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HOW TO DATE FUTURE EVENTS? COGNITIVE PROCESSES SUPPORTING THE TEMPORAL LOCATION OF AUTOBIOGRAPHICAL EVENTS IN HEALTHY INDIVIDUALS AND IN SCHIZOPHRENIA

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“Let any one try,

I will not say to arrest, but to notice or attend to, the *present* moment of time. One of the most baffling experiences occurs. Where is it, this present? It has melted in our grasp, fled ere we could touch it, gone in the instant of becoming”

William James, (1890). The Principles of Psychology (p. 608)

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Be cool, eat moules

ABSTRACT

The aim of this thesis was to investigate the processes involved in the temporal location of personal future events in healthy individuals and in patients with schizophrenia. To do so, we used a think-aloud procedure in three experimental studies to analyse the strategies used to determine the times of autobiographical events. In Study 1, we found that participants mostly used reconstructive/inferential processes to date events. They relied most frequently on autobiographical knowledge (i.e., lifetime periods/extended events) and general knowledge to reconstruct or infer the times of events, both for past and future events. In Study 2, we found that personal goals influenced the temporal location process by increasing the direct access to the times of important future events, and by favouring the use of autobiographical knowledge to infer the times of events when dates are not directly accessible. In Study 3, we found that patients with schizophrenia had difficulties to rely on episodic information to reconstruct or infer the times of personal events, and made more errors when they were asked to temporally order the previously dated events. Based on these novel findings, we propose a dual-process model of the temporal location of autobiographical events that articulates the cognitive mechanisms engaged in the dating of past and future events.

RÉSUMÉ

L’objectif de cette thèse était d’étudier les processus impliqués dans la localisation temporelle des événements personnels futurs chez les sujets sains et les patients atteints de schizophrénie. Pour cela, nous avons utilisé la méthode de réflexion à voix haute dans trois études expérimentales pour analyser les stratégies utilisées pour déterminer la localisation temporelle des événements autobiographiques. Dans l’Etude 1, nous avons constaté que les participants utilisaient principalement des processus de reconstruction/d’inférence pour dater les événements. Ils s’appuyaient le plus souvent sur des connaissances autobiographiques (c.-à-d., des périodes de vie/événements étendus) et des connaissances générales pour reconstruire ou inférer le moment des événements, à la fois pour les événements passés et futurs. Dans l'Etude 2, nous avons constaté que les buts personnels influençaient le processus de localisation temporelle en augmentant l'accès direct à la date des événements futurs importants et en favorisant l'utilisation de connaissances autobiographiques pour inférer le moment des événements lorsque les dates ne sont pas directement accessibles. Dans l’Etude 3, nous avons constaté que les patients atteints de schizophrénie avaient des difficultés à s’appuyer sur des informations épisodiques pour reconstruire ou inférer la date des événements personnels, et qu’ils commettaient davantage d’erreurs que les participants témoins lorsqu’on leur demandait de classer dans l’ordre chronologique les événements précédemment datés. Sur la base de ces nouvelles découvertes, nous proposons un modèle à double processus pour la localisation temporelle des événements autobiographiques qui articule les mécanismes cognitifs engagés dans la datation des événements passés et futurs.

TABLE OF CONTENTS

PREFACE

As human beings, we are able to mentally travel back in time to remember personal events. We can remember what happened, where and when. However, our memories are not exact records of what actually happened, and the temporal locations of events are often wrong or imprecise (Thompson, Skowronski, Larsen & Betz, 1996). Try to think about some past experiences that happened only once in your life. Although the exact dates of important events may be immediately available (such as one's graduation, wedding, or children's birth), you may find it hard to remember the exact dates of other events. To determine when past experiences occurred, we frequently use various information to infer or reconstruct their temporal location, rather than directly accessing to dates. For instance, we may know the life period during which the event happened (e.g., during my high school years) or recall another event for which we know the date and that can be used as a temporal landmark (e.g., it happened one week after the day of my car accident).

While memory for the times of past events has attracted much attention, little is known about how envisioned future events are located in time. Understanding how we locate imagined events in time is important to determine the mechanisms involved in the anticipation of future times. Research focusing on future-oriented mental time travel has attracted much interest in cognitive neuroscience and psychology. To date, however, little is known about the processes involved in the temporal location of future events. While numerous findings show that remembering the past and imagining the future share similarities (for instance, in their functions and contents) and recruit a common neural network, it is still unknown whether similar temporal location processes are used to determine past and future times.

In this context, the first aim of my thesis was to unravel the processes involved in the temporal location of envisioned future events. To this end, in a first study, we compared the temporal location processes used to date past and future events. Then, in a second study, we examined the influence of personal goals in the dating of future events. The second aim of my thesis was to determine whether an alteration of temporal location processes might be involved in the difficulties experienced by individuals with schizophrenia to envision the future and to engage in successful goal pursuit. Schizophrenia is a severe mental disorder that impacts the life trajectory of individuals at an important period during which personal goals are set up. The ability to envision future events at particular points of time and to organize them temporally may be critical for successful goal pursuit. Understanding how individuals with schizophrenia represent and anticipate the future may help both physicians and psychologists to improve therapeutic cares and may help patients better anchor their life projects.

To address these questions, I will first describe the theoretical background (Part I) that will help to understand and discuss our experimental findings (Part II). In Chapter 1, I will describe how time is represented in autobiographical memory, and discuss the cognitive processes that allow one to date memories. In Chapter 2, I will define episodic future thinking and review current knowledge about time representation in future-oriented mental time travel. In Chapter 3, I will briefly describe the symptoms of schizophrenia and detail the nature of patients' difficulties in remembering the past and imagining the future. In the experimental part (Part II), Chapter 4, I will present the aims of my thesis, the hypotheses in relation to the scientific literature, and the results of our studies. Finally, in Chapter 5, our findings will be discussed.

PART I.

THEORETICAL BACKGROUND

CHAPTER 1

THE REPRESENTATION OF TIME IN AUTOBIOGRAPHICAL MEMORY

A definition of time

Time in models of autobiographical memory organization

Memory for the times of past events

Reconstruction of the times of past events

Summary

A definition of time

Although we are all familiar with time, the concept is not easy to formally define. Dictionaries provide different definitions that may help to understand what time actually is. Time is defined as: “the indefinite continued progress of existence and events in the past, present, and future regarded as a whole” (Oxford Dictionary); “the continuous passage of existence in which events pass from a state of potentiality in the future, through the present, to a state of finality in the past” (Collins Dictionary); “as the measured or measurable period during which an action, process, or condition exists or continues”, or “as a nonspatial continuum that is measured in terms of events which succeed one another from past through present to future” (Merriam-Webster Dictionary); “the part of existence that is measured in minutes, days, years, etc.” (Cambridge Dictionary).

From these definitions, we understand that time may be something ongoing, and may represent the course of existence. It can be measured in terms of the succession of events or in terms of physical units (e.g., minutes, days, years). Centuries ago, humans invented several instruments to measure time based on the observation of periodical changes (e.g., shadow movement, seasons, moon cycle). Today, and in everyday life, we can measure time precisely using clocks (for the timing of events within a day) or calendars (for the timing of events lasting more than a day).

The ability to apprehend time allows us to date past events, to order events, and to envision when future events will likely happen. Time is thus somehow closely linked to memory. In this chapter, we will try to answer the following question: how are we able to remember when past events occurred?

Time in models of autobiographical memory organization

Humans have the remarkable ability to mentally travel backward to remember personal experiences and forward to envision personal experiences that could happen in the future (Tulving, 2002). In his pioneer reflection on the organization of memory, Tulving referred to *episodic memory* as memory for personal experiences, along with their temporal and spatial contexts of occurrence (Tulving, 1972). In other words, "episodic memory receives and stores information about temporally dated episodes or events, and temporal-spatial relations among these events" (p. 385). He distinguished *episodic memory* from *semantic memory*; the latter referring to "a mental thesaurus, organized knowledge that a person possesses about words and other verbal symbols, their meaning and referents, about relations among them, and about rules, formulas, and algorithms for the manipulation of these symbols, concepts and relations" (p. 386). Tulving added that "information stored in the semantic memory system represents objects—general and specific, living and dead, past and present, simple and complex-concepts, relations, quantities, events, facts, propositions and so on" (p.389). Contrary to episodic memory, semantic memory is detached from an "autobiographical reference", which means that it does not encode and store the temporo-spatial context of the acquisition of semantic knowledge. For example, I cannot remember the occasion during which I learned that Paris is the capital of France, I simply know this fact.

Tulving noted that "each experienced event always occurs at a particular spatial location and in a particular temporal relation to other events that already have occurred, events occurring simultaneously with it, or events that have not yet occurred" (p. 388). He assumed that the temporal relations among these experiences are somehow represented as "properties" in the episodic memory system. This implies that we are able

to remember when a past experience happened, in relation to other lived experiences. In episodic memory, the temporal location of an event is not necessarily expressed in clock or calendar terms, but it can be recorded in reference to temporal occurrences of other events "in some as yet little understood manner" (p. 388). On this view, episodic memories (at least for the recent past) are somehow organized in terms of chronological sequences.

It has been argued, however, that most episodic memories are no longer accessible after a few days, implying that the organization of events in chronological sequences may not be long-lasting (Conway, 2009). To be maintained for a longer time, episodic memories have to be integrated into a long-term autobiographical knowledge structure. This autobiographical knowledge, which contains more abstract representations of our past (e.g., lifetime periods and general events) along with long-term goals, provides a personal context to episodic memories and allows one to locate them in one's life story. Episodic memories, in turn, provide specific evidence (i.e., sensory, perceptual or affective records derived from past experiences) for this conceptual framework.

Autobiographical knowledge plays a key role in the organization of specific memories. Indeed, according to hierarchical models (Conway, 2005, 2009; Conway & Pleydell-Pearce, 2000), autobiographical memory relies on a knowledge base that comprises three broad classes of information: conceptual knowledge about features (e.g., others, locations, activities, personal goals) that characterized broad lifetimes periods (e.g., "when I was at University"); summary representations of repeated events (e.g., "sundays at Grandma's house) or events extended in time (e.g., "my week-end in Paris"), together referred to as general events; and episodic memories which are themselves constituted by episodic details that represent components of a specific past experience, often in the form of visual images (e.g., "an image of one's child walking for the first

time"). Autobiographical memory is hierarchically organized in partonomies, in which specific events are part of general events which are themselves nested in lifetime periods. On this view, higher-order autobiographical knowledge (e.g., lifetime periods) contextualizes specific memories in someone's personal life and contributes to temporally organize autobiographical events.

Lifetime periods, in particular, may contain temporal knowledge that could be useful to place specific events in time. A lifetime period is defined as "a representation that contains knowledge about goals, others, locations, activities, evaluations that were common to that period" (Conway, 2005, p. 608). Lifetime periods are subjectively delimited, and people can perceive their beginnings and endings (Thomsen, 2015). They can be hierarchical or nested, with more abstract and longer lasting autobiographical periods (e.g., living in Strasbourg) including less abstract and shorter periods (e.g., doing my PhD). They can also be chronological, causally related or parallel to each other (Thomsen, 2015). There is evidence that people frequently rely on lifetime periods to date past events (Thompson et al., 1996; Thompson, Skowronski & Betz, 1993; Friedman, 1987), suggesting that knowledge about periods may play an important role in the temporal organization of specific autobiographical memories (see the following section for more details about the role of lifetime periods in temporal location processes).

What is guiding the construction and organization of lifetime periods? According to the Self-Memory System (Conway, Singer & Tagini, 2014), the conceptual self (which consists of abstract knowledge about one's goals, beliefs, attitudes, values, and so on) informs and constrains autobiographical knowledge and can, in particular, influence the content and organization of lifetime periods (and their connection with episodic memories) to keep a coherent view of one's self across time and corresponding to current goals. "For instance, an individual who held a view of himself as 'practical' instead of

‘intellectual’ might have a lifetime period representation of his time at university as being largely negative. General event and specific episodic memories might be preferentially available to confirm this belief” (Conway et al., 2004, p. 500).

Another view—referred to as Transition Theory—assumes that the content and organization of autobiographical memory mirror the structure of experience and reflect the operation of more basic memory processes (i.e., repetition, co-occurrence, distinctiveness of experiences), without involving the existence of higher-order autobiographical knowledge (e.g., representations of self and goals; Brown, Schweickart & Svob, 2016). According to this theory, transitions play a major role in the organization of autobiographical memory. Transitions are defined as an event (or a set of events) that produce an enduring change in the fabric of daily life, which can be collective (e.g., wars) or personal (e.g., relocation). Transitions that bring a sudden change in the environment (for instance, regarding people, locations, or activities) will delimitate the beginnings and ends of identifiable lifetime periods. Lifetime periods are thus constituted by networks of events that are causally, thematically or temporally associated, and the boundaries of periods can be used, for instance, to infer when past events happened.

Whatever the exact mechanisms underlying their formation, lifetime periods may play important roles in the capacity to locate and organize past events in time. The term *autobiographical memory* itself may imply the metaphor that “memory is like a narrative of one’s life, organized by chronology, much as the sequence of chapters and pages of a book might reflect the order in which the events of a life unfold” (Friedman, 2001, p. 139). However, remembering lifetime periods may not be the only way of temporally locating past experiences in time. Indeed, several mechanisms may be involved in the ability to remember when past events occurred, which are detailed in the following section.

Memory for the times of past events

Personal events are often remembered with at least a sense of when they happened. Following an extensive review of studies on temporal location processes, Friedman (1993, 2004) argued that memory for personal events may not be chronologically organized. Instead, personal memories are more like "islands in time" (Friedman, 2001, p.139), and their temporal location may rely on a combination of processes, most notably the reconstruction of past times. There may not be a special system for assigning temporal codes to specific memories. Instead, to remember when events happened, people most frequently reconstruct or infer temporal information from whatever available information is associated with them. In this process, people are especially adept at remembering *locations* (in other words, points of time) in the many temporal patterns that structure their lives (for example, calendars), but some information about the *order* of related events, *distances* and specific dates is also available and contributes to determine the times of past events.

To understand how we are able to remember when personal events occurred, Friedman (1993, 2004) reviewed existing theories and categorized proposed mechanisms according to three types of temporal information: distances, locations and order. *Distances* refer to the amount of time that has elapsed between a particular event and the present, which can be understood through the spatial metaphor that is implicit in its term. Distance-based processes give rise to the impression that an event happened a long time ago or recently. For example, someone may have the impression that an event happened a long time ago, maybe more than ten years ago. According to some distance-based theories, the representation of events is automatically encoded in memory by their order of occurrence, and this representation could then be used to determine how far away in

time an event was from the present (Koffka, 2013; Murdock, 1974). Other theories postulate that changes in the properties of memory representations (such as their strength or amount of details) with the passage of time can be used as a clue to determine how long ago the events occurred (Hinrichs, 1970; Brown, Rips & Shevell, 1985).

Locations refer to particular points in conventional (e.g., parts of day, months, years), natural (e.g., seasons), or personal (e.g., lifetime periods) time patterns. Examples include recalling that an event happened on a weekend, during winter, or when I was in college. Two main theories on temporal locations have been proposed. First, time-tagging theories (Flexser & Bower, 1974; Hasher & Zacks, 1979) assume that time information is uniformly and automatically associated to the event at encoding. In other words, time information is part of the memory representation and can be directly retrieved. This automatic process may thus imply, for instance, that we could date every remembered personal event in a directly manner. However, these time-tagging theories do not specify the nature of the temporal information that is assigned to the event, such that the mechanisms involved remain unclear. On the other hand, reconstructive theories (Thompson et al., 1996; Thompson et al., 1993; Friedman & Wilkins, 1985; Friedman, 1987; Shum, 1998; Skowronski, Betz, Thompson & Larsen, 1995) postulate that people judge the times of past events by using other information that is available when remembering. According to this view, temporal locations are often not intrinsic properties of memories but are inferred or reconstructed using contextual details associated with an event (i.e., persons, places, activities, or any other content) and general knowledge of time patterns and events of one's life (e.g., knowledge of autobiographical periods or specific landmark events). Unlike time-tagging theories, there is no assumption that temporal information is assigned to the event at encoding. Rather, the information used to infer or reconstruct the times of past events may evolve across time and new life experiences.

Finally, *order* refers to the before-after relations between events, which can be used to place events relative to each other. According to order theories, an order code is automatically created in memory and can later be accessed to determine which of two events occurred earlier. Although these theories may explain how people can judge the order of meaningfully related events, they do not explain how they are able to judge the order of unrelated events. Empirical findings showed that order accuracy did not differ between related and unrelated events, which does not support the view that order information is automatically created and encoded at the time of encoding (Friedman, 2007).

Reconstruction of the times of past events

Although distance and order processes may be partly involved in the ability to date past events, people are especially adept at determining the temporal locations of past events. Extensive research has been made to identify the types of information that people use to locate past events in time. Friedman (1987) asked ninety-nine participants to date (according to different time scales, i.e., year, month, day of month, day of week, hour) an earthquake that occurred nine months earlier (and that they personally experienced), and to list the things that they thought of during the time estimation. The strategies reported were classified into eleven categories of dating method, and percentages of use of each category were computed for each time scale. Friedman found that the majority of participants did not retrieve the date directly (less than 10% of events for all time scales), but instead inferred the time of the earthquake from other information. The dating strategy based on the judgement of event distance relative to the present time (i.e., how many years ago the event happened) were common only for the year scale. Furthermore, the strategies involving a reconstruction of the date from information recalled about the experience (e.g., by relating the event to a routine, to another event whose time was recalled, to the weather or clothing) were predominant for the hour (87%), month (80%), and day of the week (72%), and were common for the day of the month (39%) and year (36%).

Using subjective reports of memory strategies, Thompson et al. (1993) asked 63 undergraduate students to date a series of personal events that had been recorded in a diary. Participants had to specify the strategy (only one) used according to a list of seven categories, as follows: exact date was known, specific reference to another event, general time period (e.g., summer) was known, estimated number of intervening events since the

event being dated, clarity of memory, prototypical temporal information (i.e., the typical day, week or month in which an event occurs), and guess. They found that participants most frequently reported using personal periods (e.g., the final part of a semester, a vacation in Europe) to infer when past events occurred (this strategy was used for 29% of events). They also frequently referred to linear landmarks (i.e., reference events that do not occur in every temporal cycle; for 22% of events) and to cyclic landmarks (e.g., always bowl on Wednesdays, mother's birthday; for 13% of events). Only 18% of events were directly located in time. Interestingly, they further found that the use of dating strategy was a significant predictor of dating accuracy, showing that date estimations were more accurate when participants thought they remembered the exact date. The estimations were fairly good when participants used a reference to other events, and intermediate when they relied on the knowledge of periods, intervening events, memory clarity, and prototypic dating (remembering the day, week or month). As expected intuitively, guessing yielded the lowest level of dating accuracy. It is worth noting that the temporal distance of events was relatively short in that study, ranging from 2 days to 10-15 weeks (70-105 days).

Using the same method, Skowronski et al. (1995) added support to the view that people most frequently used periods (for 37% of events) and cyclic (9%) and linear (19%) landmarks to date events from their recent past (between 1 and 100 days into the past). Moreover, a similar percentage (compared to Thompson et al.) of direct dating was reported (21%). Regarding middle (100 days to 1 year) and long (more than 1 year ago) retention intervals, they found a substantial decrease of direct dating and use of landmarks, with corresponding increase in the use of personal periods (58% for middle term, 56% for long term) and in pure guessing (12% for middle retention time, 21% for long retention time). They also assessed the accuracy of dating for each strategy and found

that, at the longest retention time, 72% of events were dated exactly when participants reported having used a direct dating (i.e., with no use of any strategies). This dropped to 32% of events when they used cyclic landmarks, to 25% for linear landmarks, and to 10% for personal periods.

Brown and his colleagues conducted several studies in which they did not use a subjective report of dating strategies, but asked participants to verbalize their thought flow while dating events (think-aloud procedure; Fox, Ericsson & Best, 2011). Participants' thought flow was recorded, transcribed and then analyzed to determine which information (or strategies) was used to determine the times of past events. Brown and colleagues were particularly interested in studying the "living-in-history effect", which refers to the "frequent use of public events and historical periods to date personal events" (Brown et al., 2016, p. 260). Their studies showed that people frequently mentioned both personal (e.g., when I first went to the USA) and public (e.g., during the war) periods when attempting to locate specific past events in time (Brown, 1990; Brown et al., 2016; Zebian & Brown, 2014).

In addition to the important role of personal periods, knowledge about meaningful events (e.g., university graduation) can be used as reference points to infer or reconstruct the times of past events (Shum, 1998; Thompson et al., 1993; Skowronski et al., 1995, Friedman, 1987). These meaningful events, also known as temporal landmarks, can be vivid personal events (such as first experiences), personal or cultural reference points in the calendar (Shum, 1998), and beginnings and/or endings of lifetime periods (Thomsen, 2015). In a pilot study, Shum asked Northwestern University students to list from four to five landmarks; 255 students answered the questionnaire in September at the beginning of the school year, and 262 in January after they completed the first quarter at University. To be considered as temporal landmarks, events had to fulfill three requirements: they

had to involve the participant personally, to be personally important, and to act as points of reference in the personal history of the participant. Shum found that the most frequently recalled temporal landmarks were academic-based events: high school graduation (reported by 50% of students), and acceptance at University (reported by 28.5% of students), for the two time periods. The list of temporal landmarks also included predictable events on calendar (e.g., birthday, prom, graduation), less predictable events (e.g., broke up with significant other, death of a friend), and first experiences (e.g., first day at university, met significant other for first time).

Summary

In the present chapter, we examined how people remember when past events occurred. Research has shown that several processes give rise to the sense of past times. Information regarding locations, order and distances of events all contribute to build a representation of the past. However, people are especially adept at determining the temporal locations or dates of past events. To do so, they mostly reconstruct or infer the times of events by remembering any other available information (e.g., lifetime periods, contextual details) that would help to remember when the events occurred, rather than directly access to their dates. The preponderance of reconstructive processes for temporal location of personal events suggest that time may not be embedded in memory representation.

