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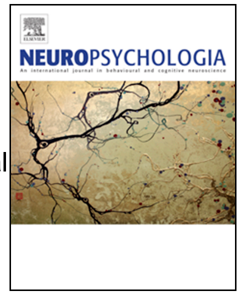


Scrutinizing the grey areas of declarative memory: Do the self-reference and temporal orientation of a trait knowledge task modulate the Late Positive Component (LPC)?

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**Scrutinizing the Grey Areas of Declarative Memory:**

**Do the Self-reference and Temporal Orientation of a Trait Knowledge Task Modulate the Late Positive Component (LPC)?**

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**Abstract**

Knowledge about the future self may engage cognitive processes typically ascribed to episodic memory, such as awareness of the future self as an extension of the current self (i.e., autonoetic consciousness) and the construction of future events. In a prior study (Tanguay et al., 2018), temporal orientation influenced the Late Positive Component (LPC), an ERP correlate of recollection. The LPC amplitude for present traits was intermediate between semantic and episodic memory, whereas thinking about one's future traits produced a larger LPC amplitude that was similar to episodic memory. Here, we examined further the effect of temporal orientation on the LPC amplitude and investigated if it was influenced by whether knowledge concerns the self or another person, with the proximity of the other being considered. Participants verified whether traits (e.g., *Enthusiastic*) were true of themselves and the "other," both now and in the future. Proximity of the other person was manipulated between subjects, such that participants either thought about the typical traits of a close friend ($n$ = 31), or those of their age group more broadly ($n$ = 35). Self-reference and temporal orientation interacted: The LPC amplitude for future knowledge was larger than for present knowledge, but only for the self. This effect of temporal orientation was not observed when participants thought about the traits of other people. The proximity of the other person did not modify these effects. Future-oriented cognition can engage different cognitive processes depending on self-reference; knowledge about the personal future increased the LPC amplitude unlike thinking about the future of other people. Our findings strengthen the notion of self-knowledge as a grey area between semantic and episodic memory.

*Keywords:* Late Positive Component (LPC), self-knowledge, future thinking, episodic memory, personal semantics, personality traits.

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## 1. Introduction

> "…episodic memory differs from other kinds of memory in that its operations require a self. It is the self that engages in the mental activity that is referred to as mental time travel: there can be no travel without a traveler. If it is not self that does the traveling, then who, or what? "Self" and "self-awareness" are among those terms that are indispensable for discussing phenomena of the mind, yet have many meanings that are difficult to define and explicate (Kircher & Leube, 2003). We can think of self as the traveler who engages in mental time travel." (Tulving, 2005, pp. 14-15).



Our daily thoughts often turn toward the future, be it in anticipation of mundane matters or meaningful ones (Baird, Smallwood, & Schooler, 2011; D'Argembeau, Renaud, & Van der Linden, 2011). The "mental time machine" that supports this feat seems almost magical and has captivated scientists from many disciplines, including cognitive, developmental, and social psychology, as well as neuroscience. Endel Tulving coined the term "mental time travel" to describe the human capacity to re-experience events from our past (which Tulving referred to as 'episodic memory'), including their accompanying sensations, thoughts, and emotions, as well as to project into the future to plan or imagine events that have not yet occurred (Szpunar & Tulving, 2011; Tulving, 1985; 2002b). Tulving has conveyed the special nature of episodic memory by contrasting it with another type of declarative memory, *semantic memory* (e.g., Tulving, 1972, 1983, 2002b, 2005; Wheeler, Stuss, & Tulving, 1997), which involves knowledge of culturally-shared facts about the world, such as “snow is white”. Episodic memory implicates the self (Tulving, 2002b) and involves *autonoetic awareness* (“an awareness of self in time”; Tulving, 2002b) and *chronesthesia* (i.e., the subjective experience of time; Tulving, 2002a), whereas semantic memory does not (Tulving, 2002b, 2005).

### 1.1 Episodic and Semantic Memory versus Self-knowledge

Tulving’s distinction between episodic and semantic memory has been fundamental to progress in the cognitive science and neuroscience of declarative memory. Yet, there is growing evidence that there are intermediate forms of memory that might not easily fit within, or might even cut across, the episodic-semantic distinction. *Self-knowledge* is one such case. This form of knowledge is self-evaluative, and often assessed by having people rate their personality traits (Grilli, Bercel, Wank, & Rapcsak, 2018; Klein, Cosmides, & Costabile, 2003; Klein, Cosmides, Costabile, & Mei, 2002; Renoult, Davidson, Palombo, Moscovitch, & Levine, 2012; Warrington & McCarthy, 1988). Similar to episodic memory, self-knowledge is inherently self- and internally-focused (Craik et al., 1999; D’Argembeau, Stawarczyk, Majerus, Collette, Van der Linden, Feyers, et al., 2010); yet, unlike episodic memory, it does not involve autonoetic awareness or a subjective sense of time or construction of events (Klein & Lax, 2010). And, similar to semantic memory, self-knowledge is abstracted from specific events; yet, it differs from semantic memory in that it is highly idiosyncratic to oneself. Consistent with this theoretical distinction, neuropsychological studies have suggested that self-knowledge can remain intact when episodic and/or semantic memory are impaired (Klein & Lax, 2010). Tulving (1993) was the first to document a dissociation between self-knowledge and episodic memory:

The amnesic patient K.C. could judge his current personality accurately, despite profound post-injury anterograde and retrograde amnesia and changes in personality (Klein & Lax, 2010). Drawing on this and other evidence, Renoult, Davidson, Palombo, Moscovitch and Levine (2012) proposed that self-knowledge is a type of "Personal Semantics", an intermediate memory type that neither corresponds perfectly to semantic nor episodic memory by definition, nor when considering behavioural and brain data.

**1.2 Temporal Orientation of Self-Knowledge**

Although self-knowledge appears dissociable from semantic and episodic memory, there may be cases in which it overlaps to a greater degree with one or the other. One example of this may involve *time*. Self-knowledge often extends across time, such as when we contemplate the many possible versions of who we might become in the future (Markus & Nurius, 1986). Thinking about past or future traits might increase our reliance on episodic processes relative to thinking about current traits, for at least two reasons. First, the attribution of a characteristic to a past or future self presupposes an awareness of the self as evolving within a temporal context (Szpunar & Tulving, 2011). Second, the knowledge of prospective characteristics and the imagination of future events have been shown to closely interact with and shape one another (D'Argembeau, 2015; D'Argembeau, Lardi, & Van der Linden, 2012; D'Argembeau, Stawarczyk, Majerus, Collette, Van der Linden, Feyers, et al., 2010; Demblon & D'Argembeau, 2017; Rathbone, Conway, & Moulin, 2011). Although prior research has emphasized the links between the episodic and semantic aspects of future thinking, the recollection of past events might likewise inform knowledge about future selves. Details from the past could provide an actual or alternate version of events (when recombined) to assess the eventual relevance of personal characteristics, particularly in light of everyone's expectation of change from the past to the future (Chambers, 2008; Kanten & Teigen, 2008). Additionally, the recollection of past events to predict future traits might sustain a sense of self-continuity through time. Whether past or future oriented, the construction of events produces an increased reliance on episodic processes (Addis, 2018; Schacter et al., 2017; Schacter & Addis, 2007).

Recent event related potential (ERP) findings from Tanguay et al. (2018) using the Late Positive Component (LPC) as an index of episodic recollection (Rugg & Curran, 2007; Wilding & Ranganath, 2012; reviewed below) are consistent with these ideas. The task involved thinking about personality traits: People had to decide whether traits reflected their own personality five years ago, currently, and five years from now (i.e., past, present, and future self-knowledge), or the personality of people holding an occupation (e.g., soldiers -courageous; semantic memory). Participants also completed a recognition task with old and new traits (i.e., episodic recognition memory). Thinking about one's current traits elicited a mean LPC amplitude that ranked in the middle between the minimal amplitude of semantic memory and the maximal amplitude of episodic recognition memory. In contrast, the mean LPC amplitudes for thinking about one's past and future traits (relative to present traits) were closer to the LPC amplitude for the episodic recognition memory condition (and, in fact, not significantly different from it) compared to present self-knowledge.

What exactly did these LPC effects reflect in Tanguay et al.'s (2018) study? The temporal orientation of knowledge, by itself, might not offer a sufficient explanation because "…there can be no travel without a traveler." (Tulving, 2005). That is, the effect of temporal orientation on knowledge may depend on self-referential processing, namely, the degree to which it concerns the self (i.e., the traveler). In the present study we test this hypothesis directly by replicating the Tanguay et al. (2018) design but manipulating both self-reference and temporal orientation to obtain a fully crossed design, which was not done in Tanguay et al. (2018; i.e., other-knowledge was only present-oriented and not temporally specified).

**1.3 Theories of Self-Knowledge Across Time**

Tulving's distinction between episodic and semantic memory has been applied to explain how we envision a future self, with different perspectives either emphasizing episodic or semantic contributions. The first perspective emphasizes that thinking about future traits increases the reliance on common processes with episodic memory. A few lesion studies have indicated that one's knowledge about personal traits is constrained to time periods of preserved episodic memory or intact self-awareness. For instance, K.C.'s description of his past personality was less accurate than his current personality (e.g., 52% vs. 73%; Tulving, 1993), suggesting that his retrograde amnesia may have affected his ability to retrieve knowledge about his personality in the past. Additional data from groups (e.g., older adults, and Alzheimer's disease or semantic dementia) with varying presentation of episodic memory decline (e.g., mild to severe, affecting the recent or remote periods) suggest that their distant selves might be perceived as more similar to their present selves or be represented closer in time to the present self (compared to young adults or healthy older adults; Chessell, Rathbone, Souchay, Charlesworth, & Moulin, 2014; Rutt & Löckenhoff, 2016; Tippett, Prebble, & Addis, 2018), and/or it might lead to a distorted representation of the present self (for those with a memory impairment affecting the recent past, Klein et al., 2003; reviewed in Strikwerda-Brown, Grilli, Andrews-Hanna, & Irish, 2019).

