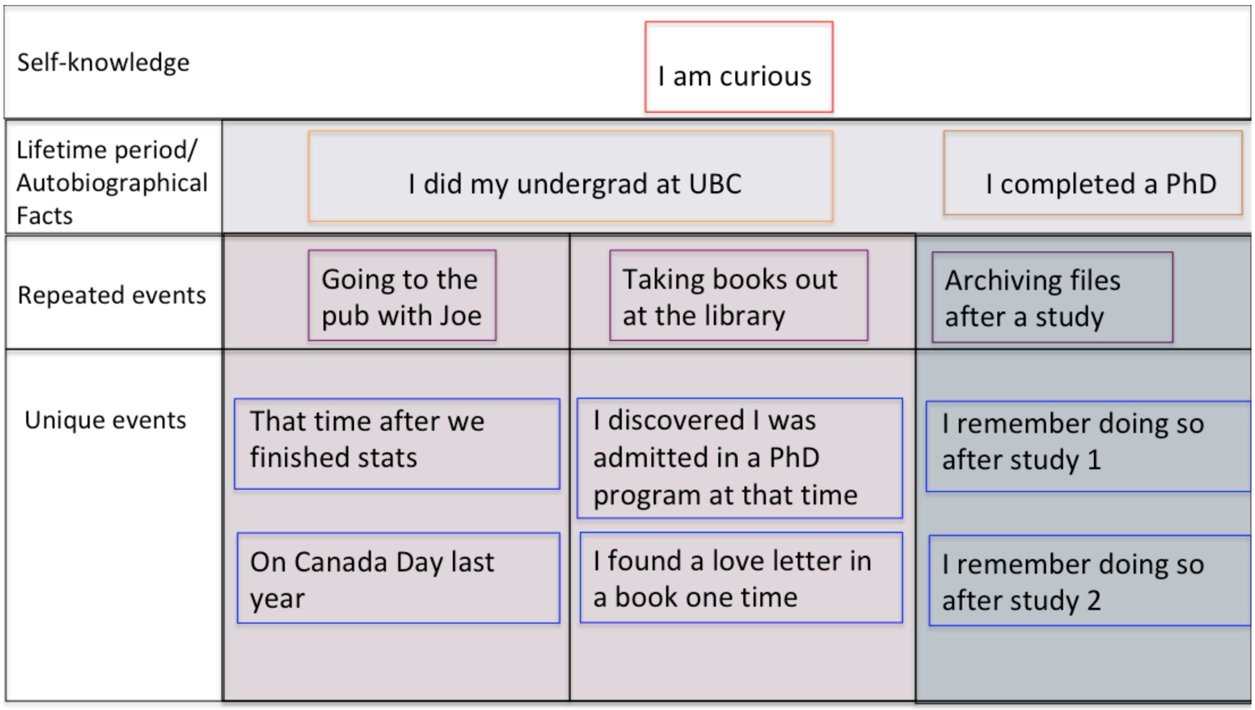


Figure 1. The ideal design and analysis could detect similarities within a category type (e.g., undergrad and PhD compared to other types of memory), but also could decode similarities within a nested structure. For example, the unique event of remembering to archive after study 1 and remembering to archive after study 2 should be more similar to one another than remembering to archive after study 1 compared to going to the pub on Canada Day last year (and so on). For simplicity, I combined lifetime period and autobiographical facts.

3.5 The applications of ERPs

My ERP studies have shown some sensitivity to 1) semantics processing (N400), 2) recollection (LPC), 3) self-relevance (LPC), 4) temporal orientation (LPC), and 5) attentional/emotional processes (P200). Some of these effects I have already replicated, whereas others should be replicated (ideally, in another laboratory). However, if these effects are indeed reliable in healthy adults, these ERPs could become markers of declarative memory in psychiatric disorders (e.g., Major Depressive Disorder; MDD, suicidal ideation, personality disorders), and neurological or neurodegenerative disorders (e.g., Alzheimer's disease) (Verleger, 2011). The advantage of ERPs, from a clinical and practical standpoint, is the few contraindications to its use. As an example of an application: The accuracy of self-knowledge can be difficult to quantity, for example, when a close other is unavailable to corroborate the ratings (Grilli et al., 2018). Even if my studies cannot address the element of accuracy, it could provide additional indications about the integrity of a memory type (e.g., if the LPC was comparable to age-matched controls). Performance can be intact, yet, brain activity differ (e.g., Addante, Ranganath, Olichney, & Yonelinas, 2012) However, we must conduct a lot more research before reaching the status of a "clinical marker" (in addition to replication). First, we need to further understand age-differences. Note that we are currently conducting such a study on self-knowledge with young and older adults. Secondly, we need a certain appreciation of the medication's effects on the ERPs, for example in MDD. Thirdly, we should investigate the relationship between inter-individual differences in cognitive function and ERPs in *healthy* (neurotypical) adults. The study could provide indications about whether memory function relates to any ERP effects. In the meantime, that is, before reaching any clinical usefulness, we can still use EPRs to improve the scientific understanding of some psychiatric or neurological disorders. For example, we will investigate whether symptoms of depression influence the behavioral and ERP correlates of present and future self-knowledge, as a follow up to study 3.

3.6 Conclusion

Anything you would tell me about yourself would be retrieved from declarative memory. My research cannot pretend to achieve such lofty goals as informing the reader on the answer "who am I", but I can safely assert that it adds to the current scientific knowledge of personal semantics. In particular, the neural correlates of autobiographical facts, self-knowledge, and repeated events can be distinguished from semantic and episodic memory. Importantly, the neural correlates of a type of personal semantics can depend on the component processes involved, like temporal orientation. General semantics—or the knowledge of others—is little influenced by temporal orientation. Lastly, the third study suggests a special status of knowledge about the self or self-reflection, because thinking about closer relationships was similar to thinking about a group of people. The studies elaborated during my thesis have used novel designs to investigate personal semantics, and they suggest many future directions.

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