CHAPTER 2

THE REPRESENTATION OF TIME IN FUTURE-ORIENTED MENTAL TIME TRAVEL

What is episodic future thinking?

The sense of future times

Time in models of episodic future thinking

The role of personal goals in episodic future thinking

Summary

What is episodic future thinking?

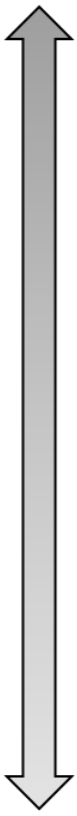
As human beings, we are able not only to mentally travel back to past times to relive previous experiences, but also to travel forward to future times, to "prelive" imagined experiences (Suddendorf & Corballis, 1997, Tulving, 2002). First coined by Atance and O'Neill (2001), the term *episodic future thinking* was defined as "the ability to project the self forward in time to pre-experience an event" (p. 537). Built upon Tulving's conception and distinction between episodic and semantic memory systems (Tulving, 1972, 1985), these authors assumed that we can use both episodic and semantic modes of future thinking. As for the representation of the past, we are able to pre-experience the details of specific future events, and also to use general or semantic information (e.g., event scripts) to predict future occurrences.

We experience many future-oriented thoughts in our daily life. D'Argembeau, Renaud and Van der Linded (2011) found that young adults experienced on average 59 future-oriented thoughts during a typical day, which roughly corresponded to experiencing one future-oriented thought every 16 minutes (considering 16 hours of awake time). It was found that these future-oriented thoughts involved different representational formats (more or less abstract or specific), embraced various thematic contents (e.g., leisure activities, work, relationships), were more frequently positive than negative, and served a range of functions (e.g., action planning, decision making). Interestingly, temporal distance influenced the characteristics of thoughts, with thoughts referring to the near future (i.e., later the same day or during the next few days or weeks) being more specific and serving action planning to a greater extent than thoughts referring to the far future (i.e., in several months or years).

Episodic future thinking is just one of several forms of future thinking. Szpunar, Spreng and Schacter (2014) recently proposed a taxonomy that distinguishes episodic and semantic forms of four modes of future thinking: *simulation*, *prediction*, *intention* and *planning* (see Table 1, for definitions of each mode). According to these authors, the modes of future thinking interact with one another to support prospective cognition. For example, simulating the steps towards a specific outcome or goal may be useful for an efficient planning of these steps. Most studies focusing on episodic future thinking involved the episodic simulation mode, which is defined as the construction of a mental representation of a specific personal future event (e.g., a meeting with a friend that will take place next week). Extensive research over the last decade has shown that episodic future thinking and episodic memory are closely linked and share (at least partly) common cognitive and neural mechanisms (for reviews, see D'Argembeau, 2012; Schacter et al., 2012; Szpunar, 2010)[1].

[1] Although the representation of past and future events shares similarities with regards to their contents, functions and cognitive mechanisms, there are also some differences between remembering the past and imagining the future. For instance, in remembering there is some (albeit imperfect) correspondence between the subject's current representation of a past event and the actual occurrence of this event in the past, whereas future thoughts are about events that have not yet occurred and thus may or may not actually occur. This fundamental asymmetry in mental representations of the past and the future may affect the processes involved in each temporal orientation (Michaelian, 2016, Perrin, 2016).

Table 1. A taxonomy of prospective cognition, adapted from Szpunar et al. (2014)

	SIMULATION	PREDICTION	INTENTION	PLANNING
EPISODIC  SEMANTIC	Construction of a mental representation of a specific autobiographical event	Estimation of the likelihood of and/or one's reaction to a specific autobiographical future event	Setting a goal in relation to a specific autobiographical future event	Organization of steps needed to arrive at a specific autobiographical future outcome
	Construction of a mental representation of a non-specific autobiographical state	Estimation of the likelihood of and/or one's reaction to a non-specific future autobiographical state	Setting a non-specific autobiographical future goal	Organization of steps needed for some non-specific autobiographical state to arise in the future
	Construction of a mental representation of a general or abstract state of the world	Estimation of the likelihood of and/or one's reaction to a general or abstract future state of the world	Setting a general or abstract goal, such as the goal of an organization	Organization of steps needed for some general or abstract state of the world to arise in the future

Different theories have been proposed to try to understand the mechanisms of episodic future thinking. According to the *constructive episodic simulation hypothesis* (Schacter & Addis, 2007), episodic memory supports future simulation by allowing individuals to flexibly retrieve and recombine elements of past experiences into novel experiences of events that might occur in the future. Similarly, Hassabis and Maguire (2007) proposed that the imagination of future events requires the construction of a complex and coherent scene or event, which involves the retrieval and integration of multiple elements in a coherent spatial context.

Besides the idea that episodic memory provides core elements (e.g., details about previously encountered objects, persons and locations) from which representations of future episodes are constructed, semantic memory may also contribute to episodic future thinking. According to the *semantic scaffolding hypothesis* (Irish, Addis, Hodges & Piguet, 2012), semantic knowledge provides the framework that enables both the reconstruction of the past and simulation of the future. For example, "when envisaging a possible trip to Paris, the semantic framework would involve semantic details about travel, Paris and France, which collectively impart meaning and structure to guide the episodic simulation (e.g., the French language, French cuisine, the Eiffel tower)" (Irish, 2016, p. 401).

In addition to the contribution of episodic and semantic memory (i.e., representations of specific past experiences as well as event schema) in the mental simulation of specific future events, there is also substantial evidence that future event representations are structured by higher-order autobiographical knowledge (i.e., representations of general events and lifetime periods) (for a review, see D'Argembeau, 2015). Based on the prominent conception of the architecture of autobiographical memory proposed by Conway (Conway, 2005, 2009; Conway & Pleydell-Pearce, 2000),

D'Argembeau posited that episodic future thinking is supported by at least two kinds of representational systems: a pool of event details (provided by episodic memory and event schemata) and an autobiographical knowledge base (see Figure 1, for a schematic representation of the model). The pool of details is composed of event components (e.g., persons, objects, locations and so on) that have been extracted from unique or multiple past experiences (details could thus be more or less abstract) and can be used to simulate novel experiences. These details have been derived from personal experiences and may also include non-personal information gleaned indirectly, for example through the media. Besides this pool of event details, episodic future thinking relies on general knowledge about facts and events that people envision in their future life. In parallel to knowledge about past lifetime periods, people may possess conceptual knowledge about various features (e.g., relationships, locations, activities, goals and so on) that they believe will characterize future lifetime periods (for example, "when I'll be married"). In particular, people may use knowledge of cultural (Berntsen & Rubin, 2004) or idiosyncratic (Thomsen, 2015) future lifetime periods to envision and anticipate the future. Furthermore, people may also use representations of general events that they anticipate to happen, including repeated events (e.g., "taking children to school") and events extended in time (e.g., "going on vacation to France next summer"). As with autobiographical knowledge of the past, these different levels of knowledge about the personal future may be organised hierarchically, with representations of future general events being part of anticipated lifetime periods, which in turn constitute the future aspects of the life story schema (D'Argembeau, 2015; Conway, Justice & D'Argembeau, in press). Furthermore, the representation of personal goals may play a major role in guiding this organisational scheme (D'Argembeau, 2016; see the section entitled "The role of personal goals in episodic future thinking").

Insofar as higher-order autobiographical knowledge about the personal future drives and contextualises the imagination of specific events, this organisational structure may also help people to locate future events in time. Before discussing the implications of theories of episodic future thinking in the temporal location of future events, we will first briefly describe how and when the sense of future times appears in development.

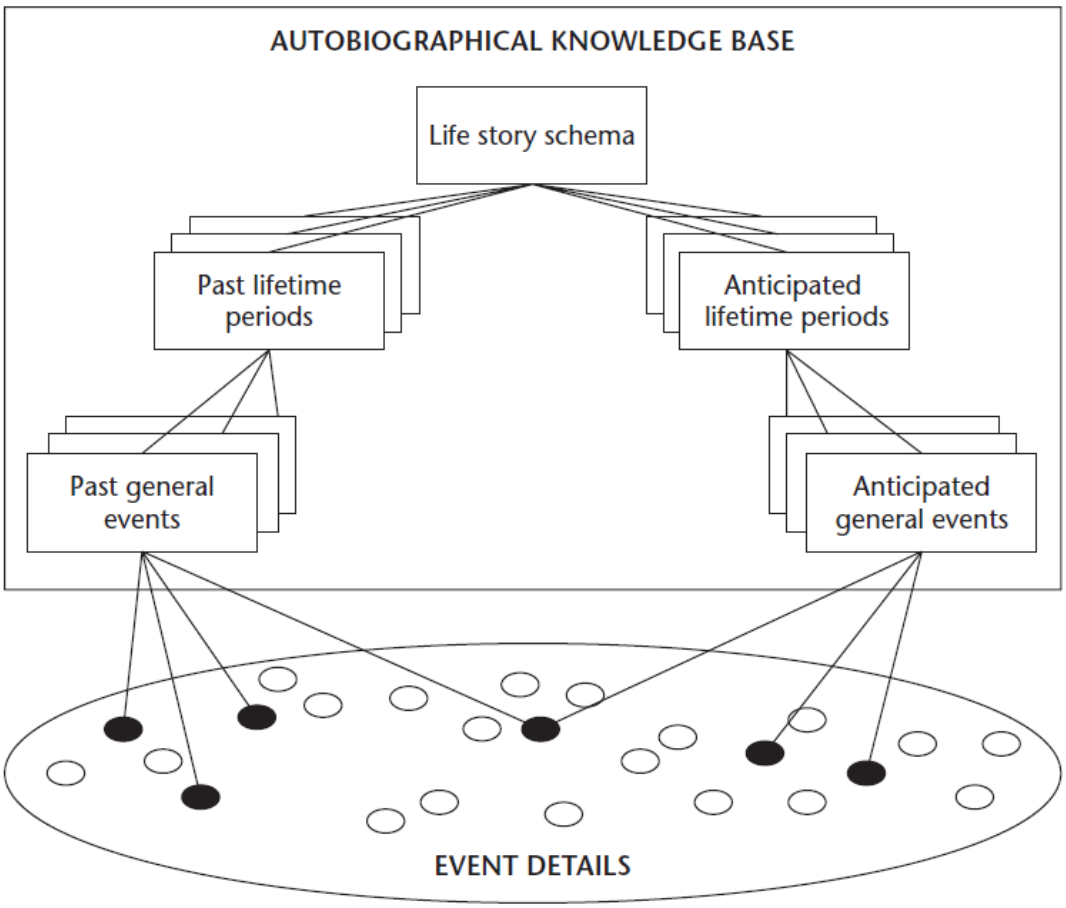


Figure 1. A dual-knowledge structure model of episodic future thinking, copied with permission from D'Argembeau (2015).

The sense of future times

While memory for the times of past events has received much attention, little is known about how people estimate the times of personal events that might happen in the future. People have internalized a view of the past and the future as parts of a temporal framework, one that can be filled with the happenings of their lives, and this view of time allows considering the pastness and futurity of events (Friedman, 2005; Suddendorf & Corballis, 1997). When we think about anticipated events, we know that they will occur at specific times in the future. However, the mechanisms that allow us to anticipate the times of future events remain poorly understood.

In Chapter 1, we discussed the processes underlying memory for the times of past events according to three types of temporal information. Although distance- and order-based processes may be involved in the ability to date personal past events (Friedman, 1993, 2004), the times of future events may be primarily determined using location processes based on representations of time patterns (Friedman, 2005). However, the use of locations, distances, and orders in envisioning the times of future events remains to be experimentally investigated.

According to Friedman (2005), two distinct types of processes and representations may be used by adults to think about specific locations within time patterns. He referred to *verbal-list* processes as "involving links between each element and its successor and allow us to move forward through the order in a step-wise manner" (p.147), such as the days of the week, or months of the year. Verbal list processes may be involved in determining the exact temporal locations, such as what month is three months after April. *Image-based* processes may be involved in determining the spatial-like relations between the elements of time patterns, such as "the wide separation of April and October" (p. 147).

These two processes may thus be involved in the ability to travel backwards to past times but also forward to future times. Considering that children's representation of time patterns seems to appear during middle childhood, we may expect that younger children find difficulties seeing the future as different from the present or past times. However, some empirical findings (reviewed below) are against this view.

To study the early development of the sense of future times, Friedman (2000) investigated children's ability to differentiate future distances of events, without involving the use of conventional time patterns, which children at their age did not understand yet. Spatial judgements of future distances (of events such as Halloween, summer, birthday) were studied using (notably) a picture showing a road curved over two hills, and graduated fence posts were used to record distances from 0 to 25 along the road. Friedman found that 5-years old children (but not 4-years old) reliably differentiated the future distances of events that will occur in the coming weeks from those of events that will occur many months in the future. This finding contrasted with the fact 4-year-olds were capable to distinguish distances in past times, from the preceding month or longer time ago. Friedman suggested that the difference between the past and the future was likely related to the vividness of memories, providing a cue for the ages of memories only for the past. The development of the sense of the past may thus precede the sense of the future, though more empirical research is needed to understand why the sense of the future may be acquired at a later age. Interestingly, Friedman also showed that children sometimes confused the past with the future, until about 6 to 7 years of age. The ability to judge distances in the future may be acquired thanks to discussions with the parents, who may frequently refer to the nearness or farness of an event, and may talk about the numbers of day, weeks, and months until important events will occur. The statements

provided by parents regarding temporal distances could be encoded in memory and later retrieved when children are asked to judge distances in the future.

By middle childhood (7 to 10 years old), children can use representations of conventional time patterns within the year cycle (which are learned at school) to locate future events in time. By 10 years, children's sense of future distances (within the year) is similar to adults one's. It is worth noting that there is also evidence that the sense of the future depends on the representations of the time patterns available; for example, children judged future distances of daily activities (e.g., dinner) at earlier ages (by 4 to 6 years of age) than of annual events (Friedman, 2002).

Overall, these findings suggest that the development of a differentiated sense of the future is not unitary but composed of multiple processes (more or less basic) and representations, allowing to mentally travel towards the future on different times scales (Friedman, 2005, 2000, 2002). Even though we expect that adults' ability to anticipate the times of future events would rely on these multiple processes and more especially on location processes, it is still unknown which information (or strategies) are used to envision the dates of future events, and whether people use similar strategies (and thus common underlying processes) to retrieve the times of past events and to estimate the times of future events.

Time in models of episodic future thinking

As reviewed above, different theories have been proposed to account for the mechanisms underlying people's ability to imagine future events. From these theories, we can make assumptions regarding the implications of these models for the temporal location processes of future events. First, according to the constructive episodic simulation hypothesis (Schacter & Addis, 2007), the simulation of future episodes requires the extraction and flexible recombination of elements of previous experiences. The temporal context of past experiences could be one of the elements that we may use to simulate the future. For example, my representation of the boat tour I did last summer in Greece may help me to envision, at the same period of time, future boat tours that I would do in the future. Second, in a similar vein, semantic knowledge about the temporal context of past experiences (Irish et al., 2012) may help me envision the times of future events. For instance, events that are annually, monthly or weekly repeated will help me anticipate the temporal locations of similar events in the future. Third, according to the dual-knowledge structure model of episodic future thinking (D'Argembeau, 2015), higher-order knowledge (e.g., anticipated lifetime periods) contextualises specific events, and may be used for locating imagined events in time. For example, I plan to buy a house when I'll have children and I expect having children around my thirties. This anticipated period (i.e., having children) could play the role of a temporal structure that would help me to determine when I will likely buy the house. These assumptions regarding the implications of episodic future thinking models on the temporal location of future events need, however, to be investigated experimentally.

The role of personal goals in episodic future thinking

The mental simulation of a specific event may not be sufficient to give someone the subjective feeling that this event belongs to his or her personal future. Connecting this event with higher-order autobiographical knowledge, and particularly personal goals, may contribute to the sense that it belongs to one's future life (D'Argembeau, 2015). There is indeed evidence that personal goals play an important role in the construction and organization of envisioned future events (see below, and for a review, see D'Argembeau, 2016).

Goals are cognitive representations of desired states or outcomes (Austin & Vancouver, 1996), and personal goals may be defined as personally important objectives that individuals pursue in their daily lives (Emmons, 1986; Klinger, 2013; Little, 1983; McAdams, 2013). Goal-related knowledge is represented in a hierarchical structure that organizes higher-order goals (e.g., having a successful academic career) in sequences of sub-goals (e.g., receiving a PhD degree with highest honors, finding postdoc positions in competitive laboratories) that specify how to attain desired states (Austin & Vancouver, 1996; Wadsworth & Ford, 1983).

To test whether the representation of personal goals may guide the construction of episodic future thoughts, D'Argembeau and Mathy (2011) asked participants to generate as many future events as possible for 60s in relation to a series of personal goals, familiar persons, or familiar locations; they found that the number of events was higher in the personal goal condition than in the two other conditions (Study 2). In another study, the authors asked participants to imagine a specific future event in relation to one of the goals, persons and locations they previously reported (one week before), and they were required to verbalize the content of their though flow during the construction process

(Study 3). They found that, on most trials, participants accessed general personal knowledge before producing a specific event. In addition, participants directly produced a specific event more frequently when they were cued with their personal goals (35% of trials) compared to the other classes of personal information (27% and 18% for person and location cues, respectively). Finally, when they recruited generative processes to construct specific future events (i.e., in the absence of direct access to a particular episode), they generated specific events more easily when cued with personal goals compared to familiar persons and locations. Altogether, these findings support the view that personal goals may guide the construction of episodic future thoughts.

To investigate the role of personal goals in the organization of episodic future thinking, D'Argembeau & Demblon (2012) asked participants to imagine a series of future events and each of these events was used to cue the imagination of another related future event (see also Brown & Schopflocher, 1998). Then, they were asked to look back at each pair of events to answer questions about the relationship between the events (i.e., the two events involved the same persons, the same location, and/or the same activity; one event could cause the other; one event could be included in the other; both events could be part of a single broader event). They found that pairs of events were frequently embedded in an event cluster, which means that they were causally and/or thematically related to each other. Furthermore, the frequency of event clusters increased with the personal importance attributed to the cueing event. Another study showed that not only cued events, but also spontaneous future thoughts were frequently organized in terms of goals and clusters but only for distant events, whereas other principles (such as chronological order) played a major role for organizing near future events (Demblon & D'Argembeau, 2014).

Besides their roles in the construction and organization of episodic future thoughts, personal goals may also contribute to the temporal location of future events. Episodic future thinking plays a critical role in planning and goal pursuit. The hierarchical and sequential representation of goals and sub-goals (Austin & Vancouver, 1996; Wadsworth & Ford, 1983) may drive the construction of a personal timeline that facilitates the temporal location of goal-relevant future events. In turn, the ability to locate goal-relevant events at specific future times may play a critical role in planning and goal pursuit. Indeed, goal achievement often requires a sequence of actions that need to be ordered and carried out at specific times (e.g., on a given day or within a particular temporal window). However, whether and how personal goals contribute to temporal location processes of future events remain to be investigated in detail.

Summary

The mechanisms that allow one to anticipate the times of future events remain poorly understood. As for the sense of past times, several processes (e.g., location, order, distance) may be involved in people's ability to envision future times. However, whether these processes (and particularly temporal location processes) are similar for the past and the future needs to be empirically investigated. Furthermore, since personal goals play a key role in the construction and organization of future thoughts, we suspect that they would also contribute the temporal location of future events, in some as yet little understood manner.

CHAPTER 3

SCHIZOPHRENIA

Brief description

Diagnosis and clinical symptomatology

Cognitive deficits

Treatments

The representation of the past in schizophrenia

Temporal dimension of memory for past events in schizophrenia

The representation of the future in schizophrenia

Temporal dimension of episodic future thinking in schizophrenia

Prospective memory in schizophrenia

Summary

Brief description

The word *schizophrenia* was coined in 1911 by Eugen Bleuler (1857-1939), a swiss psychiatrist. Etymologically, the word *schizophrenia* comes for the Ancient Greek σχίζω (skhízō, 'to split, to cleave, to cut') and φρήν (phrḗn, 'mind, soul, heart'). The term did not intend to mean the idea of split or multiple personality, as many people frequently misunderstand. Rather, this term describes individuals with a "dissociated" mind, who experience alteration of mind coherence, emotion and behaviors. Bleuler distinguished *schizophrenias* from *dementia praecox* of Emil Kraepelin (1856-1926) because the disease could sometimes appear late as well as early, and does not always lead to an inevitable deterioration.

According to the National Institute of Mental Health of the U.S., schizophrenia is defined as "a mental disorder characterized by disruptions in thought processes, perceptions, emotional responsiveness, and social interactions" (NIMH, 2018). The lifetime prevalence of schizophrenia is approximatively between 0.3% - 0.7% (McGrath, Saha, Chant & Welham, 2008), and it affects more than 21 million people worldwide[2]. The disease is typically diagnosed in late adolescence-early adulthood, even if some subtle changes in social behaviors and cognitive functioning can be seen earlier. Although the evolution of the disease varies among individuals, schizophrenia is generally persistent and can be severely disabling. Indeed, schizophrenia is listed on the fifteenth position of the top leading causes of disability worldwide, for the period 1990-2016 (Vos & Global Burden of Disease and Injury and Prevalence Collaborators, 2016). Though the suicide contributes to increase the mortality, individuals with schizophrenia have an

[2] From the World Health Organization (WHO, July 2018)

increased risk of premature mortality (with a potential life loss of 28.5 years) due to a wide range of comorbid somatic conditions (Olfson et al., 2015).