In contrast, the second perspective proposes that various forms of semantics may suffice to inform the representation (or content) of a future self, providing a sense of "semantic continuity" across temporal contexts (Prebble, Addis, & Tippett, 2013). Knowledge regarding the timeline for personal events, life narrative, current personality traits, and other aspects of the self-concept all play a role in defining semantic continuity (Prebble et al., 2013). The knowledge of cultural life scripts may also inform the perception of future selves (Rathbone, Salgado, Akan, Havelka, & Berntsen, 2016). Consistent with these proposals, K.C. possessed good knowledge of "time" as a concept and ordered his autobiographical facts mostly correctly, even if a subjective sense of p/re-experiencing past or future events was inaccessible (Craver, Kwan, Steindam, & Rosenbaum, 2014; Tulving, 2005). Additional evidence for a potential role of semantic memory in conceptualizing our future selves comes from behavioural (and neuroimaging) data (D'Argembeau, Stawarczyk, Majerus, Collette, Van der Linden, & Salmon, 2010; Pronin & Ross, 2006) indicating that future selves might be perceived similarly to knowledge about other people (Pronin & Ross, 2006). Thus, thinking about future traits could be independent from episodic memory, much like knowledge of current traits (Klein & Lax, 2010).

The theories and findings reviewed above [along with contributions from (Conway, Justice, & D'Argembeau, 2019; Conway & Pleydell-Pearce, 2000)] suggest that both episodic and semantic aspects of memory could be engaged when thinking about future traits. In the present study, we predicted that thinking about future traits would be distinguishable from presents traits (as in Tanguay et al., 2018). We also sought to answer a further question: What happens when we think about *another person's* future traits versus our own?

### 1.4 The self-relevance of knowledge and temporal orientation

Tulving's theories inspired us to ask how (or even whether) we travel mentally in time to think about other people's future traits (e.g., our children, friends, people in general). Do self-relevance, feeling of temporal distance, and the recollection or imagination of events differ between self- and other-knowledge? Previous research shows that self-referential processing and future-oriented knowledge can interact. For instance, the future traits and preferences predicted for other people may conform to stereotypes, or be heavily influenced by semantic knowledge (Kanten & Teigen, 2008; Renoult, Kopp, Davidson, Taler, & Atance, 2016; Wilson & Ross, 2001). Similarly, people tend to imagine events that are impoverished in episodic details when those events feature another person instead of the self (de Vito, Gamboz, & Brandimonte, 2012; Grysman, Prabhakar, Anglin, & Hudson, 2013; Verfaellie, Wank, Reid, Race, & Keane, 2019). Importantly, the proximity of the other person can influence differences between the self and the other person: Similarity to a generic memory sometimes increases as the “target” of the scenario moves along a continuum from the self to a close other to a generic person (Grysman et al., 2013; see also Bauckham et al., 2018). Accordingly, in the present study, we do not consider self-relevance to be a dichotomous category (me vs. others) but, rather, a continuum from high self-relevance/specific (e.g., close friend) to low self-relevance/abstract (e.g., a group). For instance, according to Aron, Aron, Tudor, and Nelson (1991), a close other could be included within the self-concept. A simple and global distinction between self- and other- knowledge may conceal several similarities – and differences – between memory types (e.g., accessibility of relevant events, emotion, self-relevance).

For clarity, in subsequent sections, “self-reference” designates whether knowledge concerns the self or another person, and we use “proximity of the other” to describe the other person’s relevance to the self.

### 1.5 ERPs and self-knowledge

Although behavioural data are valuable for evaluating theories, they can offer interpretative challenges, because the same behaviours can result from different underlying cognitive/neural processes. For instance, if one predicts that one's personality changes over time, might one merely be drawing on the cultural script (i.e., semantic memory) that says this happens to everyone (Krueger & Heckhausen, 1993; Wood & Roberts, 2006)? Alternatively, could one be episodically simulating future events to judge the pertinence and scope of a future trait, and predict a change (Klein, Cosmides, Tooby, & Chance, 2002; Klein, Loftus, Trafton, & Fuhrman, 1992)? Or, might one even conclude that one's personality/traits will not change based on those simulations? Hence, the recruitment of more or less episodic processes could result in the same or different behavioural outcome, and how heavily episodic processes are engaged could depend on the personal nature of the knowledge. To gain insight into the underlying processes supporting these kinds of personality judgements, Tanguay et al. (2018) used the LPC effects 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 (Düzel, Yonelinas, Mangun, Heinze, & Tulving, 1997), 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; Düzel, Vargha-Khadem, Heinze, & Mishkin, 2001). Yet, the retrieval of personal semantics or autobiographical events can also produce a larger LPC compared to semantic memory (Coronel & Federmeier, 2016; Renoult, Tanguay, et al., 2016).

As noted above, one complication in Tanguay et al. (2018) was that temporal orientation and self-relevance were confounded when considering the past and future selves. That is, the “semantic memory” (i.e., the other-knowledge) condition did not have a corresponding past or future condition. Thus, the findings showed that self-knowledge was associated with a larger LPC amplitude than semantic memory, with the largest amplitudes for past and future self-knowledge (Tanguay et al., 2018), but it is unknown whether temporal orientation could also modulate the LPC amplitude when thinking about other people. Little research has been carried out to disentangle the effects of self-reference and temporal orientation on people’s knowledge. Moreover, 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 the present study was to replicate our finding of a larger LPC amplitude when thinking about the future self than the present self.

### 1.6 The Present Study

For the reasons outlined above, here we investigate how self-relevance and temporal orientation (present versus future) might modulate the LPC, in a present- and future-thinking task that is similar to Tanguay et al. (2018; see Figure 1). Accordingly, we expected to replicate our previous finding of a larger LPC for thinking about the future self than the present self. Critically, to disentangle effects of temporal orientation versus self, we compared present and future traits both for self and other. In Tanguay et al. (2018), participants thought about the typical (present) traits of people holding a certain occupation (e.g., are soldiers courageous?). 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). 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 (Ebner et al., 2011). We added two additional conceptualizations of others to manipulate proximity to self: *Generic Other* and *Close Other*. This manipulation seeks to distinguish effects that stem from self-referential processing versus self-relevance. That is, thinking about a close friend might modulate the LPC by virtue of the increased self-relevance in addition to the possible recollection or imagination of events. If the temporal orientation effect depends on self-referential processing, per se, it should be found for the self and not the close friend.

Overall, we expected a temporal orientation effect irrespective of self-relevance (i.e., larger LPC for future than present), and a self-relevance effect irrespective of temporal orientation (i.e., larger LPC for self than other). However, we reasoned that temporal orientation and self-relevance could interact because 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 thinking about others. We also expected self-relevance (Close Other vs. Group Other) to reduce the difference between the self and other, but we were uncertain whether this would apply to future thinking.

To help anchor these effects at a cognitive level, we included self-report questions about self-reference, 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. These measurements were collected once at the end of each condition, offering a partial, but important, window into the cognitive processes recruited on a conscious level and corroborating that the instructions produced the expected effect. For instance, a lack of an LPC amplitude difference between the past and future could stem from an inability to think about the other person's future or the apparent similarity between the past and future characteristics of the other person. Hence, these measures act – to a certain extent – as manipulation checks and they also help to interpret the findings.

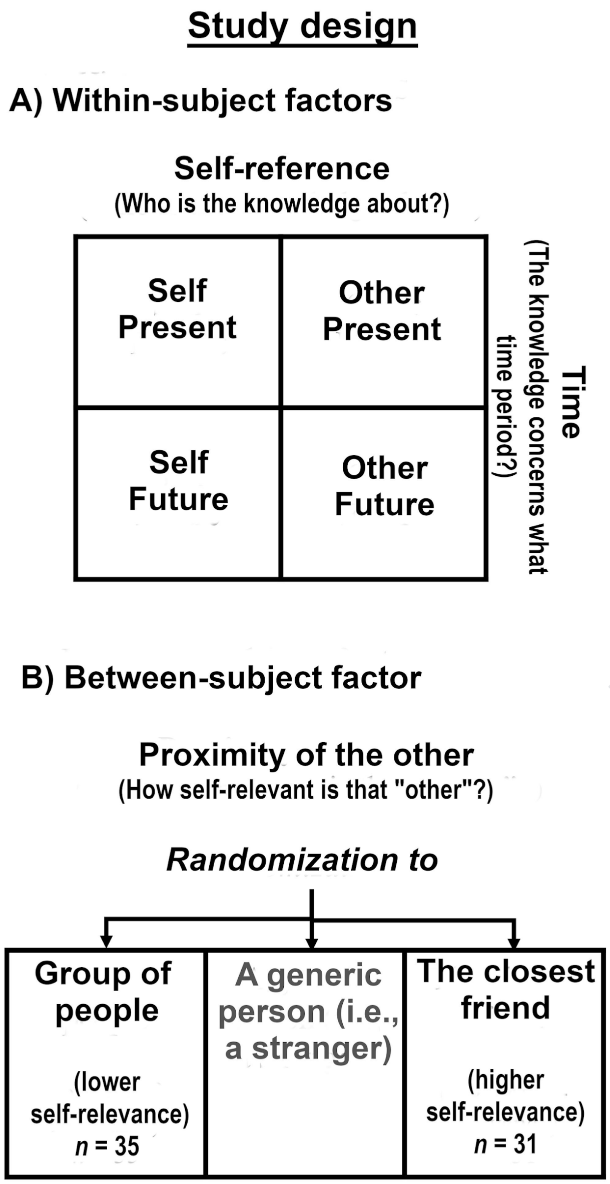


*Figure 1.* Overview of the study. A) All participants thought about their own traits in the present and the future (5 years from now) and those of the other(s) in the present and the future. B) Participants were randomized to think about others that differed in proximity to the self: a group of people, a generic person, and their closest friend (not a significant other or a family member). See Methods for the full description.