The precise causes of schizophrenia are still unknown. Nevertheless, we know that multiple factors contribute to the risk of developing schizophrenia. The existence of familial aggregation and findings from twin and adoption studies suggest that genetic vulnerability may strongly be involved in the development of the disease (Gottesman & Shields, 1982). However, the genetic hypothesis does not explain why some individuals with schizophrenia don't have a family member with the disease and conversely having some sick family members does not lead necessarily to the development of the disorder. The expression of thousands of different genes makes individuals more vulnerable to schizophrenia, but there is not 'one gene of schizophrenia'. The consensual hypothesis postulates that the etiology of schizophrenia may be due to the interaction between the genetic background and the environment of individuals during pre-/post-natal, and infantile development. The environmental factors are multiple and involve infections (viral, bacterial, and parasitic), dietary deficiencies, obstetrical issues, toxic exposure, maternal and infantile stress (Saoud & d'Amato, 2006). These environmental factors would alter the normal development of the central nervous system, leading to anatomical, functional, and neurochemical (mainly influencing the dopaminergic system, but likely others) consequences in the brain. These early-life factors, associated with the genetic vulnerability, would favor the development of the disease in late adolescence.

In addition to its role as an environmental factor during the antepartum and infantile periods, stress may act as a trigger of the so called first psychotic episode. Indeed, and according to the Stress/Vulnerability Model (Saoud & d'Amato, 2006), a psychotic episode may be due to the interaction of predisposing factors (genetical and environmental; see above) and later precipitating factors (psychological, sociological,

toxic) without which the full phenotype of schizophrenia would remain silent or subtle. For instance, cannabis consumption in adolescence increases significantly the likelihood of experiencing symptoms of schizophrenia in adulthood (Andréasson et al., 1987; Arseneault et al., 2002). Nevertheless, the mechanisms by which vulnerability and stress are interacting need to be better understood.

Diagnosis and clinical symptomatology

Schizophrenia is generally diagnosed using the criteria of the Diagnostic and Statistical Manual of Mental Disorders, fifth edition[3] (DSM-5, American Psychiatric Association, 2013). Listed in the category named "Schizophrenia Spectrum and Other Psychotic Disorders", the manual describes 5 main criteria:

A. Two (or more) of the following, each present for a significant portion of time during a 1-month period (or less if successfully treated). At least one of them must be (1), (2) or (3):

1. Delusions
2. Hallucinations
3. Disorganized speech (e.g., frequent derailment or incoherence)
4. Grossly disorganized or catatonic behaviour
5. Negative symptoms (i.e., diminished emotional expression or avolition)

B. For a significant portion of the time since the onset of the disturbance, level of functioning in one or more major areas, such as work, interpersonal relations, or self-care, is markedly below the level achieved prior to the onset (or when the onset is in childhood or adolescence, there is failure to achieve expected level of interpersonal, academic, or occupational functioning).

C. Continuous signs of the disturbance persist for at least 6 months. This 6-months period must include at least 1 month of symptoms (or less if successfully treated) that meet Criterion A (i.e., acute-phase symptoms). During these prodromal or residual periods, the signs of the disturbance may be manifested by only negative symptoms or by two or more symptoms listed in Criterion A present in an attenuated form (e.g., odd beliefs, unusual perceptual experiences).

D. Schizoaffective disorder and depressive or bipolar disorder with psychotic features have been ruled out because either 1) no major depressive or manic episodes have occurred concurrently with the active-phase symptoms, or 2) if mood episodes have occurred during active-phase symptoms, they have been present for a minority of the total duration of the active and residual periods of the illness.

E. The disturbance is not attributable to the physiological effects of a substance (e.g., a drug of abuse, a medication) or another medical condition.

F. If there is a history of autism spectrum disorder or a communication disorder of childhood onset, the additional diagnosis of schizophrenia is made only if prominent

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[3] The patients who participated in our study were recruited following the criteria of the DSM-V (APA, 2013)

delusions or hallucinations, in addition to the other required symptoms of schizophrenia, are also present for at least 1 month (or less if successfully treated).

Compared to the previous version of the manual (DSM-IV-TR, 2000), the term "schizophrenia spectrum" has been introduced to encompass the important variability across patients. In addition, subtypes of schizophrenia (e.g., paranoid, hebephrenic) have been withdrawn, since they were considered insufficiently stable across time. Other changes have been made to try to delineate the border of the *schizophrenias* (for further information, see Tandon et al., 2013).

Since the categorical approach shows limitations to encompass the clinical heterogeneity of schizophrenia spectrum disorder, it is complementary to view the illness in terms of dimensions. The dimensional approach aims to model groups of symptoms as independent dimensions that coexist, rather than in terms of categories (Saoud & D'Amato, 2006). In this view, schizophrenia (but more generally, psychotic disorders) can be seen as a continuum, with a prevalence of certain symptoms at different times of life. Frequently, we distinguish three dimensions: 1) the *positive dimension* relates to hallucinations and delusions symptoms, 2) the *negative dimension* encompasses anhedonia, avolition and emotional blunting, 3) the *disorganization dimension* represents the disorganized thoughts and behaviors, emotion and discourse symptoms (Kay, Fiszbein, Opler, 1987; Andreasen, 1984). Different neuro-anatomical and neuro-chemical hypotheses have been formulated to explain the different dimensions (for further information, see Saoud & D'Amato, 2006).

Cognitive deficits

Over the last decades, research focusing on cognition has attracted more interest, likely because cognitive dysfunction is associated to clinical symptoms and accounts for the psychosocial disability that individuals with schizophrenia usually experience (Lipkovich et al., 2009). About 85% (but likely more) patients with schizophrenia present cognitive deficits (Palmer, Dawes & Heaton, 2009; but see also Krkovic, Mortiz & Lincoln, 2017 for possible confounding factors in cognitive assessment of patients), supporting the view that neuropsychological impairments are a core feature of the illness (Wilk et al., 2005). These deficits concern all cognitive domains with a mean effect size of 1.03 (Schaefer et al. 2013). Cognitive deficits are present since the first psychotic episode (Bora & Murray, 2013; Becker et al., 2010; Saykin et al., 1994), and even before the onset of illness and may be responsible of the prodromal functional decline in people with schizophrenia (Reichenberg et al., 2009, Bora & Murray, 2013). Cognitive deficits that are present following a first episode of psychosis appear to remain stable over times for periods up to ten years, except for verbal memory deficits that are deteriorating over the long term (for a review, see Bozikas & Andreou, 2011). The severity of cognitive dysfunction varies across patients, but eight separable dimensions can be defined: speed of processing, attention/vigilance, working memory, verbal learning and memory, visual learning and memory, reasoning and problem-solving, verbal comprehension, and social cognition (Nuechterlein et al., 2004).

Treatments

The discovery of the neuroleptic drugs in 1951 improved the care of individuals with schizophrenia by decreasing the severity of positive symptoms, and improving the possibility for physicians and psychologists to communicate with them. The classical neuroleptics had, however, no or little effect on negative symptoms, no clear effect on neurocognition when acute symptoms are treated (Barnes, 2011). The atypical neuroleptics also known as the second generation of antipsychotics have been developed because 30 to 50 % of patients did not respond or respond partially to classical drugs (Kane & Marder, 1993) and to avoid their important side effects. The antipsychotics are first line treatment, target positive symptoms, and prevent new psychotic episodes. Despite recent advances of the pharmacological treatment, the efficacy of antipsychotics does not exceed a moderate effect size (Leucht et al., 2017). Furthermore, impairments in everyday functioning often persist, even after successful pharmacological treatment (Emsley, 2009). Although about 40% of individuals with schizophrenia have a good symptomatic outcome, recent meta-analyses have reported rates of true recovery (i.e., symptom remission accompanied by adequate psychosocial functioning) as low as 13.5%; with no recovery improvement over the years, despite the introduction of several new antipsychotics (Jaaskelainen et al., 2012). Adherence to medication is moderate, with reported non-adherence rates often exceeding 50% (Byberly et al., 2007).

It is worth noting that there is growing concern about the cumulative effects of long-term use of antipsychotics on physical health and on brain structure, with leading experts in the field advocating against the long-term use of antipsychotics as a standard practice, especially in recent-onset patients (Murray et al., 2016) or suggesting dose tapering in some patients after the first psychotic episode (Wunderink et al. 2013). New

approaches are developing to target neurotransmitter systems other than dopaminergic (e.g., GABA/glutamate) and to use complementary non-pharmacological treatment methods. These non-pharmacological-methods include for instance, Cognitive-Behavioral Therapy (CBT) showing significant effects on positive and negative symptoms, and functioning (see for a review, Rector & Beck, 2001; for a meta-analysis, Wykes et al., 2008); Cognitive Remediation Therapy (CRT) showing durable effects on cognition and functioning (Wykes et al., 2011); and Meta-Cognitive Training (MCT), which is effective in addressing positive symptoms, cognitive biases and insight in schizophrenia (Moritz et al., 2014; Eichner & Berna, 2016). The combination of these approaches will reduce the clinical symptoms, but also and as importantly improve quality of life and functioning of people with schizophrenia.

The representation of the past in schizophrenia

Memory impairments in schizophrenia are observed in several systems of long-term memory including semantic (McKay et al., 1996), episodic (Danion et al., 2007) non-personal memory, and personal or autobiographical memory (for a meta-analysis, see Berna et al., 2015). Here, we will review findings relating to autobiographical memories to understand how individuals with schizophrenia mentally represent their past personal experiences.

Previous research showed that individuals with schizophrenia have difficulties to remember personal events, and that these memories contain less contextual details, as compared to control participants (Riutort et al., 2003). It is difficult for patients to retrieve events that happened at a unique occasion, in a particular place, and that lasted less than a day (D'Argembeau et al., 2008; McLeod, Wood & Brewin 2006). Remembering personal experiences requires more than just retrieving the content and the context of the memory representation. Rather than just knowing that the experience happened, remembering is accompanied by the sense of relieving the experience by travelling back in time, and by the sense that it belongs to one's past; this ability is also known as autonoetic consciousness (Tulving, 1972, 1985). Autonoetic consciousness or conscious recollection of autobiographical memories is also affected in schizophrenia (e.g., Danion et al., 2005). The reduced conscious recollection of autobiographical memories may account for the disturbance of self-continuity experienced in schizophrenia (Allé et al., 2016a). In a recent meta-analysis, Berna et al. (2016) found that deficits in the richness of details, specificity and conscious recollection were associated to large-to-moderate effect sizes, which were in the same range as in other memory domains (Schaefer et al. 2013).

Autobiographical memory encompasses mundane events (e.g., shopping), but also highly significant events (e.g., graduations). Self-defining memories are defined as the most important events in one's life (positive or negative), which are highly relevant for building and maintaining the self-concept (Singer & Moffit, 1991-92; Blagov & Singer 2004). Though the number (Holm et al., 2016, 2017) and specificity (Raffard et al., 2009, 2010; Berna et al. 2011b) of self-defining memories did not differ between individuals with schizophrenia and control participants, patients' memories were often negative and more frequently related to the illness, hospitalization, life-threatening events, and less frequently to achievements than controls' memories (Berna et al., 2011a; Raffard et al., 2009, 2010a; Holm et al., 2016). The negative tone of the representation of the past in patients may contribute to maintain a negative view of their self. Furthermore, individuals with schizophrenia experienced difficulties to extract meaning and implications from their self-defining memories, spontaneously or even when they were cued (Raffard et al., 2009, 2010; Berna et al., 2011a, 2011b, Allé et al., 2016b). The ability to extract meaning from the most important life events is important to build an abstract and coherent representation of one's self across time (Blagov & Singer, 2004). This impaired integrative meaning of self-defining memories may account for the disorder of the self in schizophrenia.

Beyond memories for specific events (i.e., a unique event happening at a particular place and time and lasting no longer than a day, Williams et al., 1996), a research focusing on life story narratives showed that individuals with schizophrenia rated their life stories as less positive than control participants, and exhibited difficulties explaining how events were linked to their identity, and how they could be integrated along thematic lines (Allé et al., 2015). This suggests that the representation of both isolated events and life stories is affected in schizophrenia.

Overall, these findings demonstrate that the representation of personal past events in schizophrenia is less specific, depleted of episodic details, and less frequently associated with conscious recollection. The representation of the past is often negative and strongly related to the illness. The association between personal events and the sense of self is weakened (Bennouna-Greene et al., 2012), and the meaning and lessons from their self-defining memories are difficult to extract. Therefore, autobiographical memory can be seen as a major cognitive impairment in schizophrenia. All the more, since it is negatively associated with social communication skills (Mehl et al., 2010), targeting autobiographical memory deficits could help individuals with schizophrenia reduce their social and functional disability, and enhance coherence between past experiences and the sense of identity across time.

Temporal dimension of memory for past events in schizophrenia

The present thesis focuses on the temporal dimension of remembering the past and imagining the future. To understand whether the temporal dimension of memory for past events is altered or not in schizophrenia, we will now review and discuss previous findings relating to different aspects of the temporal dimension. We will start by examining the temporal distribution of memory deficits, and of salient memories and then classified the results of previous studies according to the distinction made by Friedman (location, order and distance, Friedman, 1993, 2004; see above). Finally, we will examine the temporal organization of interrelated memories and complex narratives in schizophrenia.

The temporal distribution of memory deficits

Autobiographical memory impairments in schizophrenia differ depending on which period of life is considered. Feinstein et al. (1998) showed that patients with schizophrenia retrieved significantly fewer personal facts and personal events for three life periods (childhood, early adulthood, very recent past), compared to controls. Interestingly, however, individuals with schizophrenia exhibited a U-shaped temporal gradient, with the worst recall performance for the early adulthood period for both personal facts and personal events, indicating that the onset period of the illness may have altered the encoding and/or the consolidation of personal facts and events. McLeod et al. (2006) found a similar temporal gradient, but not Riutort et al. (2003) who found, however, that the impairment was more apparent after the onset of the disease. Using free recall of autobiographical memories, Elvevag et al. (2003) found that individuals with schizophrenia recalled fewer memories that controls for the first 10 years of life, the

middle years and the 10 most recent years of life, and the depletion was more important for the recent decade. Nonetheless, when the overall number of memories generated was controlled for, the between-group difference for the most recent decade was no longer significant. In addition, there was no difference in the amount of memories generated from the period before illness onset *versus* after illness onset.

The temporal distribution of salient memories

Regarding the temporal distribution of frequently retrieved memories, Cuervo-Lombard et al. (2007) used a free recall of salient events (contrary to most of the previous studies which constrained the recall with lifetime periods) in order to investigate the reminiscence bump in schizophrenia. The reminiscence bump refers to an increase of recall of memories in the early adulthood period, which is important for identity consolidation. In their study, participants were asked to freely give the first 20 specific memories that came to their minds. The authors found that the reminiscence bump peaked earlier in individuals with schizophrenia (ages 16-25) than in controls (ages 21-25). When analyzing the temporal distribution of self-defining memories, similar findings support the view of an earlier reminiscence bump in schizophrenia (ages 15-19) than in controls (ages 25-34; Holm et al., 2017; Raffard et al., 2009). Interestingly, Holm et al. (2017) showed the existence of an abrupt drop of memories defining the self in the years following a diagnosis of schizophrenia. Self-defining memories of individuals with schizophrenia increased in the years leading up to diagnosis and declined abruptly in the years following diagnosis, suggesting that the illness might disturb the ability to establish new or evolve definitions of self.

Location processes

Regarding the temporal location processes, the study of Venneri et al. (2002) showed that people with schizophrenia made more dating errors and were less precise when they were asked to date historical events (for example, the fatal car accident of Princess Diana). In their study, Venneri et al. distinguished the content of events from their temporal context, in line with the view that each may rely on different processes (Friedman, 1993, 2004). Nonetheless, they asked participants to recall and date public events (which relates to semantic and non-personal memory) and not personal events. Thus, it is still unknown whether the cognitive mechanisms underlying the temporal location of personal events are impaired or not by the illness.

Danion et al. (2005) investigated the quality of memory for time information related to a specific event. These authors asked individuals with schizophrenia to retrieve specific autobiographical memories and to indicate their subjective states of awareness (i.e., remember, know or guess) associated with the recall of what (the content) happened, when (the time) and where (the location). Interestingly, they found that conscious recollection was affected in schizophrenia, and that the impairment was more important for time information than for content and location (i.e., where) information. Time information may thus be particularly difficult to access consciously in patients with schizophrenia, tentatively suggesting that patients may encounter difficulty to locate personal past experiences in time.

Order processes

During the 90s, some researchers were interested to study the temporal order processes of non-personal events in schizophrenia. Using recency discrimination tasks in

which participants were instructed to judge which of two items (e.g., words, Schwartz et al., 1991; images, Rizzo et al., 1996; or household objects, Waters et al., 2004) was most recently memorized, it was found that individuals with schizophrenia performed less efficiently than control participants. These findings suggest that schizophrenia is associated with a deficit in temporal ordering of non-personal events, independently of their nature (i.e., words, images, or household objects). Nevertheless, it should be noted that the temporal order was highly correlated with generally poorer recall of items, and when matching the two groups regarding recall performance, the difference in order performance between patients and controls seem to be eliminated, suggesting that deficits of temporal order might not be specific (Elvevag et al., 2000). Notwithstanding the results, the 'events' in these studies represented only 'items' encoded and recalled in a very short time. To better understand whether temporal order may be altered and may account for the disturbance of self-continuity, more research focusing specifically on autobiographical events is needed in schizophrenia.

Another study (which did not specifically target temporal order processes) used a picture-sequencing task to investigate sequencing of non-personal events in disorganized and non-disorganized individuals with schizophrenia. It was found that disorganized individuals with schizophrenia made more errors in temporal sequencing for all types of sequences, while non-disorganized performed more poorly only in a story involving theory of mind (i.e., false-beliefs), when compared to controls (Zalla et al. 2006). This suggests a relative preservation of temporal order processes of non-personal events in non-disorganized individuals. The question that arises is whether the relative preservation of sequencing processes (for non-disorganized individuals) may be also present if we would ask individuals with schizophrenia to order autobiographical events, rather than non-personal events.

To the best of our knowledge, only one study specifically investigated the temporal order of autobiographical events in individuals with schizophrenia (Allé et al. in prep). In this study, participants were asked to walk around a town, for one hour, while wearing a small camera that automatically takes pictures of the scene, every thirty seconds. One week later, participants were presented with 2 sets of 12 pictures from distinct parts of the tour, and they were asked to chronologically order the sequences. Interestingly, individuals with schizophrenia did not perform less efficiently than controls, suggesting (tentatively) a preservation of memory for the temporal order of personal events. However, this is the only study on memory for the temporal order of autobiographical events and given that the events to memorize happened one week before testing, this conclusion requires more empirical support and must be confirmed for more remote personal events.

Distance processes

To our knowledge, only one study investigated the ability for patients to estimate the temporal distance between two (personal or non-personal) events. Potheegadoo et al., (2012) asked individuals with schizophrenia to retrieve specific autobiographical memories, then to evaluate subjectively how distant each event appeared to them and to explain the reasons why they gave this estimated distance. They found that patients rated the decrease of subjective temporal distance from remote to recent periods as less sharp than control participants. Interestingly, events from the period from 20 years old to 1 year before the test (thus following the onset of the illness) were perceived as more distant in people with schizophrenia than in controls. However, no difference was found for the estimation of distance regarding the other lifetime periods. This suggests that patients

with schizophrenia may have a distorted perception of the subjective temporal distance of events for the period following the illness onset. To justify their ratings of estimated distances, patients produced fewer subjective explanations (e.g., "this event seems far away because it is no longer important to me"), and more objective explanations (e.g., "this event seems far away because it happened 10 years ago") and were more frequently unable to provide any explanation. Furthermore, these authors showed that the subjective temporal distance of events correlated with the amount of memory details, but only in control participants. This finding suggests that a poorer access to memory details in individuals with schizophrenia may account for their (relative) distorted perception of the subjective temporal distance of autobiographical events.

Time information of interrelated memories and complex narratives

Regarding the temporal organization of autobiographical events, Morise, Berna and Danion (2011) investigated the organization of chains of events in individuals with schizophrenia, compared to control participants. They analyzed the similarity of basic characteristics (i.e., sensory-perceptive, cognitive, emotional and temporal) and the presence of cluster-type links (i.e., causally and/or thematically related events) between the cued and cueing events. They found that the use of temporal contiguity to organize events was as frequent in both groups of participants, suggesting that the temporal organization of chains of events may be preserved in individuals with schizophrenia. Interestingly, however, individuals with schizophrenia mostly organized the chains of events in terms of their emotional link, whereas controls mostly relied on sensory-perceptive and cognitive characteristics of events. In the same vein, Bennouna-Greene et al. (2012) asked individuals with schizophrenia and controls to retrieve autobiographical

memories cued by “I am” statements, which reflected self-images. They found, similarly for both groups of participants, that the temporal distribution of autobiographical memories was centered around the date of emergence of the self-images and that the temporal contiguity was higher between memories related to the same “I am” than between memories belonging to distinct “I am”, suggesting again a preservation of the temporal organization of memories in individuals with schizophrenia. However, their memories were less frequently thematically linked to self-images than in control participants. Overall, these findings support the view that individuals with schizophrenia may be able to use temporal information to organize chains or groups of events in memory.

Using a detailed quantitative analysis of complex narratives (i.e., life story narratives), Allé et al. (2015) asked participants with and without schizophrenia to recall the seven most important events they had ever experienced, then to order them in a chronological order, and finally to narrate their life story integrating these important events. These authors investigated the temporal coherence of the narratives, at a local level by the presence of temporal indicators of date, age, life periods or distance, and anachronisms; at a global level, by the ability to identify when and in what order the events narrated took place allowing the listener to understand the chronology of the narrative (using the procedure of Habermas et al., 2009). Though the proportion of local indicators that temporally structured the narratives did not differ between the groups, individuals with schizophrenia reported higher anachronisms, which made it harder to understand the temporal location and order of events. The global temporal coherence was judged as lower in schizophrenia’s group, than in control’s group. These findings were replicated in another study in which the authors used a free recall of life narratives (i.e., without retrieving important events, Allé et al., 2016b, Study 1). The temporal

incoherence of patients' narratives was even more important in this free recall condition. These results are consistent with previous findings showing that individuals with schizophrenia ordered narratives of single events less chronologically than controls (Raffard et al., 2010a). The alteration of temporal coherence appears to be lessened if individuals with schizophrenia are asked to narrate chapters of their life (therefore giving more structure), rather than a whole life story (Holm et al., 2016).