# 2. Methods

## 2.1 Participants

Data from 66 (of 118) participants was retained for the analyses (see below). Of these 66, 49 were women (1 non-binary, 16 male) with a *M* age = 19.98 years (*SD* = 2.63) and a *M* education = 13.25 years (*SD* = 1.65; see Supplementary material 5.1 for a breakdown per group). The participants were randomly assigned to the experimental groups. 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 posters at the University of Ottawa. These participants received $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 the Generic Other condition (*n* = 28), because the manipulation failed to elicit processing in relation to a single person, as initially intended[1]. Therefore, the final analyses contrasted thinking about a close friend to thinking about a group of people. We excluded another 24 participants (before running statistical analyses) because they did not meet the eligibility criteria (*n* = 18), because of technological failure or excessively poor EEG (e.g., due to very thick hair, the computer stopped working mid-testing, *n* = 5) or failure to follow instructions (e.g., demonstrating a repeated lack of comprehension and interest during the instructions, not

[1] Some participants reported thinking about an ideal self to imagine this stranger and ratings indicated that they thought more about their self. Participants seemed to imagine the generic person in such a vivid manner that they responded to some follow-up questions as though they truly knew the person (e.g., saying that they knew the person for the last three years). Upon probing, these participants confirmed that they were “pretending” to know the person. In general, the manipulation evoked heterogeneous processes. A summary of the findings can be requested from the corresponding author.

responding to the first two questions of a condition [about activities and housing], and asking to skip ahead, $n$ = 1). The exclusion rate was in part a by-product of the recruitment strategy (i.e., the student pool; e.g., misunderstanding eligibility criteria and an experimenter error (i.e., left-handedness was not specified in the exclusion criteria initially). Excluded participants were replaced on an ongoing basis and participant exclusion was re-examined prior to analyses. This resulted in 31 participants for Close Other and 35 participants for Group Other after exclusion. We planned for sample sizes slightly larger 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 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 condition—included enough participants to detect the effect, and the full sample ($N$ = 66) provides ample power (98% assuming a similar effect size). 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.

**2.2 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 each list, $t(98) \geq 20.06$, $p < .001$.

**2.3 Design**

We randomly assigned the participants to one of the three experimental Other conditions (Group Other, Generic Other, Close Other). Having Proximity of the Other as a between-subject factor enabled us to preserve an identical number of trials overall and a similar study duration as Tanguay et al. (2018), while also increasing (rather than reducing) the number of trials per task. 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-reference (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 all exclusions, 1 to 3 (median = 2) participants completed the study in a given list and task order and experimental condition.

**2.4 Interpersonal Questionnaire**

The questionnaire was adapted from (Aron et al., 1991; Ersner-Hershfield, Garton, Ballard, Samanez-Larkin, & Knutson, 2009; Liviatan, Trope, & Liberman, 2008; Rutt & Löckenhoff, 2016). We collected information on the close friend (contingent on randomization to that experimental condition): age, sex, number of years they had known the person, and number of years they had been close. Moreover, the participants rated how close and how similar they felt to the other person, and how much they liked him/her. All the participants, Group Other included, rated the effort they invested in the task about the other person/people their age, and task difficulty for self and for Other(s). All these ratings were made using a scale ranging from 1 (not at all) to 9 (very much). Lastly, participants selected increasingly overlapping 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 5 years from now. The distance of 5 years matches the distance of the future conditions in the experimental tasks. These are called "similarity measures" to encompass the three dimensions. Most of these measures serve as manipulation checks (e.g., verifying whether the friend is indeed close, confirming that the friend feels closer to the self than a group of people).

**2.5 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., about the 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, 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 thinking about the commonalities of the age group. In the Close Other condition, participants selected their closest friend who was not a family member or romantic partner. The participants decided whether the traits reflected their friend's current or future traits. We reasoned that thinking about the traits of a very close other should increase self-relevance and might entail the recollection of events.

The friends were known for a *M* of 7.22 years (*SD* = 5.14), and held a close relationship with the participants since a *M* of 5.9 years (*SD* = 5.36). The relationship was judged to be near the maximum on closeness (i.e., 9; *M* = 8.08, *SD* = 1.3) and on how much the friend was liked (i.e., 9, *M* = 8.32, *SD* = 0.83). The age of the chosen friend correlated almost perfectly with the participants' own age, $r(29) = .967$, $p < .001$, and all but one participant selected a friend of the same sex.

Each task began with two preliminary questions about the self or the other(s), either thinking about the present or the future; one pertained to activities and the other to housing situation. For example, when the task concerned the present self, participants received these instructions: "In this next task, we will ask you to think about yourself, and what may be some of your characteristics CURRENTLY. What are some of your current activities? (…) What is your current housing situation?" The participants had 60 seconds to type their response for each question, and these responses were recorded (inspired from D'Argembeau, Stawarczyk, Majerus, Collette, Van der Linden, & Salmon, 2010; Tanguay et al., 2018). For the remaining conditions, we adapted the wording of the questions minimally to refer to the future or to the other person/people, as appropriate.

The participants then viewed the 50 positive and 50 negative words in a randomized order using E-Prime, and produced a yes or no response to judge the traits as instructed. The yes response was assigned to the index finger (button = 1) and the no response to the middle finger (button = 2). The stimuli were shown over a white screen in a courier new font with a 24 size. Each trial started with a fixation cross lasting from 1500 to 2000 ms (random duration). 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 condition, participants evaluated: 1) how much they thought about the future (about five years from now); 2) how much 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: 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 Interpersonal Reactivity Index (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 understood as expected (this step was omitted for a few participants due to time constraints).

**2.6 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 were 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 particularly distort these channels 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 identified noisy channels during visual inspection and removed them. 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 $M$ = 0.64 channels, $SD$ = 0.25, Mode = 0, range of 0 to 4 channels). An average mastoids reference (TP9/TP10) was computed offline and used for all analyses. The epochs of interest started at -200 prior to the onset of the words and ended 800 ms after, and only yes responses were retained, as in Tanguay et al. (2018), because they are more likely to reflect the presence of a memory trace rather than an unrelated event (e.g., inattention). 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) signifies that a somewhat different subset of electrodes were selected for the parietal region of interest (ROI) as compared to Tanguay et al. (2018), i.e., P3/Pz/P4 (vs. P1/P2, P3/P4, PO3/PO4). The mean Late Positive Component (LPC) was defined as the mean amplitude from 500 to 800 ms over the parietal ROI (Tanguay et al., 2018). For additional analyses, the frontal ROI was composed of the mean of F3/Fz/F4, and the central ROI of C3/Cz/C4. Other time windows are included in Supplementary material.

The mean number of trials included in the average and the mean percentage of retained trials after artifact rejection are shown in Table 1[2].



[2]There were a relatively similar number of rejected trials in Tanguay et al. (2018; see section 2.2.2 in that paper; i.e., < 8% of trials in both studies) but a lower number of trials per condition before artifact rejection (i.e., 80 vs. 100). Thus, the number of trials was lower in the previous study compared to this one (i.e., mean of 35 vs. 45 trials). Additionally, the number of interpolated channels was greater in the previous study as can be expected from the higher number of channels recorded in it (63 vs. 31), but the number of interpolated channels did not exceed 10% of channels in both studies. These values were not reported previously and are, therefore, noted here: $M = 2.53$ interpolated channels, $SD = 1.84$, $Mode = 3$, range of 0 to 6 channels). The changes in trial and channel numbers between studies were intended to increase signal and reduce noise. Lastly, a difference in preprocessing resulted from the number of channels: the channels were re-referenced to the average of all electrodes in the previous study, and to the mastoids in the current study.

Table 1.

*Mean number of trials included in the ERP averages and mean % of trials after artifact rejection from total responses made; range and SD in parentheses.*

| | | Self – Present | Self – Future | Other – Present | Other – future |
|---|---|---|---|---|---|
| **Group Other** | | | | | |
| | Yes - Included in average | 43.94 (24-69; ±8.49) | 43.71 (24-57; ±6.49) | 53.17 (31-67; ±8.55) | 49.34 (26-66; ±8.14) |
| | Yes – % retained | 94.86 (80.36-100; ± 5.35 | 93.81 (75- 100; ± 6.39) | 93.82 (72.58- 100; ± 6.86) | 93.52 (70.27-100; ± 7.47) |
| | No – Included in average | 48.83 (26-75; ±9.16) | 49.14 (30-63; ±7.55) | 39.23 (22-56; ±8) | 42.86 (30-56; ±8.25) |
| | No – % retained | 93.23 (67.44-100; ± 7.22) | 94.42 (72.22-100; ± 5.90) | 92.30 (70.27- 100; ± 7.34) | 93.23 (72.09-100; ± 7.30) |
| **Close Other** | | | | | |
| | Yes – Included in average | 46.45 (30 – 70; ±9.92) | 44.13 (28 – 66; ±7.95) | 41.42 (28 – 55; ±6.55) | 42.29 (28 – 54; ±6.28) |
| | Yes – % retained | 93.65 (76.92-100; ±6.53) | 95.26 (76.19-100; ±5.58) | 92.68 (77.27- 100; ±5.73) | 92.34 (80.43-100; ±5.40) |
| | No – Included in average | 45.48 (21 – 62; ±9.81) | 49.81 (34 – 67; ±8.08) | 50.32 (37 – 66; ±6.80) | 48.84 (37 – 60; ±6.04) |
| | No – % retained | 92.96 (71.93 – 100; ±6.77) | 94.85 (79.17 – 100; ±5.04) | 92.69 (76.79 – 100; ±5.62) | 92.31 (79.25 – 100; ±6.00) |

### 2.7 Statistical Analyses

**2.7.1 EEG**. We evaluated whether Self-reference and Time resulted in an effect on the LPC amplitude, and if these factors interacted with one another or with the Proximity of Other. The mean LPC amplitude was entered in a mixed ANOVA with Self-reference (self, Other) and Time (present, future) and Proximity of Other (Group Other, Close Other). In these and most analyses below, except where indicated, we report the $\eta^2_p$ for the measure of effect size.

We aimed to characterize the scalp distribution of key contrasts using mixed ANOVAs with Anteriority (frontal, central, parietal) and Hemisphere (left, right) as factors, each composed of three Electrodes: Anterior left (Fp1, F7, F3), Anterior right (Fp2, F8, F4), Central left (C3, T7, Cp5), Central right (C4, T8, Cp6), Posterior left (P3, P7, O1) Posterior right (P4, P8, O2). We added Proximity of Other as a factor to test whether these groups differed in scalp distribution.

**2.7.2 Behavioural**. 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. In addition, participants might have reported that they recalled or imagined more events during the future tasks than the present tasks. As outlined in the introduction, knowledge of current traits is thought to be independent from episodic memory (Klein & Lax, 2010), whereas some findings suggest there could be a certain interdependence for past or future self-knowledge (Klein et al., 2003; Tanguay et al., 2018; Tippett et al., 2018; Tulving, 1993). The recollection or imagination of events might explain that relation (at least in part). Regardless of the direction of the temporal orientation (past or future), we expected that the construction of those events would be associated with heightened episodic processes and a correspondingly larger LPC amplitude.

We ran a mixed ANOVA for each of these ratings (i.e., future thinking, self, events) with Self-reference (self, Other) and Time (present, future) as within-subject factors, and Proximity of Other (Group Other, Close Other) as a between-subject factor. Prior to running these analyses, we removed univariate outliers from the dependent variables, i.e., values outside the acceptable range, $z \pm 2.58$ (see Supplementary material 5.2 for additional details).

Further, we compared task difficulty and effort using a 2 x 2 x 2 mixed ANOVA, as described above. There were no outliers on these measures using the aforementioned criterion. We compared the effort invested in the task about the Other using an independent-sample t-test, and reported the Hedges' *g* as an unbiased measure of effect size (similar to Cohen's *d*; Lakens, 2013).

Lastly, the proportion of yes responses was entered in a mixed ANOVA with Self-reference (self, Other), Time (present, future), Valence (positive, negative), and Proximity of Other (Group Other, Close Other).

Note that we conducted these analyses (described in 2.7.2) primarily to inform the interpretation of the LPC effects.

**2.7.3 Correction for multiple comparison.** Statistical tests were corrected to maintain an alpha level of $p = 0.05$ per hypothesis, which were, by definition, specified a priori. Other main effects and interactions that did not bear on the hypotheses were corrected using the Holm-Bonferroni procedure per statistical test (e.g., per ANOVA). If a hypothesis was associated with multiple tests, it was also corrected using the Holm-Bonferroni (Holm, 1979). The corrected cut-offs are disclosed in text where applicable. We applied the Sidak correction (Šidák, 1967) for post-hoc tests.

**2.7.4 Supplementary analyses.** The analyses of order effects (5.7), and reaction times (5.8) during the task, P200, N400 (5.9), and valence (5.10) are included in Supplementary material. These analyses are provided for the sake of comprehensiveness and transparency. They were not corrected for multiple comparisons, and the reader should judge significance levels accordingly. Some non-significant effects are also reported in the Supplementary material to lighten the text.

## 3. Results

### 3.1 EEG

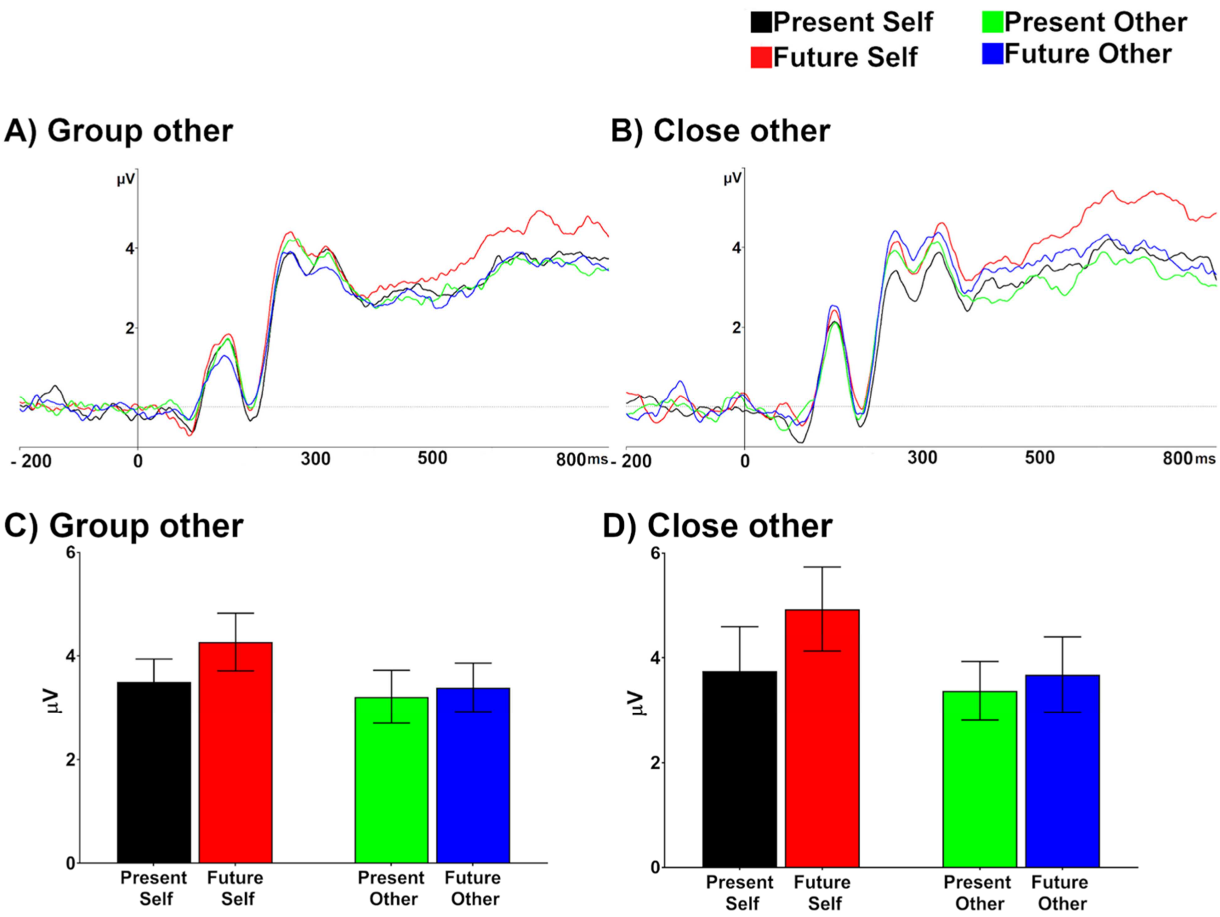


*Figure 2*. Top panel: Grand mean ERP average of participants in the A) Group Other condition ($n$ = 35) and B) the Close Other condition ($n$ = 31) over the parietal ROI (mean of P3, Pz, P4). The LPC time-window ranged from 500 to 800 ms. Positive is plotted upward. Lower panel: Bar chart of the mean amplitude with error bars ± 1 S.E. for C) Group Other and D) Close Other.

We tested whether Self-reference, Time, and Proximity of Other modulated the LPC amplitude. The 2 x 2 x 2 mixed ANOVA included Self-reference (self, Other) and Time (present, future), and Proximity of Other (Group Other, Close Other; see Figure 2). The main effects of Self-reference ($F$[1, 64] = 9.41, $p$ = .003, $\eta^2_p$ = 0.13) and Time ($F$[1, 64] = 9.9, $p$ = .003, $\eta^2_p$ = 0.13) were both significant, and they interacted ($F$[1, 64] = 5.81, $p$ = .019, $\eta^2_p$ = 0.08). Future self ($M$ = 4.6, $SE$ = 0.48) was more positive than present self ($M$ = 3.63, $SE$ = 0.46), $p$ < .001, $\eta^2_p$ = 0.2, but future Other ($M$ = 3.53, $SE$ = 0.42) was not more positive than present Other ($M$ =

3.29, *SE* = 0.38), $p$ = .329, $\eta^2_p$ = 0.02. None of these effects interacted with Proximity of Other (three possible interactions related with a single hypothesis: *Self-reference, $F[1, 64] = 0.24$, $p$ = .624, $\eta^2_p < 0.01$ [cut-off of $p$ = 0.05]; *Time, $F[1, 64] = 0.50$, $p$ = .483, $\eta^2_p$ = 0.01 [cut-off of $p$ = .0168]; Self-reference*Time, $F[1, 64] = 0.23$, $p$ = .632, $\eta^2_p$ < .01 [cut-off of $p$ = .025]).