Conclusion

Taken together, the findings reviewed above suggest that some aspects of the temporal dimension of autobiographical memory may be preserved in schizophrenia. People with schizophrenia are able to use temporal indicators to structure the narration of their life stories. Moreover, they can correctly rely on temporal contiguity to organize chains or groups of past personal events. The temporal order of single personal events seems also to be preserved (at least within one-week interval), though more empirical research is needed to confirm this finding, and specifically for more remote autobiographical memories.

Nonetheless, people with schizophrenia experience alterations in other aspects of the temporal dimension of autobiographical memory. They have difficulties to date historical events, to consciously recollect the temporal context and judge the subjective temporal distance of personal events. When they narrate their life stories, the presence of anachronisms makes it hard to understand the chronology of the narrated events. Moreover, the onset of the illness alters the temporal distribution of both mundane and salient memories.

Considering that memory for the times of past events relies on location, order, and distance processes (Friedman, 2004, 1993), the findings reviewed above suggest that location, distance and order processes may all be (at least partly) altered. However, more empirical research is needed to specifically unravel the mechanisms at play. In particular, numerous studies asked people with schizophrenia to date personal memories, without investigating whether temporal location processes are preserved or not. Empirical findings showed that people with schizophrenia experience difficulties in dating historical events, but it remains unclear whether and how they are able to date autobiographical events. Moreover, since temporal order of non-personal events and the chronology of life story narratives may be messy, it may be tempting to considerate that order processes for autobiographical events are impacted. However, one study contrasts with the latter view showing that the temporal order of personal events was preserved (after a one-week delay) (Allé et al., in prep). More investigation is therefore needed to determine whether people with schizophrenia would exhibit impairments in ordering chronologically (remote) autobiographical events.

The representation of the future in schizophrenia

Only a few studies focused on the representation of future events in schizophrenia. Interestingly, these studies showed evidence of similar disturbances between the representation of past and future events. D'Argembeau et al. (2008) asked individuals with schizophrenia and controls to recall a series of past events and to imagine events that might reasonably happen in their personal future in response to sentence-cues, which described situations of feelings that could potentially be associated with a variety of specific events (e.g., a situation in which you feel guilty about something). Participants were instructed to give only specific events, which were defined as events that would occur at a particular place and time, and lasting no longer than a day. It was found that people with schizophrenia recalled fewer specific past events than did controls, and were even more impaired in generating specific future events.

Besides the poorer specificity of the representations of future events, how do people with schizophrenia mentally experience anticipated future events? de Oliveira et al. (2009) asked individuals with schizophrenia and controls to imagine specific future events that were connected to three plans they had concerning vacation or entertainment, work or any occupation, and family, for four different time periods (i.e., next week, next month, next year and the next 5 years). The participants were instructed to indicate the subjective state of awareness associated (i.e., picture, know or guess answers) with the description of what would happen (content information), where (location information) and when (temporal information). Though autonoetic awareness of both close (i.e., next week and next month periods) and distant (i.e., next year and the next 5 years periods) anticipated events did not differ between the groups, they found that its drop from the near to distant future was less pronounced in the schizophrenia group, suggesting an

attenuated effect of the temporal distance on the feeling of pre-experiencing the future in schizophrenia. Moreover, individuals with schizophrenia gave fewer plans, and anticipated fewer specific events in association with their plans, indicating a depletion of detailed and vivid representation of future events associated to personal goals. Another study showed that individuals with schizophrenia rated the vividness of personally significant future events as lower than did controls (Allé et al., 2016a).

Similarly to the impairment of self-defining memories (Raffard et al., 2009, 2010a; Berna et al., 2011a, 2011b), it has been shown that people with schizophrenia exhibited difficulties in reflecting on the broader meaning and implications of future events that could be very important for their life and identity (Raffard et al., 2016). Nonetheless, it is worthy to note that when people with schizophrenia were asked to make explicit connection between personally significant future events and self-attributes, the proportion of self-event connections in their narratives did not differ from controls (Allé et al., 2016b). Regarding the affective valence of events, and contrary to the finding that self-defining memories were often negative (Berna et al., 2011a; Raffard et al., 2009, 2010; Holm et al., 2016), individuals with schizophrenia imagined future self-projections that were as positive as controls, and these were frequently constituted by achievements and relationships events (Raffard et al., 2016). This suggests the existence of a positivity bias for the relevant future events, showing that people viewed their future as more positive than their past, and this was true for both patients with schizophrenia and control participants.

Although some alterations regarding the representation of the future have been documented in schizophrenia, the mechanisms at play are not fully understood. It has been suggested that scene construction (i.e., the process of mentally generating and maintaining a complex and coherent scene) impairment may explain (at least partly) the

difficulties to envision the future in schizophrenia. Indeed, Raffard et al. (2010b) asked individuals with schizophrenia and controls to imagine new fictitious experiences in response to commonplace scenarios (e.g., “Imagine you’re standing in the busy main hall of a museum containing many impressive exhibits”) and new realistic events that might plausibly happen in the future, in response to cues (e.g., “Imagine the next time you’ll meet a friend”). The participants were instructed to describe the experience and the surroundings with as much detail as possible, using all their senses including what they can see, hear, and feel. They found that the ability to imagine experiences rich of sensory details and spatial references was impaired in schizophrenia. Moreover, descriptions of individuals with schizophrenia lacked spatial coherence and were more fragmented, in comparison with controls. Interestingly, the observed differences were similar between fictitious experiences and realistic events, suggesting that the impairments in envisioning specific future representations may be (at least partly) the consequence of a defect in scene construction processes. Notwithstanding the implication of this hypothesis, other processes, such as temporal processes (which will be discussed in the following section), may also be critical to envision and anticipate the future. The ability to locate anticipated future events in time, and to order them temporally, may be critical to build a coherent representation of future times.

Temporal dimension of episodic future thinking in schizophrenia

While temporal processes may account for the difficulty experienced by patients with schizophrenia to envision the future, little is known regarding the temporal dimension of future events representations in this population. Regarding autonoetic awareness of time information for future events, people with schizophrenia did not present large differences with controls (de Oliveira et al., 2009[4]). Similarly, no inter-group difference was found regarding the temporal distance of self-defining future projections (Raffard et al., 2016, Allé et al., 2016a). Nevertheless, considering the lack of research which targeted the temporal aspects of episodic future thinking in schizophrenia, it may be too early to conclude in favor of a preservation or alteration of the sense of future times. Whether people with schizophrenia are able to envision when future events would occur, to order them chronologically and to evaluate their subjective distance remain to be investigated in detail. Since temporal location, order and distance processes may be involved in the sense of the future (Friedman, 2005, 2000, 2002), examining these processes may be important to understand how people with schizophrenia view their future, and why they often find it difficult to be engaged in a successful goal-pursuit.

[4] However, the proportion of future events associated with a "picture-type" awareness was significantly lower in patients than in control participants.

Prospective memory in schizophrenia

Better understanding the mechanisms underlying the ability to envision future times is essential to anticipate, plan and execute intended actions at a particular moment of time in the future. Closely related to episodic future thinking, prospective memory is defined as the ability to remember to carry out an intended action at a particular point of time in the future (Einstein & McDaniel, 1990). According to the nature of the cue, prospective memory can be divided into event-, activity- and time-based (Wang et al., 2018). Event-based prospective memory requires someone to execute an intention at the appearance of a cue (e.g., buying bread when one passes by the supermarket). Activity-based prospective memory requires someone to execute an intention at the end of an activity (e.g., send an email after dinner). Time-based prospective memory requires an individual to execute an intention at a particular time, or after a period of time (e.g., attend a wedding next Sunday). Previous research showed that people with schizophrenia exhibit impairments in all types of prospective memory and these deficits are associated with medication adherence and functional outcomes (Wang et al., 2018). Interestingly, time-based prospective memory was found to be more impaired than event-based prospective memory (see Wang et al., 2009 for a meta-analytic review). Thus, it would be important to investigate the integrity of the representation of future times, since a disorganization of temporal location processes could contribute to explain (at least partly) time-based prospective memory impairments in schizophrenia. Better understanding how patients with schizophrenia temporally represent and organize anticipated events could also help develop therapeutic interventions for a successful pursuit of life goals and thus reduce functional disabilities (see Wang et al., 2018 for intervention suggestions).

Summary

The findings reviewed in this chapter indicate that patients with schizophrenia experience difficulties to remember their past and to imagine their future. The alteration of some (but not all) aspects of the temporal dimension of autobiographical memory suggests that location, order and distances processes may be impacted by the disease. However, empirical evidence is needed to understand whether and how patients with schizophrenia are able to date and order personal events in past and future times, particularly for distant events. The hypothesized alteration of temporal location and order processes may contribute to blur the temporal component of mental time travel in schizophrenia.

PART II.

EXPERIMENTAL PART

CHAPTER 4

OBJECTIVES, HYPOTHESIS AND RESULTS

How to date future events?

Investigation of the role of personal goals in the temporal location of future personal events

Exploration of the temporal location and order of past and future personal events in schizophrenia

How to date future events?

The first aim of the thesis was to determine how people locate future events in time. To address this question, we investigated the strategies that people use to determine the times of past and future events, using a think-aloud procedure (Fox et al., 2011). In **Study 1**, participants were first asked to generate a series of past and future events and, for each event, they then described everything that came to their minds while attempting to determine when this event occurred (past condition) or will likely occur (future condition). The strategies used to determine temporal locations were analysed according to a scoring system that we created based on previous research on memory for the times of past events (Friedman, 1987; Thompson et al., 1996, Thompson et al., 1993, Skowronski et al., 1995, Brown, 1990) and included five categories: lifetime periods/extended events, specific events, conventional time patterns, factual knowledge (about the self, others and the world), and contextual details.

Based on previous studies showing that memory for time is largely reconstructive (Friedman, 1993, 2004, Thompson et al., 1996, Shum, 1998), we expected that participants would frequently rely on reconstructive strategies to locate past events in time. Following previous findings showing that remembering the past and imagining the future share (at least partly) common mechanisms (D'Argembeau, 2012, Schacter et al., 2012, Szpunar, 2010), we predicted that the strategies used to locate past and future events would be largely the same, suggesting that the temporal location of future events would be based on similar reconstructive and inferential processes. In addition to examining dating strategies, we also sought to determine whether the dates of some future events can be directly accessed, as has been previously shown for some past events (Friedman, 1987, Thompson et al., 1993), and whether directly dated events present distinguishing

features. We predicted that directly located events would be judged as more important for personal goals than events that are located in time using reconstructive strategies.

STUDY 1

"Reconstructing the times of past and future personal events"

Adapted from: Ben Malek, H., Berna, F., & D'Argembeau, A. (2017). Reconstructing the times of past and future personal events. *Memory*, *25*(10), 1402-1411. http://dx.doi.org/10.1080/09658211.2017.1310251

Abstract

Humans have the remarkable ability to mentally travel through past and future times. However, while memory for the times of past events has been much investigated, little is known about how imagined future events are temporally located. Using a think-aloud protocol, we found that the temporal location of past and future events is rarely directly accessed, but instead mostly relies on reconstructive and inferential strategies. References to lifetime periods and factual knowledge (about the self, others, and the world) were most frequently used to determine the temporal location of both past and future events. Event details (e.g., places, persons, or weather conditions) were also used, but mainly for past events. Finally, the results showed that events whose temporal location was directly accessed were judged more important for personal goals. Together, these findings shed new light on the mechanisms involved in locating personal events in past and future times.

Introduction

Humans have the remarkable ability to mentally travel through past and future subjective times (Suddendorf & Corballis, 1997; Tulving, 2002). This consciousness of time emerges (at least in part) from an internalized view of the past and future as parts of a temporal framework in which we locate life events (Friedman, 2005). When mentally travelling to the past, we often feel that events have occurred at particular points in time, although we may not necessarily know their exact date (Thompson, Skowronski, Larsen, & Betz, 1996). There is substantial evidence that this temporal information often is not an intrinsic property of memories but instead is inferred or reconstructed using various processes (Friedman, 1993, 2004). Little is known about whether similar construction processes are also used to locate imagined events in future times (Friedman, 2005). In the present study, we sought to address this question by investigating strategies that people use to determine the times of past and future personal events.

The times of past events can be determined using three types of information: *locations, distances,* and *order* (for review, see Friedman, 1993, 2004). Locations refer to particular points in conventional (e.g., parts of days, months, years), natural (e.g., seasons), or personal (e.g., lifetime periods) time patterns. Examples include recalling that an event happened on a weekend, during winter, or when I was in college. According to time tagging theories (Flexser & Bower, 1974; Hasher & Zacks, 1979), such temporal information is automatically assigned to the event at encoding, while for reconstructive theories (Friedman & Wilkins, 1985; Shum, 1998; Thompson et al., 1996), locations are often not intrinsic properties of memories but are reconstructed using contextual details associated with an event (i.e., persons, places, activities, or any other content) and general knowledge of time patterns and events of one's life (e.g., knowledge of autobiographical periods or specific landmark events). Distances refer to the amount of time that has

elapsed between a particular event and the present. Distance-based processes can give the impression that an event happened a long time ago or recently, in part due to some memory properties, such as its vividness (Friedman, 2001). Finally, order refers to before-after relations between events, which can be used to place events relative to each other (Friedman, 2007). These three types of temporal information may each contribute to memory for the times of past events, although people are especially adept at determining temporal locations in the many patterns that structure their lives (Friedman, 1993, 2004).

There is substantial evidence that the temporal location of past events is most frequently determined using reconstructive processes (for review, see Friedman, 1993, 2004; Thompson et al., 1996). For example, based on verbal reports of memory strategies, Friedman (1987) showed that when attempting to date an earthquake that occurred 9 months earlier, the majority of participants did not retrieve the date directly, but instead inferred the time of the earthquake from other information (e.g., by relating the event to a routine or another event whose time was recalled). In the same vein, studies from Thompson, Skowronski, and Betz (1993) and Skowronski, Betz, Thompson, and Larsen (1995) demonstrated that people frequently use reconstructive strategies to date events from their personal past. In these studies, participants were asked to date a series of personal events that had been recorded in a diary and to report the strategies they used for locating these events in time. It was found that participants most frequently reported having used knowledge of personal life periods (e.g., the final part of a semester, a vacation in Europe) to infer when past events occurred (this strategy was used for 29 % of events in Thompson et al. and for 40 % of events in Skowronski et al.). Only a few events (18 % in Thompson et al. and 10 % in Skowronski et al.) were directly located in time. Other studies that used a think-aloud procedure showed that people frequently mentioned both personal (e.g., when I first went to the USA) and public (e.g., during the

war) periods when attempting to locate specific past events in time (Brown, 1990; Brown, Schweickart, & Svob, 2016; Zebian & Brown, 2014).

While memory for the times of past events has received much attention, little is known about how people estimate the times of personal events that might happen in the future. By the age of five, children have a differentiated sense of the future, which allows them to judge future distances; by middle childhood, they can use multiple representations of conventional time patterns (e.g. parts of the day, week, month, and year) to locate future events in time (Friedman, 2000, 2002, 2005). Once these temporal structures are fully developed, future times might be determined or inferred using various processes. For instance, people might use culturally shared knowledge about the timing of major life events (e.g., marriage, first job, retirement; Berntsen & Rubin, 2004) and more idiosyncratic autobiographical periods (e.g., when I'll move to France; D'Argembeau & Mathy, 2011; Thomsen, 2015) for locating imagined events in future times, and some planned events might serve as reference points (or temporal landmarks; Shum, 1998) for determining the location of other future events. Interestingly, a recent fMRI study has shown that judgments of temporal order recruit a common neural network for past and future events, suggesting that (at least partly) similar processes are used for determining the times of past and future events (D'Argembeau, Jeunehomme, Majerus, Bastin, & Salmon, 2015). However, the precise nature of these processes remains to be investigated in detail.

The aim of the present study was to address this question by examining the strategies that people use to locate personal events in past and future times. Participants were first asked to generate a series of past and future events and, for each event, they then described everything that came to their minds while attempting to determine when this event occurred (past condition) or will likely occur (future condition). Each event

was also rated on several scales assessing the phenomenological characteristics of mental representations (e.g., vividness, personal importance, affective valence).

Following previous studies showing that memory for time is largely reconstructive (Brown, 1990; Friedman, 1993, 2004; Thompson et al., 1996), we expected that participants would frequently rely on reconstructive strategies to locate past events in time. Furthermore, we hypothesized that some of the main strategies used to infer the location of past events (i.e., linking events to life periods or landmark events, using general knowledge about patterns that structure one's life; Thompson et al., 1993) would also play an important role in determining the times of imagined future events. However, there might also be differences in the processes used to locate past and future events in time. Theoretical and empirical arguments suggest the existence of asymmetries between remembering the past and imagining the future (for discussion of whether or not these asymmetries imply that episodic remembering and future thinking are different in kind, see (Michaelian, 2016; Perrin, 2016). For example, in remembering there is some (albeit imperfect) correspondence between the subject's current representation of a past event and the actual occurrence of this event in the past, whereas future thoughts are about events that have not yet occurred and thus may or may not actually occur. This asymmetry between mental representations of the past and future may affect the use of some temporal location processes. In particular, contextual details of represented episodes (e.g., details about the weather, persons, locations, and so on) might be more frequently used to infer the temporal location of past than future events because of differences in the epistemic status of events (i.e., for past events, event details are shaped by what actually happened and can thus offer clues about temporal location, whereas details of future events are mainly constrained by imagination processes).

In addition to examining the strategies that people use to locate personal events in time, we also sought to determine whether the dates of some future events can be directly accessed, as is the case for some past events (Friedman, 1987; Thompson et al., 1993). Furthermore, we explored whether events that are directly located in time present distinguishing features. In particular, we predicted that events whose dates are directly determined would be judged more important for personal goals than events whose dates need to be inferred using reconstructive processes.

Method

Participants

Thirty-nine young adults volunteered to participate in the study. They were mostly undergraduate students recruited at the University of Liège. Two participants were excluded because of a history of depression (treated with antidepressant drugs) or brain injury. The final sample consisted of 37 participants (24 females), ranging in age from 18 to 25 years (M = 22.49, SD = 1.63). The participants were all native French speakers (four of them were native bilinguals) and reported to be free of neurologic, psychiatric, and language disorders. The sample size was estimated a priori using G*Power 3 (Faul, Erdfelder, Lang, & Buchner, 2007) in order to achieve a statistical power of above 80%, considering an alpha of .05 and a medium within-subjects effect size (d = 0.50). This study was approved by the Ethics Committee of the Faculty of Psychology of the University of Liège.

Materials and Procedure

Participants were asked to think aloud while they attempted to locate a series of past and

future events in time. The experimental task was inspired by previous work on past event dating (Brown, 1990; Brown et al., 2016; Nourkova & Brown, 2015) and involved three phases. First, participants had to recall ten past events and to imagine ten future events in response to cue words (event-generation phase). Twenty cue words referring to common places and objects (e.g., book, apartment, restaurant, dog) were divided into two lists of ten cues that were matched for frequency of use and imageability (Desrochers & Thompson, 2009). The allocation of the two lists to the past and future conditions and the order of presentation of the two conditions were counterbalanced across participants. For each cue word, participants were instructed to remember or imagine a personal and specific event (i.e., a unique event occurring in a particular place at a particular time, and lasting no more than 24 hours). A brief description of each generated event was written down by the experimenter.

Immediately following the event-generation phase, the descriptions of past and future events that had been produced were presented one at a time and, for each event, participants were asked to describe everything that came to their minds (i.e., to think aloud; Fox, Ericsson, & Best, 2011) while they attempted to determine as precisely as possible when the event occurred (past condition) or will likely occur (future condition). To avoid influencing temporal location processes, the instructions did not specify which type of temporal information should be reported (e.g., days, months, years). We considered that an event was located in time if the participant could provide at least the year during which the event happened (past condition) or would happen (future condition); note, however, that the majority of past and future events received a more precise temporal location. All verbal protocols collected during the think-aloud task were audio-recorded. For each trial, participants were also asked to rate their degree of certainty

in the reported temporal location on a 7-point Likert scale (from 1 = extremely weak, to 7 = extremely strong).

After having located all events in time, participants were asked to rate each event on several 7-point Likert scales: the clarity of event representation (from 1 = not at all clear, to 7 = extremely clear), emotional valence (from -3 = very negative, to +3 = very positive, with 0 = neutral), importance for personal goals (from 1 = not important at all, to 7 = very important), sense of mental time travel (from 1 = not at all, to 7 = totally), subjective temporal distance (from 1 = very close, to 7 = very distant), previous thought about the event (from 1 = never, to 7 = very often), and previous thought about when the event occurred or would occur (from 1 = never, to 7 = very often).

Scoring

All the audio-recorded verbal protocols obtained while participants attempted to locate events in time were transcribed for scoring. When the temporal location of an event was immediately produced (i.e., without using any strategy), this was scored as direct event dating. When temporal location was not directly produced, we scored the strategies used by the participants during the event-dating phase. To characterize these dating strategies, we created a scoring grid based on strategies identified in previous studies of memory for the times of past events (Friedman, 1987; Jack, Friedman, Reese, & Zajac, 2016; Thompson et al., 1993), as well as additional strategies (i.e., categories 3 and 4 described below) that were identified when reading the verbal protocols of participants. In the end, five categories of strategies were considered (see Table 1 for a description of each category and examples of corresponding verbal reports): (1) lifetime periods/extended events, (2) specific events (landmarks), (3) conventional time patterns, (4) factual information, and (5) contextual details; events that were not located in time were scored

as uncategorized.