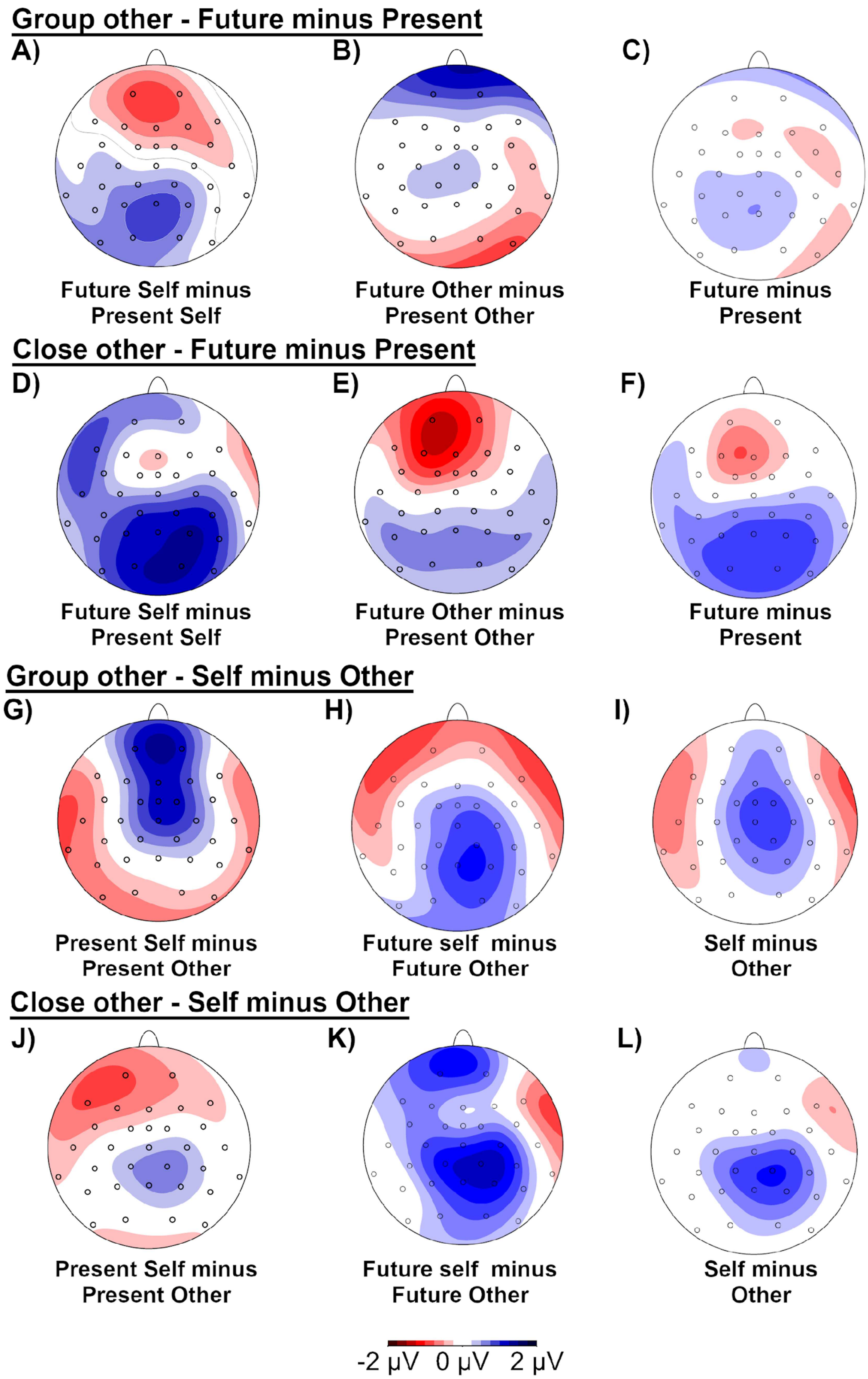
Group other - Future minus Present
A)
B)
C)
Future Self minus Present Self
Future Other minus Present Other
Future minus Present
Close other - Future minus Present
D)
E)
F)
Future Self minus Present Self
Future Other minus Present Other
Future minus Present
Group other - Self minus Other
G)
H)
I)
Present Self minus Present Other
Future self minus Future Other
Self minus Other
Close other - Self minus Other
J)
K)
L)
Present Self minus Present Other
Future self minus Future Other
Self minus Other
-2 μV 0 μV 2 μV

Figure 3. Scalp distribution of mean amplitudes for the 500 to 800 ms time period for the Time contrast (Future minus present) for Group Other (A, B) and Close Other (D, E), and for the Self-reference contrast (self minus Other) for Group Other (G, H) and Close Other (J, K). The right-most scalp map shows the Time contrast aggregated across Self-reference conditions (C, F) and for the Self-reference contrast aggregated across Time conditions (I, L).

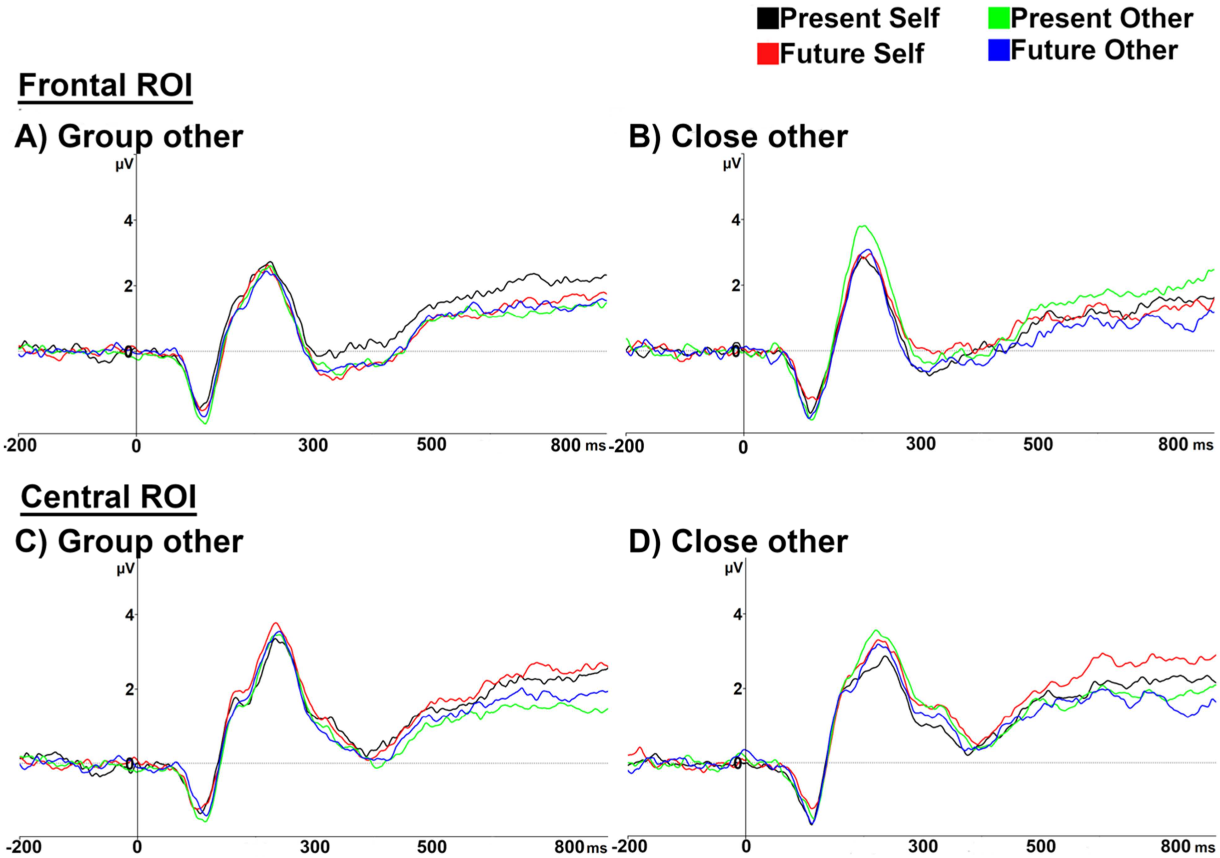


*Figure 4.* Grand mean ERP average of participants in the A) Group Other condition ($n$ = 35) and B) Close Other condition ($n$ = 31) over the frontal ROI (mean of F3, Fz, F4), and C) Group Other and D) Close Other over the central ROI (mean of C3, Cz, C4). Note that positive is plotted upward.

We conducted mixed ANOVAs with Anteriority (anterior, central, posterior) and Hemisphere (left, right), and Proximity of Other to characterize the scalp distribution of critical contrasts. The dependent variables were the differences in mean amplitude between two conditions (mirroring the scalp maps in Figure 3): panels A and D) Future self vs. present self, panels B and E) Future Other vs. present Other, panels G and J) Present self vs. present Other, and panels H and K) Future self vs. future Other. The waveforms for the frontal and central ROI are displayed in Figure 4. We conducted separate ANOVAs on each of these contrasts following this order (i.e., A/D, B/E, G/J, H/K).

The first analysis aimed to represent the scalp distribution of the effect of Time for the self (see Figure 3A and D). The main effect of Anteriority was not significant after correction, $F(1.24, 79.15) = 4.84$, $p = .024$, $\eta^2_p = 0.07$ (cut-off of $p = 0.008$). None of the effects were significant (see Supplementary material 5.3).

The second analysis focused on the scalp distribution of Time for the Other (see Figure 3B and E). Anteriority and Proximity of Other interacted, $F(2, 128) = 4.97$, $p = .008$, $\eta^2_p = 0.07$ (cut-off $p = .0083$). Whereas the scalp distribution did not vary as a factor of Anteriority for Group Other ($p$s $\geq .795$, Hedges $g \leq 0.21$; anterior: $M = 0.28$, $SE = 0.39$; central: $M = 0.05$, $SE = .20$; posterior: $M = -0.143$, $SE = 0.29$), it did for Close Other. That is, for Close Other, posterior ($M = 0.60$, $SE = 0.30$) sites were more positive than anterior sites ($M = -0.753$, $SE = 0.41$), $p = .045$, Hedges $g = 0.67$. Central sites ($M = 0.16$, $SE = 0.21$) did not differ from anterior ($p = .074$, Hedges $g = 0.50$) or posterior sites ($p = .254$, Hedges $g = 0.30$). The interaction between Anteriority and Hemisphere was not significant after correction, $F(2, 128) = 3.91$, $p = .022$, $\eta^2_p = .06$ (cut-off of $p = .01$; see Supplementary material 5.3 for non-significant effects).

None of the main effects or interactions were significant for the mean difference between the present self and present Other (which would have reflected an effect of self-reference when thinking about current traits; see Figure 3G and J and Supplementary material 5.3).

Lastly, for the future self minus future Other contrast, the effect of Anteriority depended on Hemisphere, $F(2, 128) = 8.31$, $p < .001$, $\eta^2_p = 0.12$ (cut-off of $p = .008$; representing an effect of Self-reference when thinking about the future; see Figure 3H and K). The right hemisphere ($M = 0.81$, $SE = 0.25$) was more positive than the left hemisphere ($M = 0.26$, $SE = 0.22$) over the posterior sites, $p < .001$, $\eta^2_p = 0.18$, but hemispheres did not differ over anterior ($p = .349$, $\eta^2_p = 0.01$; right: $M = -0.06$, $SE = 0.25$; left: $M = 0.13$, $SE = 0.25$) and central sites ($p = .164$, $\eta^2_p = 0.03$; right: $M = 0.51$, $SE = 0.2$; left: $M = 0.19$, $SE = 0.18$; see Supplementary material 5.3 for non-significant effects).