As participants could rely on several strategies to date a particular event, each verbal protocol was scored for the presence or absence of each strategy. Thus, the dating protocol obtained for a particular event could include more than one type of strategy; however, a particular piece of information within the protocol was classified in only one category. For example, the following verbal protocol contained two strategies: *If it is going to happen as I wish, it will occur during next summer vacation, so between early July and mid-August… To avoid mass tourism, I would say that it will be during the third week of July;* "Next summer vacation" was coded as a lifetime period/extended event and "to avoid mass tourism" was coded as factual information.

All transcriptions were scored by the first author and the reliability of our coding scheme was assessed by asking a second trained rater who was blind to the hypotheses to score a random selection of 20% of the verbal protocols. Percentages of raw agreements showed substantial inter-rater reliability for the five categories of interest: 87% for lifetime periods/extended events, 94% for specific events, 97% for conventional time patterns, 81% for factual information, and 94% for contextual details. Cohen's kappa was 0.75 for lifetime periods/extended events; the kappa coefficient was not computed for the other four categories because their marginal distributions were not uniform (see von Eye & von Eye, 2008).

Table 1. Definition and examples of categories of temporal location strategies for past and future events

	Definition	Examples
Lifetime periods/extended events	Use of knowledge about lifetime periods or extended events for attempting to locate the event in time	It was during my Master's degree (past event); It will happen during my internship (future event)
Specific events (landmarks)	Use of another specific event for which the precise temporal location is known (i.e., temporal landmark)	I met John a few days after my 25th birthday (past event); It would be just before my thesis defence which is scheduled on the 1st of November 2016 (future event)
Contextual details	Use of event details (such as locations, activities, persons, or the weather) to infer its temporal location	I was with François that day, so it certainly happened one month ago (past event); It has to be snowy, so it will likely happen in December (future event)
Conventional time patterns	Reasoning using calendar time (weeks, months, years) or natural time patterns (e.g., seasons)	It was a Monday, during this year, on October or November but I would say on October (past event); It will happen during the 1st or the 2nd week of July, more likely the first days of July (future event)
Factual information	Use of general knowledge (about self, others, or the world) to infer the temporal location of the event	At that time, my brother was still a baby, he is 6 years younger than me so it was on July 2005 (past event); To avoid mass tourism, I will go there during the 1st week of September (future event)

Results

In total, 364 past events and 366 future events were included in the analyses; another ten events were excluded because they did not meet the specificity criterion. For each participant, data were averaged across events in each condition (past vs. future) for statistical analyses.

Direct retrieval versus reconstruction of temporal location

As expected, participants mainly used reconstructive strategies to locate past and future events in time (see Figure 1). On average, the temporal location of events was directly produced for only 28% of past events and 25% of future events; very few events were uncategorized (2% in the past condition, and 1% in the future condition). A 2 (mode of location: direct vs. reconstructive) by 2 (temporal orientation: past vs. future) repeated-measures analysis of variance (ANOVA) confirmed that events were more frequently located in time using reconstructive strategies, $F(1, 36) = 102.33$, $p < .001$, $\eta_p^2 = .74$; there was no main effect of temporal orientation, $F(1, 36) = 0.73$, $p = .39$, and no interaction, $F(1, 36) = 0.67$, $p = .42$.

We also investigated whether the certainty with which participants located events in time differed as a function of their mode of location and temporal orientation (data from five participants were not included in this analysis because they did not report any direct retrieval of temporal location for either past or future events). An ANOVA showed a significant main effect of the mode of location, $F(1, 31) = 18.87$, $p < .001$, $\eta_p^2 = .38$, but no main effect of temporal orientation, $F(1, 31) = 1.19$, $p = .28$, and no interaction, $F(1, 31) = 0.45$, $p = .51$. The degree of certainty of temporal location was judged higher for events whose dates were directly retrieved ($M = 5.76$, $SD = 0.77$) than for events that were dated using reconstructive strategies ($M = 4.72$, $SD = 0.81$).

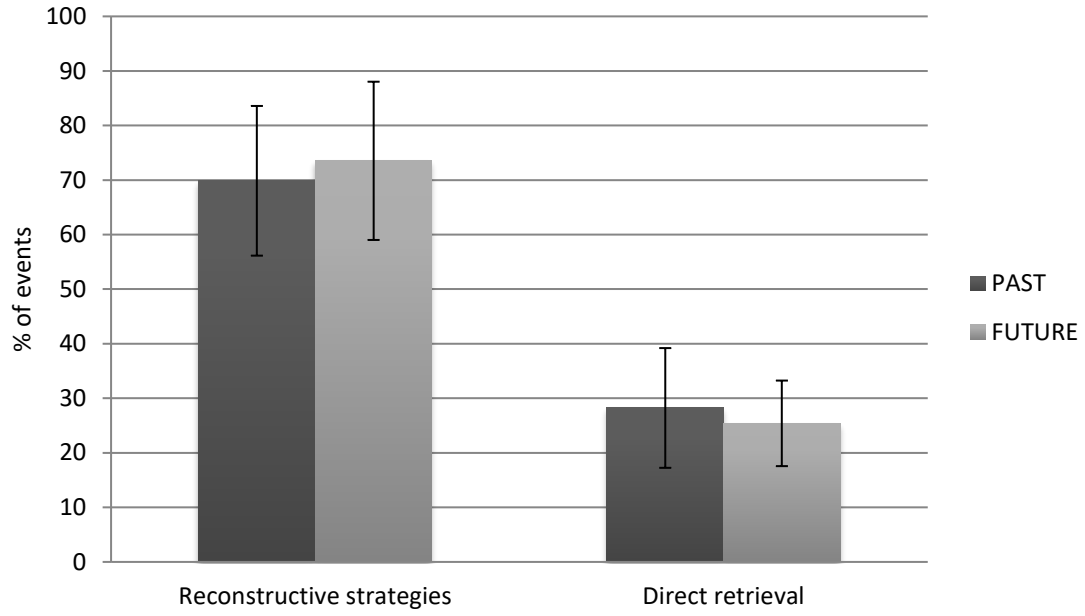

Figure 1. Mean percentage of past and future events that were located in time using reconstructive strategies or direct retrieval. Error bars represent the 95% confidence interval for within-subject designs (O'Brien & Cousineau, 2014).

Frequency of reconstructive strategies

The mean percentages of the various strategies used for locating past and future events in time are shown in Figure 2. A 2 (temporal orientation) by 5 (type of strategy) ANOVA showed a significant main effect of types of strategies, $F(4, 144) = 61.72$, $p < .001$, $\eta_p^2 = .63$. As can be seen from Figure 2, knowledge of autobiographical periods/extended events was the strategy most frequently used by participants to locate both past and future events in time; this strategy was significantly used more frequently than all other strategies (all *ps* < .001). Factual information was also frequently used by participants to locate past and future events in time and was significantly more frequent than all the other remaining strategies (all *ps* < .001). Differences in the frequency of use of specific events, knowledge of conventional time patterns, and contextual details did not reach statistical significance (all *ps* > .053).

The ANOVA also showed that the main effect of temporal orientation was not significant, $F(1, 36) = 3.44$, $p = .07$, $\eta_p^2 = .09$, but there was a significant interaction between temporal orientation and the types of strategies used by participants, $F(3.64, 131.14) = 4.34$, $p = .003$, $\eta_p^2 = .11$ (the Huynh-Feldt correction was used here because the assumption of sphericity was violated and ε was greater than .75). As can be seen from Figure 2, this interaction was due to a significantly higher frequency of use of contextual details to infer the temporal location of past events than future events ($p < .001$). Apart from contextual details, the frequency of use of temporal location strategies did not differ between past and future events (all *ps* > .32).

We also computed the frequency with which participants used more than one reconstructive strategy for locating past and future events in time. This showed that the use of multiple strategies (2 or more) was more frequent for past events ($M = 53\%$ of events, $SD = 31$) than for future events ($M = 34\%$ of events, $SD = 24$), $t(36) = 3.68$, $p < .001$, $d = 0.61$.

Finally, we investigated whether the certainty of temporal location varied with the use of some reconstructive strategies. A 2 (use of strategy: yes vs. no) by 2 (temporal orientation: past vs. future) ANOVA on certainty ratings indicated that the certainty of temporal location did not differ between events that were located with or without the use of lifetime periods/extended events, $F(1, 31) = 0.004$, $p = .95$; there was no interaction between the use of this strategy and temporal orientation, $F(1, 31) = 2.52$, $p = .12$ (note that 5 participants had to be excluded from the analysis because they did not use this strategy). Similarly, the certainty of temporal location did not differ between events that were located with or without the use of factual information, $F(1, 29) = 0.35$, $p = .56$, and there was no interaction between the use of this strategy and temporal orientation, $F(1, 29) = 0.02$, $p = .89$ (7 participants had to be excluded from the analysis because they did

not use this strategy). Thus, the certainty with which participants located events in time was not related to the use of lifetime periods/extended events or factual information.[5] The certainty of temporal location could not be examined for the other types of strategies due to missing values for either past or future events in a high number of participants.

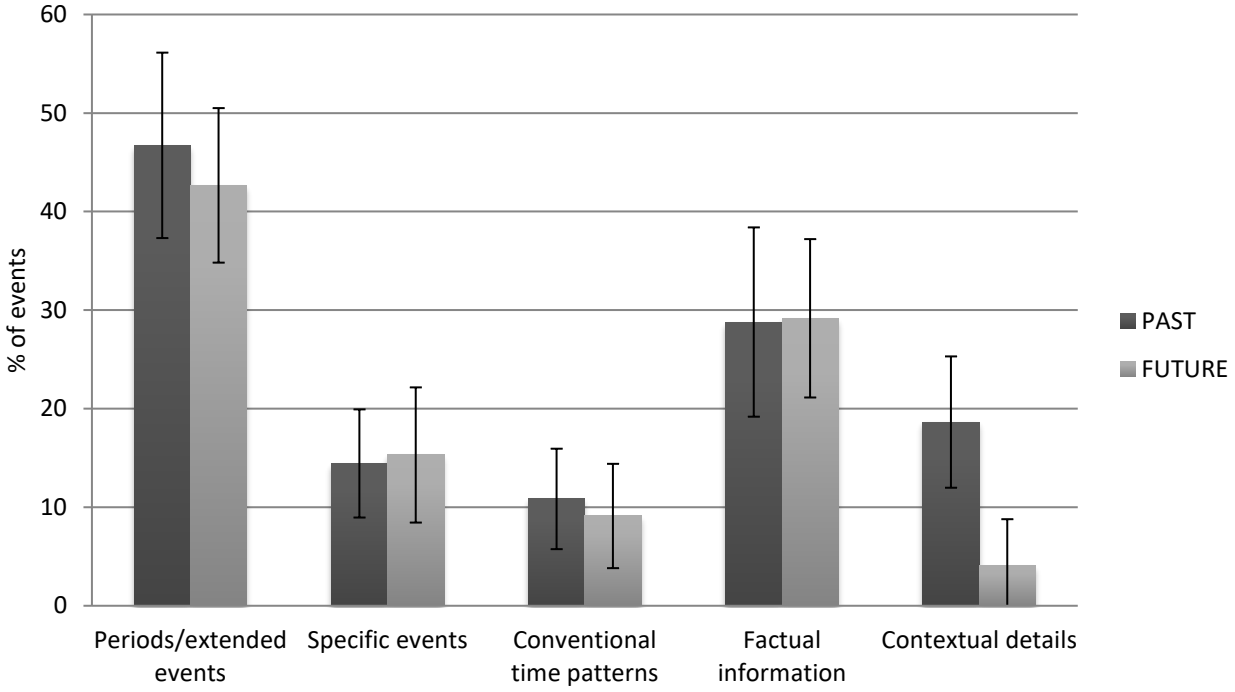

Figure 2. Mean percentage of temporal location strategies for past and future events. Error bars represent the 95% confidence interval for within-subject designs (O'Brien & Cousineau, 2014).

[5] For past events, we also found that the certainty of dating did not differ between events that were located with or without the use of contextual details, $t(25) = -0.52$, $p = .61$ (but note that 11 participants had to be excluded from this analysis because they did not use this strategy).

Event characteristics that are associated with direct access to temporal location

Our next goal was to investigate whether events that were directly located in time presented distinguishing features. To address this question, the ratings of past and future event features were averaged separately for events that were directly located in time and events that required reconstructive strategies[6]. A series of paired *t*-tests showed that events that were directly located in time were subjectively more vivid, were associated with a stronger feeling of time travel, and were judged more important for personal goals than events that were located in time using reconstructive strategies (see Table 2). The results also showed that events that were directly dated were closer to the present (in terms of both objective and subjective temporal distance). Finally, participants indicated that they had more frequently thought about the temporal location of directly located events than non-directly located events. Event rehearsal and affective valence did not significantly differ between the two kinds of events.

[6] Data from past and future events were collapsed for these analyses because five participants did not produce direct temporal locations either for the past or the future. However, to examine whether differences between directly located and reconstructed events were similar for the past and future, we also conducted 2 (direct retrieval *vs.* reconstruction) by 2 (past *vs.* future) ANOVAs on each event characteristic for participants who reported at least one event per condition (i.e., 32 participants). These additional analyses showed similar differences between directly and reconstructed events as presented in Table 2 and, importantly, we did not find any significant interaction between temporal orientation and mode of temporal location (all $Fs(1,31) < 2.37$, $ps > .13$), indicating that the event characteristics that differentiated between direct and reconstructive modes of temporal location were similar for past and future events.

Table 2. Mean ratings (and standard deviations) of event characteristics in direct retrieval and reconstruction of temporal information

	Direct retrieval	Reconstruction	*t*(35)	*p*	*d*
Subjective vividness	5.35 (0.82)	4.46 (0.79)	5.26	<.001	0.89
Affective valence	1.33 (0.82)	1.11 (0.68)	1.56	.13	0.26
Personal importance	4.65 (1.13)	4.11 (0.70)	2.94	.006	0.50
Mental time travel	4.95 (0.99)	4.33 (0.82)	4.26	<.001	0.72
Event rehearsal	3.63 (1.15)	3.41 (0.64)	1.26	.22	0.21
Time rehearsal	3.37 (1.09)	2.88 (0.75)	3.06	.004	0.52
Subjective temporal distance	3.09 (0.88)	4.49 (0.51)	-8.90	<.001	1.50
Temporal location (months)	29.39 (30.28)	57.88 (32.69)	-4.90	<.001	0.83

Note. All dimensions were assessed on a Likert scale ranging from 1 to 7, except affective valence, which was assessed on a Likert scale ranging from -3 to 3, and temporal distance from the present (which was assessed in months). Data from one participant were not analyzed (n = 36) because no direct retrieval was used to locate events in time.

Temporal distribution of events that were directly located in time

Considering the previous finding that, on average, events that were directly located in time were closer to the present, we aimed to further examine the temporal distribution of directly located events for the past and the future. The majority of directly located events were distributed within a one-year interval from the present, both for the past (55% of directly located events referred to the previous year, with each following year containing less than 10% of directly located events) and the future (77% of directly located events referred to the next year, with each following year containing less than 5% of directly located events). The temporal distribution of directly located events within a two-year interval from the present (i.e., one year in the past and one year in the future) is shown on Figure 3 using one-month time bins. As can be seen, most directly located events referred to the very recent past and future (i.e., the previous or next month), with the percentage

of directly located events declining rapidly with increasing temporal distance in both the past and the future. As also shown on Figure 3, such a decline was not observed for the temporal distribution of events whose dates were reconstructed (i.e., the percentages of reconstructed events were more evenly distributed across temporal distances).

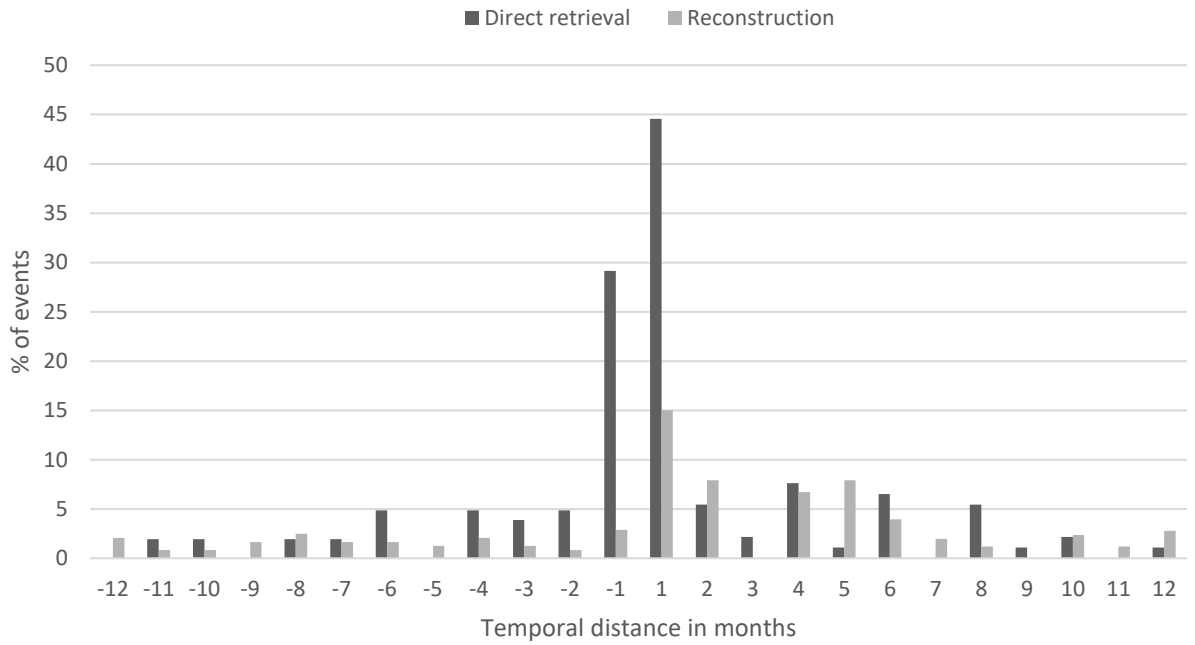

Figure 3. Temporal distribution of past (left panel) and future (right panel) events associated with direct access to temporal information and with temporal reconstruction. Each bar represents the percentage of directly located or reconstructed events in a given one-month time bin (i.e., number of directly located or reconstructed events in this time bin / total number of directly located or reconstructed events).

Discussion

While memory for the times of past events has attracted much attention, little is known about how envisioned future events are located in time. To address this question, we investigated the strategies that people use when attempting to determine the temporal location of past and future events. The results showed that people rarely have a direct access to the temporal location of past and future events, but instead use reconstructive and inferential strategies. Reference to lifetime periods and factual knowledge were the most frequently used strategies to determine the times of both past and future events, and specific landmarks were also sometimes used for both types of events. Finally, contextual details also contributed to temporal location attribution, but mainly for past events.

In line with previous studies on memory for the times of personal and public events (Brown, 1990; Friedman, 1987; Skowronski et al., 1995; Thompson et al., 1993), we found that only a minority of past events were directly located in time. This finding adds support to the view that temporal information is often not an intrinsic feature of memories, but is instead inferred and reconstructed using various strategies (Friedman, 1993, 2004; Thompson et al., 1996). In the present study, the most frequent strategy for dating past events was the use of autobiographical periods, which is consistent with previous studies (see e.g., Arbuthnott & Brown, 2009; Skowronski et al., 1995; Thompson et al., 1993). Factual knowledge and event details were also frequently used to infer the location of past events, and participants sometimes referred to other specific events that served as temporal landmarks (Shum, 1998). Overall, these findings are consistent with current knowledge about the processes underlying memory for the times of past events (Friedman, 2004).

An important finding of this study is that largely similar strategies were used to locate future events in time. As for past events, knowledge of autobiographical periods

was most frequently reported, supporting the view that people have some knowledge of future lifetime periods (e.g., *after my post-doc*) that can be used to determine the temporal location of imagined future events (D'Argembeau, 2015; Thomsen, 2015). Participants also frequently used factual knowledge to infer when imagined events would likely occur. More specifically, they referred to general information about the self (e.g., I know that I will busy next month), others (e.g., my friend will not be able to join me next summer because she got an internship abroad), and the world (e.g., the concerts generally take place in September) to estimate the temporal location of envisioned future events. Furthermore, some future events whose dates were known served as landmarks for locating other imagined events in time, paralleling the use of temporal landmarks in dating past events (Shum, 1998). In future studies, it would be interesting to further investigate the nature of these landmark events; one possibility is that the dates of future events that are related to important personal goals are highly accessible (see below) and serve as points of reference for locating other future events in time.

A notable difference between the past and future in terms of temporal location strategies was that participants used contextual details (such as locations, activities, persons, or the weather) to a greater extent for past than future events. A possible explanation for this finding is that details of past events are constrained by what happened and thus can be used as clues for determining temporal location, whereas details of future events are more malleable and influenced by imagination processes, thus being less relevant for inferring temporal location. Indeed, details that helped participants to determine the temporal location of future events were mainly details about the weather (70% of reported event details) suggesting that other contextual details (such as locations, activities, persons) may not provide relevant information for inferring temporal location. This difference in the use of contextual details for locating past and future events in time

might thus be related to asymmetries between remembering and future thinking in the actuality of represented events (Perrin, 2016).

Another difference between the past and future that might influence temporal location processes is that the dates of past events are fixed and can be verified, whereas the dates of future events are more malleable and may change over time (e.g., the temporal location of imagined future events might be revised depending on current goals, emotional states, or unplanned intervening future events). Thus, when attempting to locate imagined events in time, people might be aware of the fact that the dates of future events might change, which might influence temporal location processes. In addition, differences in the causal structure of event sequences might also affect the way people estimate the times of personal events: past events followed a determined causal order (i.e., some events resulted from other events), which might be used to reconstruct temporal locations, whereas the causal structure of imagined future events is more open (although most future events are represented as parts of higher-order event sequences; D'Argembeau & Demblon, 2012) and thus might be a less reliable indicator of temporal location.

Interestingly, we found that a substantial proportion of past events (53%, on average) were located using a combination of (i.e., two or more) reconstructive strategies, which is consistent with previous findings (Arbuthnott & Brown, 2009). The use of multiple reconstructive strategies was significantly less frequent for future events (occurring in only 34% of events, on average). This suggests that the temporal location of past events often need to be refined or confirmed using multiple sources of information, perhaps as means to check the accuracy of reported dates (e.g., information derived from a past lifetime period can be confirmed by contextual details or factual knowledge). Again, this finding points to some asymmetries in the processes used to locate past and

future events in time, which might be related to differences in the epistemic status of remembering and future thinking (Perrin, 2016).

Although temporal location was most frequently inferred using reconstructive strategies, it is interesting to note that some past and future events were directly located in time. For past events, this finding suggests that some episodes might be time-tagged at encoding, such that time information can later be directly retrieved from memory (Friedman, 1993, 2004). Another explanation would be that temporal information was not encoded in memory during the initial episode but instead had been reconstructed during a previous retrieval attempt; this reconstructed date might then be encoded in memory along with the event representation, such that it can directly be accessed during subsequent retrieval occasions. In the same vein, a direct access to the temporal location of future events might occur because people have already thought about these future events as well as their possible dates on a previous occasion, such that this information has been encoded in memory (as part of "memories of the future"; Jeunehomme & D'Argembeau, in press; Szpunar, Addis, McLelland, & Schacter, 2013). In line with this view, the present results showed that participants had more frequently thought about the times of events that were directly located in time. Recent findings have shown that previously imagined future events can be directly accessed in response to relevant cues (Cole, Staugaard, & Berntsen, 2016; Jeunehomme & D'Argembeau, 2016), and a similar phenomenon might thus occur for the temporal location of imagined events.

Importantly, our findings showed that a number of event features differentiated between events that were directly located in time and events whose dates were reconstructed. Indeed, directly located events were rated as more vivid and associated with a stronger feeling of mental time travel, were more important for personal goals, and were less temporally distant than events located in time using reconstructive strategies. It

should be noted that some of these event features (e.g., vividness and personal importance) tend to co-vary with each other and it would be interesting in future studies (by collecting a greater number of directly located events) to further investigate the specific contribution of each of these features to direct temporal location processes. Be that as it may, the present findings suggest that the times of events that are personally important and close to the present (i.e., within the past and next month) may be particularly accessible. This increased accessibility might facilitate plans for the near future and contribute to successful goal pursuit.

On a more general theoretical level, our results support the view that lifetime periods are central components of autobiographical knowledge that play an important role in locating past and future events in time (Thomsen, 2015). This key role of lifetime periods can be interpreted in terms of hierarchical models of autobiographical memory (Conway, 2005; Conway & Pleydell-Pearce, 2000), according to which autobiographical knowledge form partonomies in which specific events are part of general events which are themselves nested in lifetime periods. On this view, higher-order autobiographical knowledge (general events and lifetime periods) contextualizes specific memories in an individual's personal life and contributes, in particular, to determine the temporal location of events. It has been recently proposed that the boundaries of such lifetime periods are defined by transitions that bring about significant changes to one's life circumstances (e.g., relocation; Brown, 2016), and there is indeed evidence that such transitions play a key role in locating specific past events in time (Brown et al., 2016; Zebian & Brown, 2014). Interestingly, our results suggest that mental representations of autobiographical periods can not only be formed following actual changes in material conditions (e.g., changes of job, house, partner), but also in response to expected changes in the future (e.g., when I will have graduated, when I will be living in Paris, when I move in with

Claire; note that some of these expected transitional events are likely governed by cultural life scripts; Berntsen & Rubin, 2004). These anticipated life transitions may play a key role in locating imagined events in future times.

Since the upsurge of interest in episodic future thinking about 10 years ago (Atance & O'Neill, 2001; Schacter & Addis, 2007; Suddendorf & Corballis, 2007), most studies have focused on the contribution of episodic and semantic memory (i.e., representations of specific past experiences as well as event schema) in the mental simulation of specific future events (for review, see Schacter et al., 2012). However, there is now substantial evidence that future event representations are structured by higher-order autobiographical knowledge (i.e., representations of personal general events and lifetime periods; D'Argembeau, 2015). In particular, it has been shown that general knowledge about one's personal future plays an important role in the construction and organization of episodic future thoughts (D'Argembeau & Mathy, 2011; D'Argembeau & Demblon, 2012) and may contribute to the subjective feeling of mental time travel (D'Argembeau & Van der Linden, 2012). The present study adds to this growing body of evidence by demonstrating that autobiographical knowledge also plays an important role in locating imagined events in time. A key difference between episodic future thoughts and mental representations of atemporal events (i.e., events not explicitly located in the past or future; de Vito, Gamboz, & Brandimonte, 2012; Hassabis, Kumaran, Vann, & Maguire, 2007) may be precisely that only the former are placed in an autobiographical context.

Finally, some issues regarding the validity of think-aloud protocols should be acknowledged. One could legitimately argue that thinking aloud might alter temporal location processes (reactivity issue) and that a verbal protocol might not accurately reflect the underlying location processes (nonveridicality issue) because participants might not

report some thought or, conversely, might report mental events that did not occur (Russo, Johnson & Stephens, 1989). Although these validity issues cannot be totally excluded, it should be noted that a recent meta-analysis (Fox et al., 2011) has shown that thinking aloud does not alter task performance, provided that participants are instructed to simply verbalize their thoughts (as was the case in the present study) rather than directing them to provide explanations for their thought processes. Furthermore, previous studies that used a think-aloud procedure to investigate temporal location processes yielded similar conclusions as studies that used other methods (Arbuthnott & Brown, 2009; Friedman, 1987; Skowronski et al., 1995; Thompson et al., 1993), thus providing evidence for the validity of think-aloud protocols for investigating strategies involved in representing the times of personal events.

To conclude, the present study shows that the temporal location of past and future events is only rarely directly accessed and instead mainly relies on reconstructive and inferential processes. Most frequently, people use general knowledge about the periods of their life to estimate the temporal location of both past and future events. This suggests that lifetime periods are central components of the personal timeline that supports mental travels to the past and future.

Investigation of the role of personal goals in the temporal location of future personal events

In **Study 2**, we sought to investigate the influence of personal goals in the temporal location of future events. To address this question, we asked participants to imagine a series of future events that were cued by personal goals, familiar places, or scenarios imposed by the experimenter, and, for each event, they then described everything that came to their minds while attempting to determine when this event will likely occur.

Following findings of Study 1, we expected that participants would frequently rely on reconstructive or inferential strategies to locate future events in time, regardless of the nature of the event (i.e., related to goals, places or scenarios). Moreover, considering the role of personal goals in the construction and organisation of episodic future thoughts, we hypothesised that goal-related events would be directly located in time more frequently than place- and scenario-related events. Finally, because personal goals may drive the organisation of autobiographical knowledge (and particularly of lifetime periods), we predicted that when future events are not directly located in time, anticipated lifetime periods would be more frequently used as a temporal location strategy for goal-related than place- or scenario-related events.

STUDY 2

“Envisioning the times of future events: the role of personal goals”

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Abstract

Episodic future thinking refers to the human capacity to imagine or simulate events that might occur in one's personal future. Previous studies have shown that personal goals guide the construction and organization of episodic future thoughts, and here we sought to investigate the role of personal goals in the process of locating imagined events in time. Using a think-aloud protocol, we found that dates were directly accessed more frequently for goal-related than goal-unrelated future events, and the goal-relevance of events was a significant predictor of direct access to temporal information on a trial-by-trial basis. Furthermore, when an event was not directly dated, references to anticipated lifetime periods were more frequently used as a strategy to determine when a goal-related event might occur. Together, these findings shed new light on the mechanisms by which personal goals contribute to the location of imagined events in future times.

Introduction

People spend a great deal of time envisioning events and scenarios that might happen in their personal future, a capacity referred to as episodic future thinking (Atance & O'Neill, 2001; Suddendorf & Corballis, 2007). While the mechanisms and functions of episodic future thought have been intensively studied in the past few years (Schacter, Benoit, & Szpunar, 2017), little is known about how people estimate the times when imagined future events are expected to happen (Friedman, 2005). A recent study showed that the strategies used to date past and future events are largely the same, suggesting that common processes may be used for locating personal events in past and future times (Ben Malek, Berna, & D'Argembeau, 2017; see also D'Argembeau, Jeunehomme, Majerus, Bastin, & Salmon, 2015). It was found that participants most frequently used general knowledge about their life to infer or reconstruct temporal locations, in line with previous research on memory for the time of past events (for review, see Friedman, 1993, 2004; Thompson, Skowronski, Larsen, & Betz, 1996). Interestingly, however, some events were directly dated and these were judged to be more important for personal goals. This finding suggests that knowledge about personal goals facilitates the estimation of when imagined events are expected to occur, although this conclusion is limited by the correlational nature of the data. In the present study, we aim to examine more directly the role of personal goals in the temporal location process by experimentally manipulating the involvement of goals in imagined events.

A growing body of evidence indicates that episodic future thinking involves the mental simulation of specific events as well as more general autobiographical knowledge that contextualizes imagined scenarios in the individual's life story (D'Argembeau, 2015). Specifically, research has shown that people's aspirations and general expectations about their personal future, including anticipated lifetime periods (e.g., "when I'll be

married") and general events (e.g., "my trip to Brazil next summer"), guide the construction of episodic future thoughts (D'Argembeau & Mathy, 2011) and help organize imagined events in coherent themes and sequences (D'Argembeau & Demblon, 2012). The evidence further suggests that personal goals is an important factor that drives the construction and organization of future-oriented autobiographical knowledge (D'Argembeau, 2016; Thomsen, 2015). Goals are cognitive representations of desired states or outcomes (Austin & Vancouver, 1996), and personal goals may be defined as personally important objectives that individuals pursue in their daily lives (Emmons, 1986; Klinger, 2013; Little, 1983; McAdams, 2013). Goal-related knowledge is represented in a hierarchical structure that organizes higher-order goals (e.g., having a successful academic career) in sequences of sub-goals (e.g., receiving a PhD degree with highest honors, finding postdoc positions in competitive laboratories) that specify how to attain desired states (Austin & Vancouver, 1996; Wadsworth & Ford, 1983). This hierarchical and sequential representation of goals and sub-goals may drive the construction of a personal timeline that facilitates the temporal location of goal-relevant future events. In turn, the ability to locate goal-relevant events at specific future times may play a critical role in planning and goal pursuit. Indeed, goal achievement often requires a sequence of actions that need to be ordered and carried out at specific times (e.g., on a given day or within a particular temporal window). However, whether and how personal goals contribute to temporal location processes remain to be investigated in detail.

Goal-related knowledge might facilitate the temporal location of imagined future events in at least two ways. First, when envisioning ways to attain desired goals people may consider the exact dates when goal-relevant events will likely occur. The temporal location of some goal-relevant future events may thus be encoded in memory (as part of

"memories of the future"; Jeunehomme & D'Argembeau, 2017; Szpunar, Addis, McLelland & Schacter, 2013), allowing people to directly access temporal information when thinking again about these events. Second, knowledge about personal goals may facilitate the temporal location of associated future events even when exact dates have not been considered on a previous occasion. As noted above, goals may drive the construction of temporally defined autobiographical periods (i.e., anticipated lifetime periods and extended events) that can be used to estimate when specific events might occur (Thomsen, 2015). For example, the goal of doing a postdoc in the U.S. defines a future period of two or three years on one's mental timeline, which can be used to locate specific events in future times (e.g., as occurring before, during or after this period). Goal-relevant future events may be more easily linked to this temporal framework, allowing one to determine when they will likely happen.

To investigate the role of personal goals in the temporal location of future events, in the present study we asked participants to imagine a series of future events that were cued by personal goals, familiar places, or scenarios imposed by the experimenter and, for each event, they then described everything that came to their minds while attempting to determine when this event will likely occur. Following our previous findings (Ben Malek et al., 2017), we expected that participants would frequently rely on inferential strategies (using lifetime periods and factual knowledge, in particular) to locate future events in time, regardless of the nature of events (i.e., related to goals, places or scenarios). However, considering the role of personal goals in the organization of episodic future thinking (D'Argembeau, 2016), we hypothesized that goal-related events would be directly located in time more frequently than place- and scenario-related events. Furthermore, because personal goals are strongly linked to autobiographical knowledge structures and may drive the organization of lifetime periods (Conway, 2005;

D'Argembeau, 2015; Thomsen, 2015), we hypothesized that when future events are not directly located in time, anticipated lifetime periods would be more frequently used as a temporal location strategy for goal-related than place- or scenario-related events.

Method

Participants

Fifty young adults who were mostly undergraduate students at the University of Liège volunteered to participate in the study. One participant was excluded because she could not follow the instructions. The final sample consisted of 49 participants (24 females), ranging in age from 18 to 25 years (M = 22.98, SD = 1.96). This sample size was estimated a priori using G*Power 3 (Faul, Erdfelder, Lang, & Buchner, 2007) in order to achieve a statistical power of above 90% to detect a significant difference between two conditions, considering an alpha of .05 and a medium within-subjects effect size (d = 0.50). Participants were all native French speakers (one of them was a native bilingual) and reported to be free of neurological, psychiatric, and language disorders. This study was approved by the Ethics Committee of the Faculty of Psychology, Speech and Language Therapy, and Education of the University of Liège.

Materials and Procedure

Participants were asked to think aloud while they attempted to locate a series of future events in time. The experimental task was inspired from previous work on past and future event dating (Ben Malek et al., 2017; Brown, 1990; Brown, Schweickart, & Svob, 2016; Nourkova & Brown, 2015) and involved four phases. First, participants were invited to produce six personal goals ('goal' condition; e.g., graduating from university, travelling around the world) and six places ('place' condition) that could be frequently encountered

in their future (e.g., my future apartment, my workplace), which were then used as cues for the imagination of future events. Second, participants were asked to imagine specific events in response to each of these cues; furthermore, six non-personal cues were also presented ('scenario' condition), which represented familiar settings (e.g., imagine walking in a shopping street, imagine sitting in a crowded bar) and were inspired from previous work (Hassabis, Kumaran, Vann, & Maguire, 2007; de Vito, Gamboz & Brandimonte, 2012). For each cue (i.e., goal, place, and scenario), participants were instructed to imagine a personal and specific future event (i.e., a unique event occurring in a particular place at a particular time, and lasting no more than 24 hours). A brief description of each generated event was written down by the experimenter. The three types of cues were presented by block and their order of presentation was counterbalanced across participants.

Immediately following the event-generation phase, the descriptions of future events that had been produced were presented one at a time and, for each event, participants were asked to describe everything that came to their minds (i.e., to think aloud; Fox, Ericsson, & Best, 2011) while they attempted to determine as precisely as possible when the imagined event would likely occur. These verbal protocols were audio-recorded. For each trial, participants were also asked to rate their degree of certainty in the reported temporal location on a 7-point Likert scale (from 1 = extremely weak, to 7 = extremely strong).

After having located all events in time, participants were asked to rate each event on several 7-point Likert scales assessing the clarity of event representation (from 1 = not at all clear, to 7 = extremely clear), affective valence (from -3 = very negative, to +3 = very positive, with 0 = neutral), importance for personal goals (from 1 = not important at all, to 7 = very important), sense of mental time travel (from 1 = not at all, to 7 = totally),

sense of pre-experience (from 1 = not at all, to 7 = totally), subjective distance (1 = very close, 7 = very distant), previous thought about the event (from 1 = never, to 7 = very often), previous thought about when the event would occur (from 1 = never, to 7 = very often), and the likelihood that the event would happen (from 1 = extremely low, to 7 = extremely strong).

Scoring

All the audio-recorded verbal protocols obtained while participants attempted to locate events in time were transcribed for scoring. When the temporal location of an event was immediately produced (i.e., without using any strategy), this was scored as direct event dating. When the temporal location was not directly produced, we scored the strategies used by the participants during the event-dating phase. To characterize these dating strategies, we used a scoring grid based on strategies identified in previous studies on the temporal location of past (Friedman, 1987; Thompson et al., 1993) and future (Ben Malek, Berna & D'Argembeau, 2017) events. Five categories of strategies were considered (see Table 1 for a description of each category and examples of corresponding verbal reports): (1) lifetime periods/extended events, (2) specific events (landmarks), (3) conventional time patterns, (4) factual information, and (5) contextual details. These five categories were not mutually exclusive (i.e., the dating protocol obtained for a particular event could include more than one type of strategy) and each trial was scored for the presence or absence of each category.

All transcriptions were scored by the first author and the reliability of our coding scheme was assessed by asking a second trained rater who was blind to the hypotheses to score a random selection of 15% of the verbal protocols. Percentages of raw agreements showed substantial inter-rater reliability for the five strategies of interest: 90% for lifetime

periods/extended events, 96% for specific events, 87% for conventional time patterns, 85% for factual information, and 92% for contextual details. Cohen's kappa was 0.75 for lifetime periods/extended events; the kappa coefficient was not computed for the other four categories because their marginal distributions were not uniform (see von Eye & von Eye, 2008).

Table 1. Definition and examples of categories of temporal location strategies

Location strategy	Definition	Examples
Lifetime periods/extended events	Use of knowledge about lifetime periods or extended events for attempting to locate the event in time	It will happen during my internship; I will organize the party after the summer vacation
Specific events (landmarks)	Use of another specific event for which the precise temporal location is known (i.e., temporal landmark)	I will meet John a few days after my 25th birthday; It would be just before my thesis defence which is scheduled on the 1st of November 2018
Contextual details	Use of specific details about the target event (i.e., details about the imagined event itself, such as its location, involved activities and persons, or the weather) to infer its temporal location	I imagine it is snowy, so it will likely happen in December; I will be with François that day, so it has to happen next month
Conventional time patterns	Reasoning using calendar time (weeks, months, years) or natural time patterns (e.g., seasons)	It will happen during the 1st or the 2nd week of July, more likely the first days of July; I would say during spring time or summer time, but more likely during summer time
Factual information	Use of general knowledge (about self, others, or the world) to infer the temporal location of the event	To avoid mass tourism, I will go there during the 1st week of September; I know that my brother will be abroad until next February, so we will meet at that time

Results

In total, 863 future events were included in the analyses; 19 additional events were excluded because they did not meet the specificity criterion (i.e., a unique event happening at a specific place and time and lasting no longer than a day; Williams et al., 1996), as determined by the first author. For each participant, data were averaged across events in each condition ('goal', 'place' and 'scenario') for statistical analyses. When the assumptions of the general linear model were violated, robust statistical methods were used (using the 20% trimmed means and 2000 bootstrap samples; Field & Wilcox, 2017).

Event characteristics

The mean ratings and statistical comparisons of event characteristics for goal-related, place-related, and scenario-related events are shown in Table 2. As expected, goal-related events were rated as more important for personal goals than place- and scenario-related events. Furthermore, place-related events were rated as more important than scenario-related events. Other significant differences between conditions were observed for the following characteristics: affective valence, mental time travel, feeling of pre-experience, rehearsal of event content and temporal information, objective temporal distance, and likelihood; subjective vividness and subjective temporal distance did not significantly differ between conditions (see Table 2 for a detailed description of the statistical differences between the three types of events).

Table 2. Mean ratings (and standard deviations) of characteristics of goal-, place- and scenario-related events.

	Goal	Place	Scenario	$F(2,96)$	p	η_p^2
Subjective vividness	3.97 (0.15)	3.96 (0.18)	3.68 (0.18)	2.70	.07	0.05
Affective valence	1.83^a (0.11)	1.53^b (0.14)	1.24^b (0.14)	9.00	<.001	0.16
Importance for personal goals	5.50^a (0.11)	4.72^b (0.18)	3.36^c (0.18)	77.90	<.001	0.62
Mental time travel	4.35^a (0.14)	4.18^a (0.17)	3.50^b (0.17)	26.80	<.001	0.36
Pre-experience	4.02^a (0.18)	3.83^a (0.20)	3.51^b (0.18)	8.10	<.001	0.14
Event rehearsal	4.19^a (0.12)	3.43^b (0.16)	2.82^c (0.12)	47.83	<.001	0.50
Time rehearsal	3.83^a (0.12)	3.29^b (0.17)	2.62^c (0.15)	32.85	<.001	0.40
Subjective temporal distance	4.44 (0.11)	4.58 (0.12)	4.60 (0.14)	0.61	0.54	0.01
Temporal location (months)	55.87^a (6.26)	49.98^a (5.56)	35.40^b (3.87)	7.02	.002	0.13
Likelihood	5.01^a (0.09)	4.92^a (0.14)	4.07^b (0.15)	29.30	<.001	0.38

Note. All dimensions were assessed on a Likert scale ranging from 1 to 7, except affective valence, which was assessed on a Likert scale ranging from -3 to 3, and temporal distance from the present (which was assessed in months). The superscript letters a, b and c represent statistical contrasts between the conditions when the ANOVA was significant: the same letter in a row indicates that the conditions did not differ significantly.

Direct access to temporal location

As expected, participants most frequently used inferential strategies to locate future events in time (see Figure 1). Importantly, however, a robust repeated-measures ANOVA showed a significant effect of the type of events on the frequency of direct access to temporal location, $Ft = 6.62$, $Fcrit = 3.49$, $p < 0.05$. Post-hoc tests indicated that direct event dating was more frequent in the goal condition than in the scenario condition, $\hat{\psi} = 0.14$ [0.03, 0.25]; differences between the 'place' and 'goal' conditions, $\hat{\psi} = 0.06$ [-0.05,

0.16], and between the 'place' and 'scenario' conditions, $\hat{\psi}$ = 0.08 [-0.01, 0.17], were not statistically significant.