Taking into account the statistical trends, these analyses suggest that Time produced a scalp distribution of increased positivity going from anterior to posterior sites when thinking about the self (statistical trend) and the close friend (significant), but not a group of people. The comparison of future self to future Other suggests that future self produced a greater difference in positivity for the right compared to the left hemisphere over the posterior sites.

## 3.2 Behavioural

We ran a 2 x 2 x 2 mixed ANOVA with Self-reference (self, Other) and Time (present, future) as within-subject factors, and Proximity of Other (Group 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. One participant missed all responses on these measures.

**3.2.1 Thinking about the self.** Participants thought more about their own self (i.e., their own personality and preferences) during the Self tasks than the Other tasks, $F(1, 58) = 236.07$, $p < .001$, $\eta^2_p = 0.80$ (see Figure 5C). Because participants were asked to think about their own traits during the Self tasks and those of other(s) during the Other tasks, this main effect was anticipated and confirms that participants complied with instructions. No other main effect or interaction reached significance (see Supplementary material 5.4).

**3.2.2 Thinking about the future.** Participants thought more about the future during the future tasks than during the present tasks, $F(1, 59) = 311.22$, $p < .001$, $\eta^2_p = 0.84$ (see Figure 5A). Participants were asked to think about the future during the future tasks, but not during the present tasks; this main effect was also expected and confirms compliance. No other main effects or interactions were significant (see Supplementary material 5.5).

**3.2.3 The imagined or real events that came to mind.** Our tentative hypothesis that events may come to mind more often when thinking about the future than the present was not supported: The effect of Time was not significant, $F(1, 58) < 0.01$, $p = .984$, $\eta^2_p < 0.01$. However, Self-Reference interacted with Proximity of Other $F(1,58) = 7.59$, $p = .008$, $\eta^2_p = 0.12$ (cut-off of $p = .01$; see Figure 5B). Participants recalled or imagined more events for the Other when it was a close friend ($M = 7.34$, $SE = 0.23$) than when it was a group of people ($M = 6.53$, $SE = 0.22$; $p = .013$, $\eta^2_p = 0.1$); the recollection and imagination of events did not differ when thinking about the self between experimental groups (Close Other: $M = 6.48$, $SE = 0.26$; Group Other: $M = 6.73$, $SE = 0.25$; $p = .485$, $\eta^2_p = 0.01$). No other main effect or interaction reached significance (see Supplementary material 5.6).

The events rating was higher than the neutral point (i.e., 5) in all conditions for both experimental groups ($p$s < .02, all significant after correction). This suggests that participants were aware of having retrieved or imagined events when verifying the relevance of traits. Although a coarse measure of an episodic process, this result reinforces the argument that a seemingly semantic task can engender the recruitment of episodic processes (e.g., recollection or imagination of events), even without relevant instructions (i.e., participants were only told to judge whether traits were reflective of self/Other in the present/future).

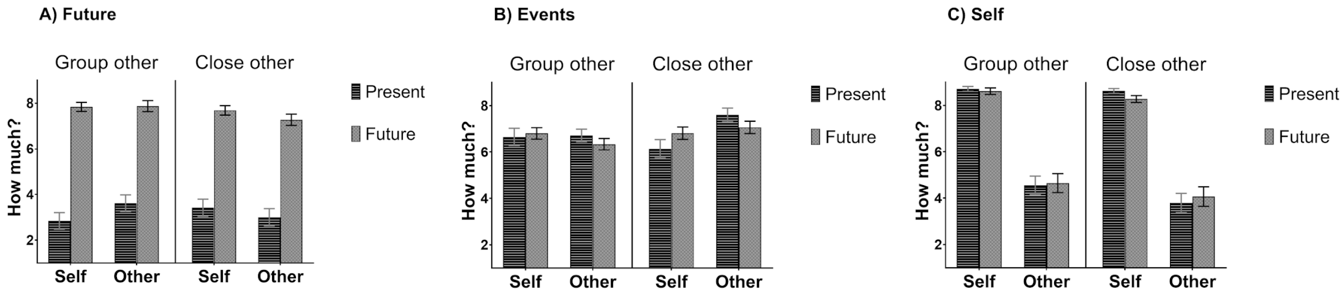


*Figure 5*. Self-report on the three measures: A) Future, B) Events, and C) Self. The bar charts contrast ratings on present and future tasks (bars coloured in black with white lines and grey), broken down by Self-reference (bar grouping) and Proximity to self (Group Other on the left and Close Other on the right). The response options ranged from 1 (not at all) to 9 (very much). Error bars ± 1 *SE*.

**3.2.4 Task difficulty and effort**. As another preliminary check to contextualize any difference in ERPs, we tested whether task difficulty differed according to Self-reference and Proximity of Other. A difference in effort or difficulty between tasks is undesirable; for that reason, $p = 0.05$ can be considered a more stringent and transparent test of a possible task difference. We used a 2 x 2 mixed ANOVA with Self-reference (Self, Other) as a within-subject factor and Proximity of Other as a between-subject factor (Group Other, Close Other). The task was perceived as more difficult when it concerned the Other ($M = 3.55$, $SE = 0.25$) than the Self ($M = 2.86$, $SE = 0.23$), $F(1, 64) = 7.98$, $p = .006$, $\eta^2_p = 0.11$. This effect of Self-reference interacted with the Proximity of Other, $F(1, 64) = 4.09$, $p = .047$, $\eta^2_p = 0.06$, that is, the task was more difficult for the Other ($M = 3.8$, $SE = 0.35$) than the Self ($M = 2.63$, $SE = .31$) in the Group Other condition ($p = .001$, $\eta^2_p = 0.16$), but not in the Close Other condition ($p = .584$, $\eta^2_p = 0.01$; Other: $M = 3.29$, $SE = 0.37$; Self: $M = 3.1$, $SE = 0.33$). An increase in difficulty can explain an increase in ERP amplitude (Luck, 2014; Vogel & Luck, 2000). If an increase in difficulty explained our ERP findings, however, we would have observed an increased difficulty for the self, not for the Other.

The effort invested was only measured in relation to the Other task, thus we compared Proximity of Other using an independent-samples t-test. There was no significant difference in effort between the Group Other (*M* = 6.57, *SE* = 0.21) and Close Other conditions (*M* = 6.26, *SE* = 0.43), $t(43.7) = .65$, $p = .518$, Hedges $g = 0.16$ (note that we selected the appropriate values for cases when the assumption of equality of variance is violated).

### 3.3 Behavioural Responses on the Task

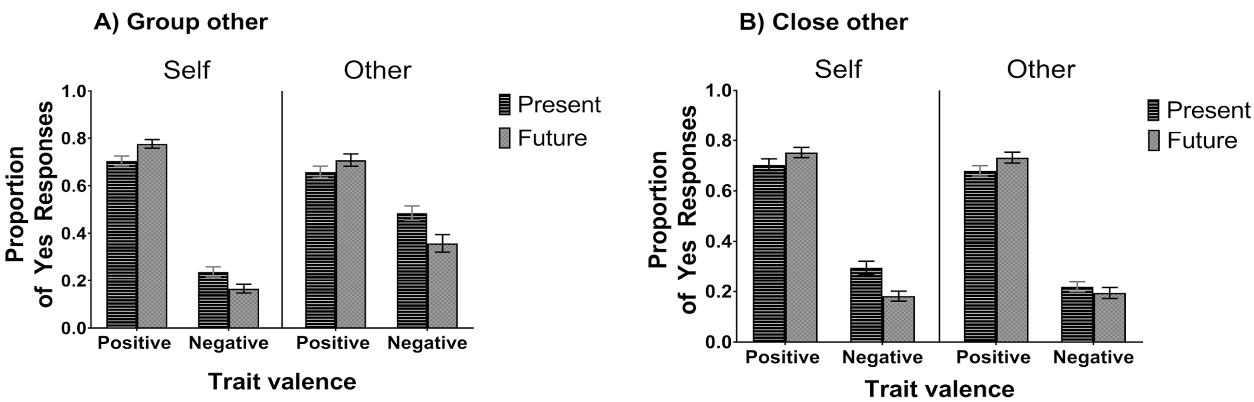


*Figure 6.* The mean proportion of yes responses is shown for A) Group Other and B) Close Other. Each panel shows the proportion of yes responses for the present (black bar with white lines) and future (grey bar), by valence (bar grouping) and by Self-reference (Self at the left and Other at the right of each panel). *SE* ± 1.

Lastly, we expected comparable results to Tanguay et al. (2018) for the proportion of yes responses: main effect of Valence (positive > negative), an interaction between Self-reference and Valence (possibly more positive traits and less negative traits for the self than Other), and interaction between Valence and Time (more positive traits and less negative traits for the future than the present), possibly particularly for the self. Other main effects and interactions were corrected.

The proportion of yes responses was entered in a mixed ANOVA with Self-reference (self, Other), Time (present, future), Valence (positive, negative), and Proximity of Other (Group Other, Close Other; see Figure 6). The behavioural data of one Close Other participant was lost due to technological failure.

As expected, more positive traits than negative traits were endorsed (main effect of Valence), $F(1, 63) = 424.04$, $p < .001$, $\eta^2_p = 0.87$. Self-reference and Valence also interacted, $F(1, 63) = 22.94$, $p < .001$, $\eta^2_p = 0.27$, in accordance with previous findings: Participants agreed with more positive traits ($M = 0.73$, $SE = 0.13$) as descriptive of themselves than the Other ($M = 0.69$, $SE = 0.02$; $p = .013$, $\eta^2_p = 0.09$) , and endorsed less negative traits for themselves ($M = 0.22$, $SE = 0.01$) than the Other ($M = .31$, $SE = 0.02$ ; $p < .001$, $\eta^2_p = 0.31$). Further, Valence and Time interacted, $F(1, 63) = 89.16$, $p < .001$, $\eta^2_p = 0.59$: Participants endorsed more positive traits in the future ($M = 0.74$, $SE = 0.01$) than in the present ($M = 0.69$, $SE = 0.01$; $p < .001$, $\eta^2_p = 0.40$, and less negative traits in the future ($M = 0.22$, $SE = 0.02$) than in the present ($M = 0.31$, $SE = 0.02$; $p < .001$, $\eta^2_p = 0.51$). However, this was not especially the case for the self compared to the Other (no Valence by Time by Self-reference interaction, $F(1, 63) = 1.16$, $p = .295$, $\eta^2_p = 0.02$).

We found another four significant effects. Two of these depended on an additional factor and are not described further (main effect of Self-reference, $F[1, 63] = 9.07$, $p = .004$, $\eta^2_p = 0.12$; cut-off of $p = .00625$, and the interaction between Self-reference and Proximity of Other, $F[1, 63] = 35.72$, $p < .001$, $\eta^2_p = 0.36$, cut-off of $p = .0045$). Self-reference, Proximity of Other and Valence interacted, $F(1, 63) = 26.60$, $p < .001$, $\eta^2_p = 0.30$ (cut-off of $p = .005$). Participants attributed more negative traits to a group of people (*M* = 0.42, *SE* = 0.03) than to a close friend (*M* = 0.21, SE = 0.03), $p < .001$, $\eta^2_p = 0.33$. Group Other and Close Other did not differ for the proportion of positive traits considered reflective of the self ($p = 0.64$, $\eta^2_p < .01$; Group Other: *M* = 0.74, *SE* = 0.02; Close Other: *M* = 0.73, *SE* = 0.02) or the Other ($p = 0.463$, $\eta^2_p = .01$; Group Other: *M* = 0.68, *SE* = 0.02, Close Other: *M* = 0.71, *SE* = 0.02), or negative traits ($p = 0.181$, $\eta^2_p = .03$; Group Other: *M* = 0.2, *SE* = 0.02, Close Other: *M* = 0.24, *SE* = 0.02) endorsed for the self . Equally of note, participants endorsed more positive traits and less negative traits for themselves than the Other only in the Group Other condition (positive: $p = .008$, $\eta^2_p = 0.11$; negative: $p < .001$, $\eta^2_p = 0.57$), whereas there was no difference for positive and negative traits of the self compared to the Other in the Close Other condition (*p*s ≥ .223, $\eta^2_p \leq 0.024$).

Lastly, Self-reference, Time and Proximity interacted together, $F(1, 63) = 12.76$, $p = .001$, $\eta^2_p = .17$ (cut-off of $p = .0056$). In the Group Other condition, the proportion of yes responses was larger for the Other than the self both in the present ($p < .001$, $\eta^2_p = 0.42$; Other: *M* = 0.57, *SE* = 0.01; Self: *M* = 0.47, *SE* = 0.02) and in the future ($p < .001$, $\eta^2_p = 0.23$; Other: *M* = 0.53, *SE* = 0.01, Self: *M* = 0.47, *SE* = 0.01). In the Close Other condition, the proportion of yes responses was larger for the self than the Other in the present condition (the opposite of Group Other, $p = .003$, $\eta^2_p = 0.13$; Other: *M* = 0.45, *SE* = 0.01, Self: *M* = 0.5, *SE* = 0.02), whereas self and Other did not differ on the future task ($p = .813$, $\eta^2_p < 0.01$; Other: *M* = 0.46, *SE* = 0.01, Self: *M* = 0.47, *SE* = 0.01).

The other main effects and interactions were not significant (Time: $F[1, 63] = 5.85$, $p = .018$, $\eta^2_p = .09$, cut-off of $p = .007$ ; Self-reference*Time: $F[1, 63] = 0.11$, $p = .744$, $\eta^2_p < 0.01$, cut-off of $p = .05$; Valence*Proximity of Other: $F[1, 63] = 4.7$ , $p = .034$, $\eta^2_p = .07$, cut-off of $p = .01$; Time*Proximity of Other: $F[1, 63] = 0.71$ , $p = .403$, $\eta^2_p = 0.01$, cut-off of $p = .025$;

Valence*Time*Proximity of Other: $F[1, 63] = 1.87$, $p = 0.18$, $\eta^2_p = 0.03$, cut-off of $p = .0125$; Self-reference*Valence*Time*Proximity of Other: $F[1, 63] = 5.73$ , $p = .02$, $\eta^2_p = 0.08$, cut-off of $p = .008$)

## 4. Discussion

A primary goal of this study was to disentangle the effect of self-reference from the effect of temporal orientation on the LPC amplitude, an ERP correlate of episodic processes. Based on prior research, we expected a larger LPC amplitude in two instances: 1) thinking about one's own traits relative to other people's traits, and 2) thinking about future traits compared to current traits. Our results echo past findings: The LPC had a larger amplitude when participants thought about their own traits than those of other people (e.g., Kotlewska & Nowicka, 2016), and when evaluating future traits compared to present traits (Tanguay et al., 2018). Thus, this conceptual replication of Tanguay et al. (2018) was successful: Temporal perspective of knowledge can modulate the LPC amplitude. Importantly, the present study refines these previous findings by showing that the effect of taking a temporal perspective depends on the personal nature of that judgement. Thinking about another person's future traits could be associated with a reduced feeling of being transported through time and could be less dependent on the recollection or imagination of events (cf. evidence-based self-knowledge; Lieberman, Jarcho, & Satpute, 2004). If so, the effects of self-reference and temporal perspective on the LPC amplitude should interact. This is what we found: the effect of temporal orientation was specific to judging one's own traits, and not those of another person.

Another major aim of the study was to investigate the potential role of personal relevance by distinguishing two of its facets. The self can be the object of knowledge (i.e., it is about "me") or the self can be a "glue" linking different parts of knowledge (Sui & Humphreys, 2015), with some of its constituents more or less closely tied to oneself (e.g., through friendship). Our main findings regarding the selectivity of the effect of temporal orientation to the self on the LPC were not modified when the other person was close to self rather than a group of people. Therefore, to make an analogy inspired from Tulving (2005), the “mental time traveler” can embark on the journey to consider the traits of a future self, but cannot borrow another person’s mental time machine to travel to their future, even if it is a friend.

The modulation of LPC amplitude through the temporal perspective of the judgement cannot be attributed to characteristics of the traits or to task difficulty. Rather, only a slight difference in instructions distinguished the conditions, which appear responsible for differences in LPC amplitude. The instructions produced the desired cognitive orientation: Participants reported feeling “transported into the future” in the future condition more than the present condition. Participants also thought more about their self during the tasks regarding their own traits than the tasks regarding the Other. Framing the Other task as pertaining to a friend rather than a group of people successfully increased the other’s proximity to the self. These manipulation checks strengthen the interpretation of the effects on the LPC amplitude as stemming from self-reference, temporal perspective, and proximity of the Other to the self, respectively.

Therefore, the personal and temporal aspects of knowledge influenced LPC amplitude, but how does these findings relate to prior work suggesting that LPC amplitude is an index of recollection? Notably, in our previous study, we found that LPC amplitude of future self-knowledge was not significantly different from episodic recognition. Comparatively, present self-knowledge had a significantly smaller LPC amplitude than episodic recognition (Tanguay et al., 2018). Similarly, in the current study, we found a significantly larger LPC amplitude when thinking about one's own future traits than present traits. The current findings regarding the LPC adhere to the patterns predicted if episodic processes contributed to trait knowledge: maximal for the self and for thinking about the future. If LPC amplitude tracked the recollection or imagination of events, one would also expect ratings reflecting greater recollection or imagination in the future self condition than the Other conditions. The results for that rating were mixed. On the one hand, we did not observe a higher rating for the future self compared to other conditions. On the other hand, participants recalled or imagined more events when thinking about a close friend than a group of people, as anticipated. Consequently, the behavioural data do not fully support the idea of an increased reliance on episodic processes when thinking about the future self. A few experimental considerations must nuance this finding. Participants rated their recollection or imagination once at the end of each condition and not on a single trial basis; this measure may represent an approximative rating of all the traits whether positive or negative and endorsed or rejected. Moreover, the rating focused on frequency of recollection or imagination (i.e., how much) rather than richness, which may have been crucial in driving differences in LPC amplitude (e.g., the number of details influence the LPC amplitude; Vilberg & Rugg, 2009). Lastly, not all episodic processes must be conscious (Renoult, Irish, Moscovitch, & Rugg, 2019). Some episodic processes could be implicit (e.g., associative, contextual processing; Bar & Aminoff, Duss et al., 2014) or by-products of episodic memory (e.g., confidence, Wynn, Daselaar, Kessels, & Schutter, 2019; other interpretations are discussed below).

**4.1 Distinctions when Thinking about the Future of the Self versus Other(s)**

Our LPC findings are consistent with behavioural data showing that predictions about traits and preferences differ when they concern the self versus other people (Bauckham et al., 2019; Kanten & Teigen, 2008; Renoult, Kopp, et al., 2016). That is, our findings (together with Tanguay et al., 2018) suggest that thinking about future traits engages episodic processes, but only for the self. This difference in the underlying cognitive processes may confer advantages in certain cases, and disadvantages in others. For instance, thinking about future facts in relation to others – when these can reasonably be inferred from context - seems to improve predictive accuracy. For example, young children mistakenly indicate that they will prefer Kool-Aid over coffee as adults, but can better predict that another child (of the same age and sex) will shift his/her preference to adult-preferable items (e.g., coffee) when older (Bélanger, Atance, Varghese, Nguyen, & Vendetti, 2014; Lee & Atance, 2016). Adults follow the same pattern by predicting more change in others' future preferences as compared to their own (Bauckham et al., 2019; Renoult, Kopp, et al., 2016). The possible reduced engagement of episodic processes when thinking about others may allow children and adults to foresee future preferences (and traits) more accurately. In the absence of full information, the best model for predictions is the mean, and that is what semantics might represent (e.g., typical life trajectories or personality changes). This stance can be integrated with findings on present-oriented knowledge: it may rely on an existing knowledge base to a larger extent than future-oriented knowledge, with regularities being already computed from multiple experiences. Yet, semantics may not always be beneficial when making predictions about other people's futures. For example, a reduction in episodic processes might bias decisions towards normative behaviour and cultural scripts thus leading to decisions that are insensitive to another person's personal history and idiosyncratic preferences. Further research could explore the practical implications of our findings and test whether interventions could increase the proximity to self, so the other is "incorporated" within the self, in those contexts in which it is appropriate to do so (e.g., in surrogate decision making; Tunney & Ziegler, 2015).