The preceding analysis indicated that, on average, a direct access to temporal location was more frequent when events were imagined in response to personal goals. It should be noted, however, that although our experimental manipulation produced the expected difference in terms of the goal-relevance of imagined events (i.e., events were judged more relevant to goals in the 'goal condition' than in the other two conditions; see above), the goal-relevance of events imagined in the 'place' and 'scenario' conditions was not nil and varied across events. Therefore, to further investigate the role of personal goals in the temporal location of future events, we examined to what extent the perceived importance of events for personal goals predicted the mode of temporal location (direct vs. inferential) on a trial-by-trial basis across the entire set of events. In line with our hypotheses, a multilevel (with events as level 1 units, and participants as level 2 units) logistic regression analysis showed that the odds of direct temporal location increased with ratings of the importance of events for personal goals (b = 0.15, SE = 0.05, Z = 2.93, p = 0.003). However, when adding ratings of temporal information rehearsal as predictor in the model, we found that direct access was significantly predicted by rehearsal (b = 0.25, SE = 0.06, Z = 4.22, $p < 0.001$) and that the effect of goal-relevance was no longer significant (b = 0.05, SE = 0.06, Z = 0.83, p = 0.40), suggesting that the influence of personal goals on direct temporal location was mediated by the rehearsal of event dates.

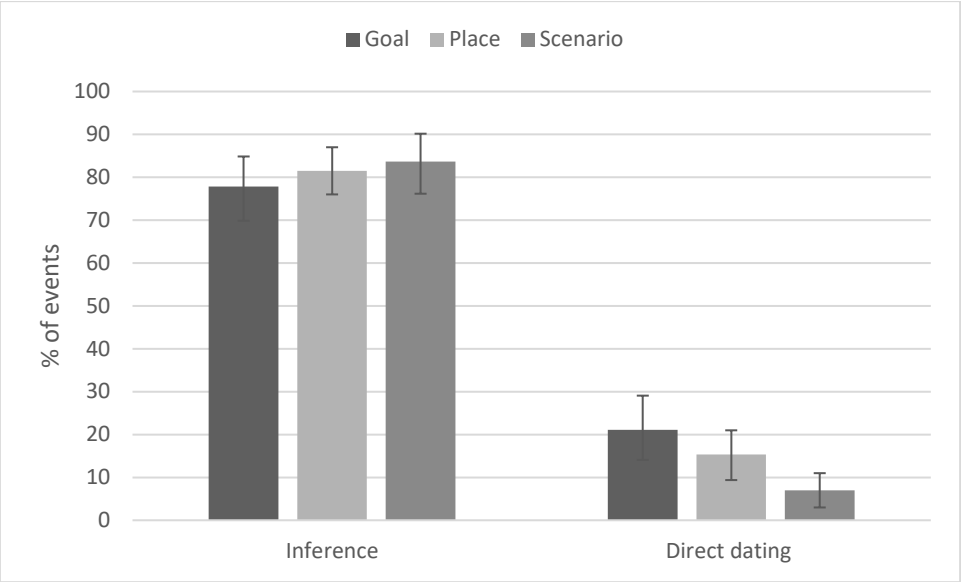

Figure 1. 20% trimmed mean percentages of future events that were located in time using inferential strategies or direct retrieval. Error bars represent the 95% robust confidence interval (Field & Wilcox, 2017).

Frequency of inferential strategies

For events that were not directly located in time, we computed, for each participant and condition, the percentage of events that involved each of the five inferential strategies of interest (see Methods). The 20% trimmed mean percentages of use of each strategy are shown in Figure 2. A 3 (nature of event) X 5 (type of strategy) robust ANOVA showed a significant main effect of the type of strategy, $Ft = 94.68$, $p < 0.001$. As can be seen from Figure 2, knowledge of lifetime periods/extended events and factual information were the strategies most frequently used to locate events in time, for the three types of events; these strategies were used significantly more frequently than all other strategies (all *ps* < 0.02). The frequency of use of lifetime periods/extended events and factual information did not differ significantly ($p = 0.53$). Moreover, the use of specific events, conventional temporal patterns, and contextual details did not differ significantly (all *ps* > 0.97).

The ANOVA also showed a main effect of the nature of events, Ft = 3.07, p = 0.047, as well as a significant interaction between the nature of events and the type of strategies used, Ft= 9.02, $p < 0.001$. As can be seen from Figure 2, this interaction was due to a significantly higher frequency of use of lifetime periods/extended events to locate goal-related events than place-related, $\hat{\psi}$ = 0.18 [0.06, 0.30], and scenario-related, $\hat{\psi}$ = 0.24 [0.12, 0.36], events; the difference between place-related and scenario-related events did not reach the significance threshold, $\hat{\psi}$ = 0.06 [-0.06, 0.19]. Furthermore, conventional time patterns were more frequently used to locate scenario-related events than goal-related, $\hat{\psi}$ = -0.18 [-0.29, -0.06], and place-related, $\hat{\psi}$ = -0.17 [-0.31, -0.04], events; the difference between goal-related and place-related events was not significant, $\hat{\psi}$ = -0.01 [-0.09, 0.07]. There was no significant difference between the three types of events in the frequency of use of the other strategies.

To further examine the role of personal goals in the use of inferential strategies, we investigated whether ratings of the perceived importance of events for personal goals predicted the use of each temporal location strategy on a trial-by-trial basis. A multilevel (with events as level 1 units, and participants as level 2 units) logistic regression analysis showed that the odds of use of lifetime periods/extended events increased with ratings of the importance of events for personal goals (b = 0.13, SE = 0.04, Z = 2.81, $p < 0.005$). The use of other specific (landmark) events also increased with ratings of goal relevance (b = 0.26, SE = 0.07, Z = 3.74, $p < 0.001$). Conversely, the use of conventional time patterns decreased with ratings of the importance of events for personal goals (b = -0.27, SE = 0.06, Z = -4.25, $p < 0.001$). Contrary to what we observed for direct access to temporal information, these effects of goal-relevance remained significant when ratings of rehearsal of temporal information were included in the models. The perceived importance of events for personal goals did not significantly predict the use of contextual

details (*b* = -0.11, *SE* = 0.07, *Z* = -1.61) and factual information (*b* = 0.02, *SE* = 0.04, *Z* = 0.52).

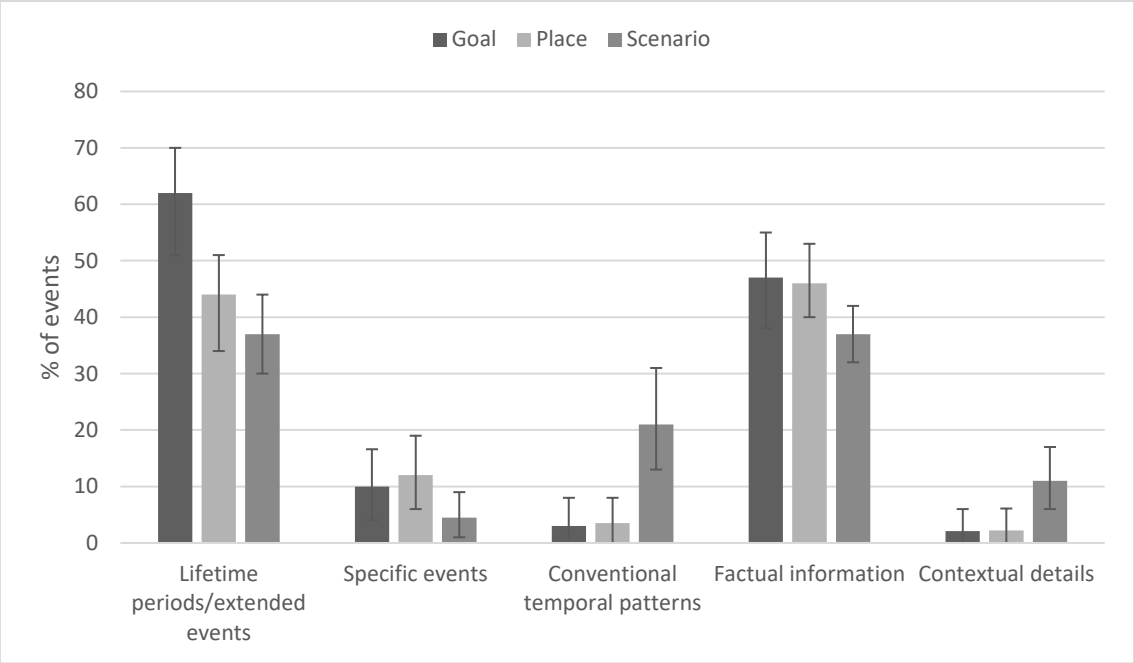

Figure 2. 20% trimmed mean percentages of temporal location strategies for goal-, place- and scenario-related events. Error bars represent the 95% robust confidence (Field & Wilcox, 2017)

Use of multiple inferential strategies

We also investigated whether the use of multiple strategies to locate an event in time differed between the three conditions. For each participant and event condition, we computed the frequency of events that were located using multiple (two or more) inferential strategies. A one-way robust ANOVA showed a significant main effect of the nature of events, *Ft* = 3.26, *Fcrit* = 3.03, $p < 0.05$. The use of multiple strategies tended to be more frequent in the 'goal' condition (trimmed mean = 29%, 95% CI [20.64-37.58]) than in the 'place' (trimmed mean = 17%, 95% CI [10.97-24.39]) and 'scenario' (trimmed mean = 18%, 95% CI [10.35-26.32]) conditions. However, post-hoc tests showed that these differences were not statistically significant, $\hat{\psi}$ = 0.12 [-0.01, 0.24] and $\hat{\psi}$ = 0.11 [-

0.01, 0.24], respectively; the difference between the 'place' and 'scenario' conditions was not statistically significant, $\hat{\psi}$ = -0.006 [-0.13, 0.12].

Certainty of temporal location

Finally, we investigated whether the certainty with which participants located events in time differed as a function of the nature of events. A one-way ANOVA showed a significant effect of the nature of events, $F(2, 96) = 5.63$, $p = 0.005$, $\eta_p^2 = 0.1$. The degree of certainty was judged higher for goal-related events ($M = 4.28$, $SD = 0.13$) and place-related events ($M = 4.25$, $SD = 0.13$) than scenario-related events ($M = 3.25$, $SD = 0.16$; $ps < 0.01$). The degree of certainty of temporal location did not differ significantly between goal-related and place-related events ($p = 0.84$).

Discussion

While memory for the times of past events has attracted much attention, little is known about how envisioned future events are located in time. Furthermore, the role of personal goals in temporal location processes has not been studied in detail. To address this question, we investigated the strategies that people use when attempting to determine the temporal location of future events that were cued by personal goals, familiar places, and experimenter-provided scenarios. The results replicated our previous findings that people rarely directly determine the temporal location of future events, but instead use inferential strategies (Ben Malek et al., 2017). Interestingly, however, the odds of direct access to event dates were higher for goal-related events. Furthermore, when an event was not directly dated, references to anticipated lifetime periods were more frequently used as a strategy to determine when a goal-related event might occur.

Considerable evidence has indicated that the temporal location of past events is mainly reconstructive and inferential (Friedman, 1993, 2004; Thompson et al., 1993, 1996; Shum, 1998), and recent studies suggest that similar mechanisms are involved in estimating the times of future events (Ben Malek et al., 2017; D'Argembeau et al., 2015). In line with these observations, we found that most future events were not "time stamped." Instead, participants used various inferential strategies to estimate when an imagined event will likely happen. References to anticipated lifetime periods and factual knowledge (about the self, others or the world) were the most frequently used strategies, replicating our previous study (Ben Malek et al., 2017). Specific landmarks, conventional time patterns, and contextual details also contributed to temporal location attribution, but to a lesser extent. Of note, a non-negligible proportion of events were located using multiple (i.e., two or more) inferential strategies, which is also consistent with our previous findings (Ben Malek et al., 2017).

The frequent use of autobiographical periods (i.e., lifetime periods and extended events) for estimating the times of imagined events can be interpreted in terms of hierarchical models of episodic future thinking, according to which autobiographical knowledge structures form partonomies in which specific events are part of general events that are themselves nested in lifetime periods (Conway, Justice, & D'Argembeau, in press; D'Argembeau, 2015). On this view, higher-order autobiographical knowledge contextualizes specific event representations in an individual's personal life and contributes, in particular, to the temporal location of events (Thomsen, 2015). For example, an anticipated lifetime period such as "my postdoc in the U.S." may organize the representation of a series of future events (e.g., giving my first talk at an international conference; visiting my aunt in Boston; going to a concert in New York) and help one to

determine that these events will likely occur in about two years from now (i.e., during my postdoc years).

An important finding of the present study is that autobiographical periods were more frequently used to infer the temporal location of goal-related than place- or scenario-related future events. Moreover, the use of autobiographical periods was predicted by the goal-relevance of events on a trial-by-trial basis. These results support the hypothesis that personal goals contribute to the temporal organization of imagined future events because they are closely associated with higher-order autobiographical knowledge (D'Argembeau, 2015, 2016). In fact, the construction of autobiographical periods may in part be determined by personal goals (Thomsen, 2015). For example, the goal of getting married will delineate a period of married life in one's mental time line, which can then be used to determine when associated (i.e., goal-relevant) events will likely happen. Thus, goals may drive the construction of a personal timeline, composed of anticipated autobiographical periods, that serves to temporally organize episodic future thoughts.

Although the majority of future events were located in time using inferential strategies, the dates of some events were directly determined and the odds of direct access to temporal information increased with the perceived importance of events for personal goals. Interestingly, however, the effect of goal-relevance was no longer significant when rehearsal of time information was taken into account, suggesting that the influence of personal goals on direct temporal location is mediated by the rehearsal of event dates. A possible explanation for these findings is that participants may have already thought about the dates of goal-relevant events on a previous occasion, such that temporal information has been encoded in memory as part of "memories of the future" (Jeunehomme & D'Argembeau, 2017; Szpunar et al., 2013). Previously imagined future events can be directly accessed in response to relevant cues (Cole, Staugaard & Bernsten, 2016;

Jeunehomme & D'Argembeau, 2016), and a similar phenomenon might occur for the temporal location of events. In line with this view, the present results showed that participants had more frequently thought about the times and content of goal-related than place- or scenario-related events. This increased accessibility of temporal information may in turn facilitate future planning and contribute to successful goal pursuit.

Another notable difference in dating strategies between the three types of events is that references to conventional time patterns (i.e., the calendar or natural time cycles) were more frequent for scenario-related than goal- and place-related events. Moreover, the odds of use of conventional time patterns decreased with the perceived importance of events for personal goals on a trial-by-trial basis. Participants also reported being less certain about the dates of scenario-related events and estimated that these events were less likely to occur. These findings suggest that conventional time patterns may be used to compensate the lack of knowledge about anticipated lifetime periods when attempting to determine the times of future events that are less clearly embedded in an autobiographical context. The temporal location of these events may be more labile because they are less contextualized within the individual's life story.

Some limitations of this study should be acknowledged. First, as our aim was to investigate the role of personal goals in the temporal location of future events, we experimentally manipulated the contribution of goals in the imagination of events. However, the three kinds of imagined events differed not only in terms of goal-relevance, but also on other dimensions that might influence temporal location processes. Notably, our results suggest that the rehearsal of time information seems a key factor in explaining the direct dating of goal-relevant events. On the other hand, the influence of goals on the use of autobiographical periods did not depend on the rehearsal of time information. Nevertheless, it would be interesting in future studies to investigate temporal location

processes for goal-relevant but unrehearsed events (i.e., events that people imagine for the first time). Second, it should be noted that the present study focused on temporal locations. More study is needed to investigate the role of goals in other aspects of temporal representation, such as distances and temporal order (Friedman, 1993, 2004). Finally, temporal location processes were inferred based on verbal reports obtained using a think-aloud procedure (Fox et al., 2011) and it will be important in future studies to obtain converging evidence using other measures (e.g., response times, self-rating of the use of various strategies).

Conclusion

In conclusion, the present study shows that the temporal location of imagined future events is more frequently directly determined when events are related to personal goals. When people cannot directly locate a future event in time, they use multiple strategies to determine its temporal location and these strategies are also influenced by the goal-relevance of imagined events. Most frequently, people use general knowledge about the anticipated periods of their life to estimate the temporal location of future events, particularly when these are related to personal goals. These findings suggest that personal goals and lifetime periods are central components of a personal timeline that is used to mentally travel to the future.

Exploration of the temporal location and order of past and future personal events in patients with schizophrenia

Finally, the aim of **Study 3** was to investigate temporal location and order processes for past and future personal events in schizophrenia. To address this question, we used the same procedure as in Study 1 in two groups of participants: individuals with schizophrenia and control participants (matched for age, gender and years of schooling). After having located events in time, participants were then instructed to order the past and future events that had been previously generated and dated.

Following the findings of Study 1 & 2, we expected that the two groups of participants would mainly use reconstructive and inferential strategies to locate both past and future events in time. However, based on previous research showing that individuals with schizophrenia experience difficulties to locate historical events in time (Venneri et al., 2002) and that the chronology of event and life story narratives are messy (Raffard et al., 2010; Allé et al., 2015, 2016a), we expected both location and order processes to be impacted. More precisely, we expected that patients with schizophrenia would exhibit difficulty using episodic (but not semantic) information to date events and would make more errors when ordering past and future events in time, relatively to control participants.

STUDY 3

"How do patients with schizophrenia locate and order personal events in past and future times?"

Adapted from: Ben Malek, H., D'Argembeau, A., Allé, M., Meyer, N., Danion, J-M., & Berna, F. How do patients with schizophrenia locate and order personal events in past and future times (submitted to *Scientific Reports*, April 8, 2019)

Abstract

People with schizophrenia experience difficulties in remembering their past and envisioning their future. However, while alterations of event representation are well documented, little is known about how personal events are located and ordered in time. Using a think-aloud procedure, we investigated which strategies are used to determine the times of past and future events in 30 patients with schizophrenia and 30 control participants. We found that the direct access to temporal information of important events was preserved in patients with schizophrenia. However, when events were not directly located in time, patients less frequently used a combination of strategies and partly relied on different strategies to reconstruct or infer the times of past and future events. In particular, they used temporal landmark events and contextual details (e.g., about places, persons, or weather conditions) less frequently than controls to locate events in time. Furthermore, patients made more errors when they were asked to determine the temporal order of the past and future events that had been previously dated. Together, these findings shed new light on the mechanisms involved in locating and ordering personal events in past and future times and their alteration in schizophrenia.

Introduction

Patients with schizophrenia experience difficulties in remembering their past and imagining their future. Notably, there is substantial evidence that autobiographical memories lack contextual details and are less frequently specific (i.e., referring to unique experiences happening at a specific place and time, and lasting no more than a day) in patients with schizophrenia than control participants (Berna et al., 2015). Similarly, patients imagine future events that are less frequently specific (Chen et al., 2016; D'Argembeau, Raffard, & Van der Linden, 2008) and less detailed (Raffard, D'Argembeau, Bayard, Boulenger, & Van der Linden, 2010). Surprisingly, however, while the ability to consider times in the past and the future is an important component of 'mental time travel'(Friedman, 2005; Suddendorf & Corballis, 2007), it remains unclear whether and how patients with schizophrenia present alterations of the sense of *when* events occurred or will occur. Given that the representation of time is crucial to the process of setting and pursuing personal goals (Etkin, 2018), investigating temporal location and order processes of personal events in schizophrenia may contribute to better understand why patients find it hard to set, plan and pursue personal goals. Therefore, the present study aimed to examine whether processes involved in the temporal location and order of personal past and future events are altered in schizophrenia.

Research has shown that three types of processes contribute to the ability to determine the times of past events: location-, order- and distance-based processes (Friedman, 1993, 2004). Location processes are used to place events at particular points in conventional (e.g., parts of days, months, years), natural (e.g., seasons), or personal (e.g., lifetime periods) time patterns; examples include recalling that an event happened on a weekend, during winter, or when one was in college. Order codes refer to before-after relations between events, which can be used to place events relative to each other.

Finally, distance-based processes give rise to the impression that an event happened a long time ago or recently, which is in part determined by some properties of memories, such as their vividness.

Although all three processes can be used to date past events, people are especially adept at determining the temporal locations of past events (Friedman, 2004) and similar location-based processes are involved in envisioning the times of imagined future events (Ben Malek, Berna, & D'Argembeau, 2018; Friedman, 2005). According to reconstructive theories (Friedman & Wilkins, 1985; Shum, 1998; Thompson, Skowronski, Larsen, & Betz, 1996), locations are often not intrinsic properties of memories but are reconstructed using multiple sources of information, for instance episodic information such as contextual details (i.e., persons, places, activities, or any other content) or specific events playing the role of temporal landmarks, and semantic information such as general knowledge of time patterns and events of one's life (e.g., knowledge of autobiographical periods or extended events). However, in some cases, the dates of important events can be directly accessed (e.g., graduations, wedding, children's birth), both for the past and the future (Ben Malek, Berna, & D'Argembeau, 2017; Friedman, 1987; Skowronski, Betz, Thompson, & Larsen, 1995; Thompson, Skowronski, & Betz, 1993).

Little is known about temporal location processes in schizophrenia. Previous studies showed that the ability to consciously recollect time information for personal events is reduced for past events (Danion et al., 2005), but relatively spared for future events (de Oliveira, Cuervo-Lombard, Salamé, & Danion, 2009). Regarding non-personal events, Venneri et al. (2002) showed that patients with schizophrenia make more dating errors and are less precise when they are asked to date historical events (for example, the fatal car accident of Princess Diana). These findings suggest that the dating of events

might be (at least partly) altered in schizophrenia, although none of these studies examined the mechanisms involved in the ability to locate events in time. Thus, it remains unclear whether the mechanisms underlying the temporal location of personal events are impaired in schizophrenia.