**4.2 Are Episodic Processes Necessary to Think about Future Traits?**

Our findings indicate that the temporal orientation of self-knowledge can modulate the LPC amplitude, a correlate of recollection, but this does not mean that episodic memory is necessary to think about future traits. After all, people can judge the future traits of other people with enough accuracy to predict changes from the present to future, which suggests that people with a memory impairment could rely on semantics to make a prediction about a future self (Palombo, Keane, & Verfaellie, 2016). If so, why might episodic processes be involved in future self-knowledge (apart from the shared component processes)? Previous research shows that people with amnesia can possess knowledge about future public events (e.g., main issues in the next 10 years; Andelman, Hoofien, Goldberg, Aizenstein, & Neufeld, 2010; Klein, Loftus, & Kihlstrom, 2002; Race, Keane, & Verfaellie, 2013). However, amnesic patients provided less detailed explanations regarding these anticipated events than healthy controls, even though the healthy controls usually resorted to other semantic details in their elaboration, and narrative ability was not at play (Race et al., 2013). Further, people with amnesia sometimes generate fewer personal facts that contain a spatial or temporal context (Damasio, Eslinger, Damasio, Van Hoesen, & Cornell, 1985; Grilli & Verfaellie, 2016). Common to the studies just described is a weakening of dense representations, even when those are presumably semantic. Following Craik (2002), we could conceptualize general semantics and episodic memory as extremes on a continuum of contextual details (from no details to very detailed; see also Cabeza & St Jacques, 2007; Jacoby & Craik, 1979), with self-knowledge being in an intermediate zone (Renoult et al., 2012) and even closer to episodic memory when future-oriented. Processes associated with episodic memory could provide the "resolving power" (to borrow a term from Craik, 2002) and the flexibility (Suddendorf & Corballis, 2007) to form a high resolution representation of the personal future. Further, episodic processes appear engaged in semantic tasks when they become open-ended, wherein facts are not immediately accessible or well defined (Sheldon & Moscovitch, 2012). The future is naturally open-ended – it is fluid - hence episodic processes may also be recruited when a presumably semantic task is future-oriented. The representation of the future would ground and enrich the images of the (many) possible selves. Our ideas in this respect are consistent with Tulving's conceptualization of episodic memory as evolving from and interacting with semantic memory (reviewed in Renoult et al., 2019).

The self usually maintains a sense of unity and temporal continuity even though the fragments from the past, present and future selves could form a disparate mosaic for a dispassionate observer (Prebble et al., 2013). According to a recent model of sense of self, both semantic memory and episodic memory may contribute to this sense of self-continuity (Prebble et al., 2013). In particular, autonoetic consciousness simultaneously integrates the past, present and future (Wheeler et al., 1997) and is an antecedent of the self-continuity derived from episodic memory (Prebble et al., 2013). Although semantics could suffice to predict future traits, as the model suggests and as discussed above, episodic memory may provide flexibility to interpret and reinterpret our perception of who we are across temporal contexts, providing a sense of coherence. The future self may be particularly context-dependent and flexible because of the multiple versions of the possible selves that can be constructed (Markus & Nurius, 1986; Oyserman & James, 2014) and the largely unconstrained future (Manning, 2016). Further, the space for reinterpretation could stem from episodic counterfactual thinking (de Brigard, Addis, Ford, Schacter, & Giovanello, 2013). The modification of past events would enable the exploration of changes in the expression and relevance of traits. This putative function of episodic memory in future self-knowledge, to sustain a sense of self-continuity, would also explain its seemingly greater involvement for the self than others, for whom it might not be necessary to maintain a sense of coherence (or for whom it might be less demanding, having less information).

In contrast to episodic memory, semantics can appear rigid: The concept of a dog is constituted of core features that can generalize to each newly encountered dog, but we can combine semantic and episodic details flexibly to imagine adopting a new dog (e.g., small or big dog, in a home or in a shelter). Nevertheless, research refutes the notion that semantics are rigid; for instance, context can influence the processing of semantics. The processing of a word's meaning depends on the sentence, the previous word, and repetition (reviewed in Kutas & Federmeier, 2011; Renoult & Rugg, 2020). In a similar fashion, social psychology demonstrates that context can shape self-knowledge. For example, we perceive ourselves as more similar to another person after having rated that person's traits and physical characteristics (than before making these ratings; Meyer et al., 2019). The effect of context (e.g., preceding tasks) on knowledge can have a prolonged effect (e.g., 24 hours; Meyer et al., 2019). Our behavioural data coheres with an interaction between social and temporal perspectives. Like other studies, participants displayed the "self-enhancement effect" in their behavioural responses (Kanten & Teigen, 2008; Tanguay et al., 2018; Wilson & Ross, 2001) when thinking about a group of people; that is, they perceived having more favourable traits than their peers in general. Participants also anticipated their traits would improve through time. These behavioural differences are possibly reflected in the significant order effects that we found for the LPC amplitude (reported in Supplementary material 5.7). Of note, the Self-reference effect on the

LPC amplitude was strongest - and only significant - when the Other tasks came before the Self tasks, whereas the Time effect was observed only when the present tasks preceded the future tasks. The first task could act like an “anchoring” for the subsequent judgements (Chambers & Windschitl, 2004). Importantly, we counterbalanced the order of the tasks, and the effects of Self-reference and Time were still significant when controlling for order. Hence, order effects do not explain our main findings. The behavioural data and order effects support the claim that self- and other-knowledge are flexible and interrelated in nature. Similar to other types of semantics, self-knowledge about the current self seems sensitive to context, which can lead to the blurring of its boundaries with other-knowledge and knowledge about the extended self.

**4.3 Does the valence of traits explain the findings regarding the LPC amplitude?**

Cultural scripts suggest that we improve through time (Krueger & Heckhausen, 1993). This introduces a difference in the preponderance of positive and negative traits that are endorsed when considering the present and future (in our study and others). Therefore, a possibility might be that a larger number of positive traits attributed to the future self explains the effect of temporal orientation. The Close Other condition speaks to this alternative explanation because the proportion of endorsed positive and negative traits did not differ between the future self and the future Other. Despite this statistical equivalence, the effect of temporal orientation on the LPC amplitude was smaller and non-significant when thinking about a close friend. Moreover, in follow-up analyses, we added the factor of Valence together with the key independent variables (i.e., self-reference, time, proximity of Other) to test whether valence influenced the LPC amplitude. The effect of temporal orientation on the LPC amplitude did not depend on the valence of the traits (all interactions including the factors of Valence and Time were not significant, nor was the main effect of Valence; see Supplementary material 5.10 for the full details). In fact, negative traits have been shown to elicit a larger positive amplitude than positive traits, a pattern opposite to what we would expect if valence explained our findings (see Luo et al., 2013, for a study on valence and temporal orientation). The valence of the traits thus cannot account for our findings.

### 4.4 The Magic of Mental Time Travel

For all of us, innumerable thoughts about the future occur every day; these range from mundane to momentous events, and can also entail developing plans that will benefit our future selves. For the authors of the present paper, many of these instances trigger a fascination for episodic memory, a faculty whose magic has been articulated by Endel Tulving (e.g., mental time travel, autonoetic awareness, chronesthesia).

In the present study, we re-examined whether some of the magic of episodic memory might also occur in an intermediate zone of declarative memory; that is, when knowledge concerns the self (i.e., personal semantics). The premise of the study lies in the grey area where distinctions between episodic and semantic memory become blurred: self versus other, chronesthesia (subjective sense of time) versus chronognosia (knowledge about time; akin to the “lived time” vs. “known time” of Klein, Loftus, & Kihlstrom, 2002), and an experience of the self as evolving through time versus self as timeless (Tulving, 2002b, 2002a, 2005). We found that LPC amplitude is larger when thinking about one’s own future traits compared to current traits, and that the temporal orientation effect interacts with self-reference. Whereas thinking about the future self elicited a larger LPC amplitude than thinking about the present self, this effect of temporal orientation was smaller (and not significant) when thinking about others. The subjective ratings, in addition to the ERP data, suggest that self-reference increases the engagement of component processes typically associated with episodic memory (e.g., temporal orientation, recollection/imagination), but self-reference itself does not align with the LPC effect.

Together, our findings, like others, underscore the privileged interaction between personal semantics and episodic processes (Grilli & Verfaellie, 2016; Renoult et al., 2015; Tanguay et al., 2018), in this case, when the personal knowledge pertains to the distant past or future. Future studies should continue to delineate whether similar factors dictate the engagement of episodic processes for events and future self-knowledge, e.g., self-reference (de Vito et al., 2012; Grysman et al., 2013; Verfaellie et al., 2019), temporal distance (e.g., Addis & Schacter, 2008) and the temporal specificity of the context (e.g., anticipated lifetime periods, general events or specific events; D'Argembeau, 2015; Renoult et al., 2012; Thomsen, 2015). In future research, subjective ratings could be obtained on a trial-by-trial basis to test their association with modulations of the LPC amplitude. Further, it would be desirable to dissociate contributions of chronesthesia (i.e., subjective sense of time) and chronognosia (i.e., knowledge about time, Tulving, 2002a) or episodic and semantic details.

In the meantime, as we ponder the future – including the many possible studies that could follow from the present one– we can be certain that the work of Endel Tulving will continue to provide inspiration.

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**Highlights**

- Endel Tulving has distinguished between episodic and semantic processes
- Participants judged their current/future traits and those of a friend or a group
- Late Positive Component (LPC) amplitude reflects episodic processing
- Future traits elicited a larger LPC than present traits, but only for the self
- A semantic task can involve episodic processes when personal and future-oriented