Regarding temporal order processes, to our knowledge, no study specifically examined the ability to order personal events in schizophrenia. Nonetheless, it has been found that patients' narratives of their life story (Allé, Gandolphe, et al., 2016; Allé et al., 2015) or of self-relevant life events (Raffard, D'Argembeau, et al., 2010) are less temporally organized than the narratives of control participants. A number of studies examined order performance for non-personal events. For example, some researchers used recency discrimination tasks in which participants were instructed to judge which of two items (e.g., words; Schwartz, Deutsch, Cohen, Warden, & Deutsch, 1991), images (Rizzo, Danion, Van der Linden, & Grangé, 1996) or household objects (Waters, Maybery, Badcock, & Michie, 2004) was most recently memorized, and found that patients with schizophrenia exhibit poorer performance than control participants, suggesting an alteration of temporal order processes. Another study that used a picture-sequencing task yielded similar results (Zalla et al., 2006). While these findings indicate that temporal order processes are impacted for non-personal events (at least after a short delay), it remains unknown whether patients with schizophrenia are able to order events that are personal and more distant in time.

The first aim of the present study was to investigate temporal location processes in schizophrenia by examining the strategies that patients use to locate personal events in past and future times. Secondly, we sought to examine the capacity for patients to order personal past and future events in time. Based on the literature reviewed above, we expected that both temporal location and ordering processes would be altered in

schizophrenia. More precisely, we expected that patients with schizophrenia would exhibit difficulty using episodic (but not semantic) information to date events and would make more errors when ordering past and future events in time, relatively to control participants.

Method

Participants

Thirty outpatients with schizophrenia (10 women) were recruited from the Department of Psychiatry of Strasbourg's University Hospital, along with 30 control participants matched on gender, age and years of schooling. All the patients fulfilled the DSM-5 criteria(APA, 2013) for schizophrenia or schizo-affective disorder, and were clinically stabilized under antipsychotic medication. The participants were all native French speakers. Exclusion criteria for both patients and controls were the following: severe somatic illness; history or current neurologic disorders (e.g., traumatic brain injury, epilepsy); psychiatric disorders (other than schizophrenia, for patients); current alcohol or substance abuse disorder; major depressive episode, defined for patients by a score higher than 6 on the Calgary Depression Scale for Schizophrenia (Addington, Addington, & Maticka-Tyndale, 1993; CDSS) and for controls as a score higher than 9 on the Beck Depression Inventory (Beck, Steer, & Brown, 1996; BDI); and IQ score below 70 on the French validated short version of WAIS-III (Grégoire & Wierzbicki, 2009; Wechsler, 1997; Weschler Adult Intelligence Scale – third edition).

This study was approved by the Ethical Review Board South-East IV (reference 2016-A01463-48). All participants gave informed written consent to take part in the study.

Materials and Procedure

Clinical assessment

A full description of the clinical and neuropsychological measures is presented in Table 1. The severity of clinical symptoms of patients was assessed using the Positive And Negative Syndrome Scale (Kay, Fiszbein, & Opler, 1987; PANSS). Depression was checked with the CDSS for patients, and the BDI for controls. For both groups of participants, apathy was assessed using the Lille Apathy Rating Scale (Sockeel et al., 2006; LARS), and the level of anxiety was checked with the State-Trait Anxiety Inventory (Schweitzer & Paulhan, 1990; Spielberger, 1983; STAI Y-A & Y-B).

Neuropsychological assessment

Pre-morbid and current IQ were assessed using the French validated version of the National Adult Reading Test (Mackinnon & Mulligan, 2005; f-NART) and the WAIS-III short version, respectively. This short version included subtests of vocabulary, matrix reasoning, and arithmetic. Executive functioning was evaluated using the Trail-Making Test (Reitan, 1958; TMT A & B), and phonologic and semantic fluency (Cardebat, Doyon, Puel, Goulet, & Joanette, 1990). Processing speed was tested using the cancellation subtest of WAIS-IV (Wechsler, 2008). Short-term memory and working memory were evaluated by the direct and reverse digit span subtest of WAIS-IV, respectively. Verbal fluency was assessed, and played a two-fold role of a measure of executive functioning (Cardebat et al., 1990) and an interfering activity between temporal location and temporal order tasks (see below). The participants had 2 minutes to give as many words as they could starting with the letter “r” (phonological fluency), and 2 minutes to give as many fruit names as possible (semantic fluency).

Table 1. Means (and standard deviations) of clinical and neuropsychological measures for patients with schizophrenia (n = 30) and controls (n =30).

	Control participants n=30		Patients with schizophrenia n=30		Statistics				
					θ		*CI* 95%		*Pr*(θ>0)
	M	*SD*	*M*	*SD*	*M*	*SD*	2.5%	97.5%	
Clinical measures									
Age	37.8	10.1	37.3	9.6	.92	2.5	-4.0	5.9	.641
Gender (number of women)	10	33.3%	10	33.3%					
Years of schooling	13.2	2.3	12.1	2.2	-1.1	.6	-2.2	0.1	.038
LARS (apathy)	-25.6	6.4	-18.1	5.9	7.0	1.6	3.8	10.2	>.999
STAI Y-A (state anxiety)	42.7	6.7	49.9	9.6	8.4	2.1	4.2	12.6	>.999
STAI-Y-B (trait anxiety)	41.4	8.2	48.2	9.6	7.5	2.3	3.0	12.0	>.999
Depression (BDI)	3.03	3.43							
(CDSS)			2.0	2.4					
PANSS total			53.6	16.2					
positive			12.2	3.8					
negative			17.5	8.2					
Psychometric measures									
fNART (pre-morbid IQ)	111.0	6.1	104.7	10.9	-2.6	2.4	-7.2	2.4	.142
WAIS-III (current IQ)	101.1	13.0	86.5	13.5	-6.3	3.9	-13.7	1.97	.063
Neuropsychological measures									
WAIS IV cancellation	10.4	2.6	7.3	2.5	-3.1	0.7	-4.4	-1.7	<.001
direct digit span	9.8	2.1	8.8	2.7	-1.0	0.6	-2.3	0.2	.053
reverse digit span	10.0	2.8	8.3	2.8	-1.6	0.7	-3.1	-0.2	.015
Fluency phonological	17.7	6.0	18.4	6.7	0.9	1.7	-2.5	4.4	.709
semantic	21.9	5.5	18.2	5.4	-3.0	1.4	-5.8	-0.1	.020
TMT A – B (time, in seconds)	34.1	17.8	67.5	58.2	23.6	7.3	9.1	37.7	>.999
TMT A – B (number of errors)	0.1	0.7	0.9	1.6	0.8	0.3	0.1	1.4	.990

Note: Results are presented as θ with a 95% Credible Interval (CI), with the probability of the θ being above 0: *Pr*(θ >0).
LARS: Lille Apathy Rating Scale, STAI: State-Trait Anxiety Inventory, BDI: Beck Depression Inventory, CDSS: Calgary Depression Scale for Schizophrenia, PANSS: Positive And Negative Syndrome Scale, fNART: French National Adult Reading Test, WAIS: Weschler Adult Intelligence Scale, TMT; Trail Making Test.

Temporal location task

Participants were asked to think aloud while they attempted to locate a series of past and future events in time. The experimental task was inspired by previous work on past (Ben

Malek et al., 2017; Brown, 1990; Brown, Schweickart, & Svob, 2016; Nourkova & Brown, 2015) and future event dating (Ben Malek et al., 2018; Ben Malek et al., 2017). The temporal location task involved three phases. First, participants had to retrieve 10 past events and to imagine 10 events that are likely to happen in the future, in response to cue-words (event-generation phase). Twenty cue words referring to common places and objects (e.g., book, house, coffee-shop, dog) were divided into 2 lists of 10 cues that were matched for frequency of use and imageability (Desrochers & Thompson, 2009). The allocation of the two lists to the past and future conditions and the order of presentation of the two conditions were counterbalanced across participants. For each cue word, participants were instructed to remember or imagine a specific personal event (i.e., a unique event happening at a specific place and time and lasting no longer than a day; Williams et al., 1996). A brief description of each generated event was written down by the experimenter.

Immediately after the event-generation phase, the descriptions of past and future events that had been evoked were presented one at a time and, for each event, participants were asked to describe everything that came to their minds (i.e., to think aloud (Fox, Ericsson, & Best, 2011) while they attempted to determine as precisely as possible when the event occurred (past condition) or will likely occur (future condition) (event-dating phase). To avoid influencing temporal location processes, the instructions did not specify which type of temporal information should be expected (e.g., days, months, years). We considered that an event was located in time if the participant could provide at least the year during which the event happened (past condition) or would happen (future condition); note, however, that the majority of the temporally located events received a more precise temporal location. All verbal protocols collected during the think-aloud procedure were audio-recorded. For each trial, participants were also asked to rate their

degree of certainty in the reported temporal location on a 7-point Likert scale (from 1 = extremely weak, to 7 = extremely strong).

After having located all events in time, participants were asked to rate each event on several 7-point Likert scales: the clarity of event representation (from 1 = not at all clear, to 7 = extremely clear), emotional valence (from -3 = very negative, to +3 = very positive, with 0 = neutral), importance for personal goals (from 1 = not important at all, to 7 = very important), sense of mental time travel (from 1 = not at all, to 7 = totally), subjective temporal distance (from 1 = very close, to 7 = very distant), previous thought about the event (from 1 = never, to 7 = very often), previous thought about when the event occurred or would occur (from 1 = never, to 7 = very often), likelihood of future events (from 1 = not likely to happen, to 7 = very likely to happen).

Temporal order task

In the temporal order task, participants were instructed to order chronologically the past and future events that were previously produced. To do so, they had to place each event on an arrow of time (which only indicated the past, present and future), drawn on a blank sheet of paper, by writing keywords referring to the event. The list of past and future events was first read aloud by the experimenter and was then given to participants. To score temporal order performance, the temporal locations that were previously provided by participants were taken as reference. Thus, we compared the expected order of events (according to the dates determined in the temporal location task) to the order given by participants and we computed percentages of order errors for past and future events.

Scoring

All the audio-recorded verbal protocols obtained while participants attempted to locate events in time were transcribed for scoring. When the temporal location of an event was

immediately produced (i.e., without using any strategy), this was scored as direct event dating. When the temporal location was not directly produced, we scored the strategies used by the participants during the event-dating phase. To characterize these dating strategies, we used a scoring grid previously designed to classify the dating strategies of past and future events (Ben Malek et al., 2017). Five categories of strategies were considered: (1) lifetime periods/extended events, (2) specific events (landmarks), (3) conventional time patterns, (4) factual information, and (5) contextual details (for the definition of each category and examples of corresponding verbal reports, see Table 2). These five categories were not mutually exclusive (i.e., the dating protocol obtained for a particular event could include more than one type of strategy) and each trial was scored for the presence or absence of each category. Events that were not located in time were scored as uncategorized.

All transcriptions were scored by the first author (HBM) and the reliability of our coding scheme was assessed by asking the third author (MA, who was trained for scoring and blind to diagnosis and hypothesis) to score a random selection of 15% of the verbal protocols. Percentages of raw agreements showed substantial inter-rater reliability for direct dating (95.4%) and for the five strategies of interest: 96.5% for lifetime periods/extended events, 95.9% for specific events, 95.9% for conventional time patterns, 93.6% for factual information, and 90.7% for contextual details. The Cohen's kappa coefficients were not computed because the marginal distributions were not uniform (von Eye & von Eye, 2008).

Table 2. Definition and examples of categories of temporal location strategies for past and future events.

Location strategy	Definition	Examples
Lifetime periods/extended events	Use of knowledge about lifetime periods or extended events for attempting to locate the event in time	It was during my Master's degree (past event); It will happen during my internship (future event)
Specific events (landmarks)	Use of another specific event for which the precise temporal location is known (i.e., temporal landmark)	I met John a few days after my 25th birthday (past event); It would be just before my thesis defence which is scheduled on the 1st of November 2016 (future event)
Contextual details	Use of event details (such as locations, activities, persons, or the weather) to infer its temporal location	I was with François that day, so it certainly happened one month ago (past event); It has to be snowy, so it will likely happen in December (future event)
Conventional time patterns	Reasoning using calendar time (weeks, months, years) or natural time patterns (e.g., seasons)	It was a Monday, during this year, on October or November but I would say on October (past event); It will happen during the 1st or the 2nd week of July, more likely the first days of July (future event)
Factual information	Use of general knowledge (about self, others, or the world) to infer the temporal location of the event	At that time, my brother was still a baby, he is 6 years younger than me so it was on July 2005 (past event); To avoid mass tourism, I will go there during the 1st week of September (future event)

Statistical analyses

Statistical analyses were performed using Bayesian methods. Univariate linear regressions were used to compute the between-group differences for clinical, psychometric and cognitive measures. Concerning the temporal location task, multilevel (with events as level 1 units, and participants as level 2 units) logistic regressions were used to analyze the influence of two predictors on the use of dating strategies: group (patients vs. controls), and time orientation (past vs. future). A multilevel Beta regression was computed to analyze the effect of the group and time orientation on order errors in the temporal order task. To compare the characteristics of directly dated events and events for which temporal information was reconstructed, we computed separate multilevel Beta regression analyses (for each characteristic) including two predictors, the group (patients vs. controls) and the mode of location (direct vs. reconstruction). Non-informative priors were used to analyze group effects. We used informative priors for time orientation and mode of location factors based on our previous findings (Ben Malek et al., 2017) (see Supplementary material), and then tested the robustness of results by means of sensitivity analyses using both non-informative and pessimistic priors. Correlation analyses were performed to investigate associations between temporal location strategies, order errors, the level of clinical symptoms and cognitive functioning.

To interpret the results, we considered both large *Pr*(OR>1) values (i.e., > .95) and small values of *Pr*(OR>1) (i.e., < .05) as reflecting meaningful effects of the factor under consideration.

Results

While the two groups were matched for age, patients had about 0.5 years of schooling less than controls (see Table 1). Concerning clinical measures, patients reported higher levels of apathy and anxiety than controls. Concerning the cognitive measures, the pre-morbid IQ did not differ between the two groups, but the current IQ was lower in patients. Overall, patients with schizophrenia had worse executive functioning (except for phonological fluency), working memory, processing speed, and logical reasoning capacities than control participants.

Frequency of unlocated events

In total, 277 past and 277 future events were included in the analyses for patients, and 299 past and 284 future events for controls; 11 additional events (5 past and 4 future events for patients, 2 future events for controls) were excluded because they did not meet the specificity criterion (i.e., a unique event happening at a specific place and time, and lasting no more than a day) and participants failed to produce an event on 52 of trials. Patients with schizophrenia were not able to date 1.5% (vs. 0.3 % for controls) of past events and 12.3 % (vs. 5% for controls) of future events. The difference between groups was not meaningful (OR=16.93, CI95%:0.54-108.19, *Pr*(OR>1) = .92). In both groups, the frequency of unlocated events was higher for the future than the past (OR=57.72, CI95%: 3.55-346.68, *Pr*(OR>1) > .99). There was no interaction between group and time orientation (OR=1.25, CI95%:0.03-6.00, *Pr*(OR>1) = .37).

Direct retrieval vs. reconstruction of temporal location

As expected, the majority of events were located in time using reconstructive or inferential strategies (see Figure 1). However, contrary to our expectation, the percentage of directly dated events did not differ between the two groups (OR=1.06, CI95%:0.65-1.65, *Pr*(OR>1) = .55). There was a meaningful effect of time orientation (OR=0.63, CI95%:0.40-0.95, *Pr*(OR>1) = .03), showing that direct access to dates was more frequent for past than future events. There was no interaction between group and time orientation (OR=0.78, CI95%:0.40-1.39, *Pr*(OR>1) = .18).

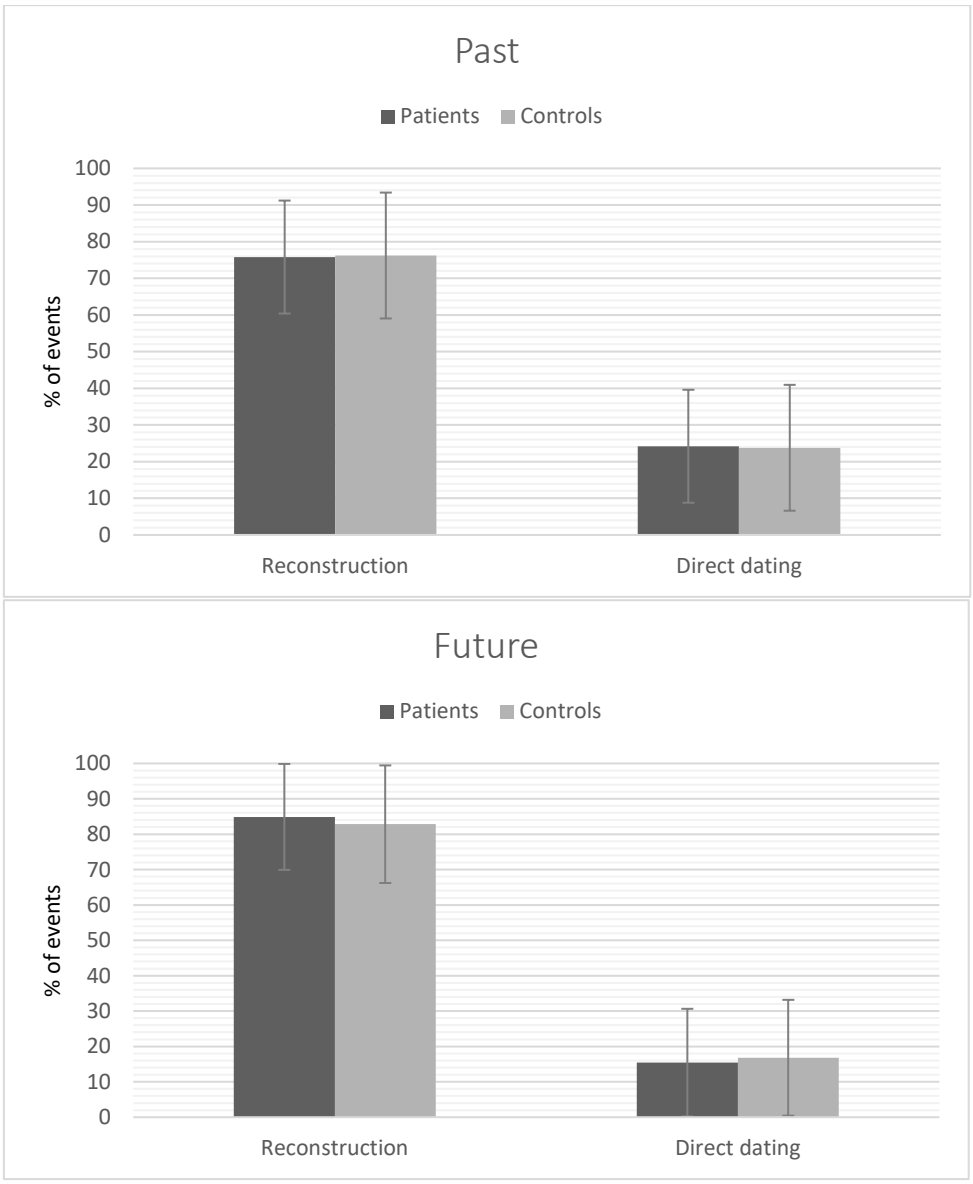

Figure 1. Mean percentages (and standard deviations) of past and future events that were located in time using reconstructive strategies or direct dating for patients with schizophrenia (n = 30) and controls (n = 30).

We also investigated whether the certainty with which participants located events in time differed as a function of the group and of their mode of location (direct vs. reconstruction). We found a meaningful effect of the group (OR=0.63, CI95%:0.47-0.83, *Pr*(OR>1) < .001), showing that the degree of certainty of temporal location was lower in patients (*M* = 5.14, *SD* = 1.42) than controls (*M* = 5.67, *SD* = 1.40). The effect of mode of location was meaningful (OR=2.12, CI95%:1.69-2.64, *Pr*(OR>1) > .99), showing that

directly dated events were judged as more certain (*M* = 6.33, *SD* = 0.98) than events located in time using reconstructive or inferential strategies (*M* = 5.18, *SD* = 1.44). No interaction was found between group and mode of location (OR=1.18, CI95%:0.84-1.62, *Pr*(OR>1) = .83).

Frequency of reconstructive strategies

To determine whether patients with schizophrenia relied on different reconstructive strategies to locate past and future events in time, we compared the percentage of use of strategies between groups and time orientations. As can be seen in Figure 2, while participants in both groups used several strategies to locate past and future events in time, they most frequently used lifetime periods/extended events to date past events and factual information to date future events. Statistical analyses showed that patients used contextual details (OR=0.67, CI95%:0.39-1.07, *Pr*(OR>1) = .04) and specific landmark events (OR=0.66, CI95%:0.40-1.02, *Pr*(OR>1) = .03) less frequently than controls, and also tended to use factual information less frequently (OR=0.71, CI95%:0.42-1.13, *Pr*(OR>1) = .07); no meaningful between-group difference was found for lifetime periods/extended events and conventional time patterns (all *Pr*s(OR>1) > .30). Concerning time orientation, the use of lifetime periods/extended events (OR=0.23, CI95%:0.15-0.34, *Pr*(OR>1) < .001), specific events (OR=0.39, CI95%:0.23-0.61, *Pr*(OR>1) < .001), conventional time patterns (OR=0.56, CI95%:0.33-0.90, *Pr*(OR>1) = .008), and contextual details (OR=0.65, CI95%:0.38-1.02, *Pr*(OR>1) = .03) was less frequent for future events than for past events. On the other hand, the use of factual information was more frequent for future than past events (OR=4.88, CI95%:3.19-7.22, *Pr*(OR>1) = >.999). There was no interaction between group and time orientation for the frequency of use of any of the reconstructive strategies (all *Prs*(OR>1) between .13 and .91).

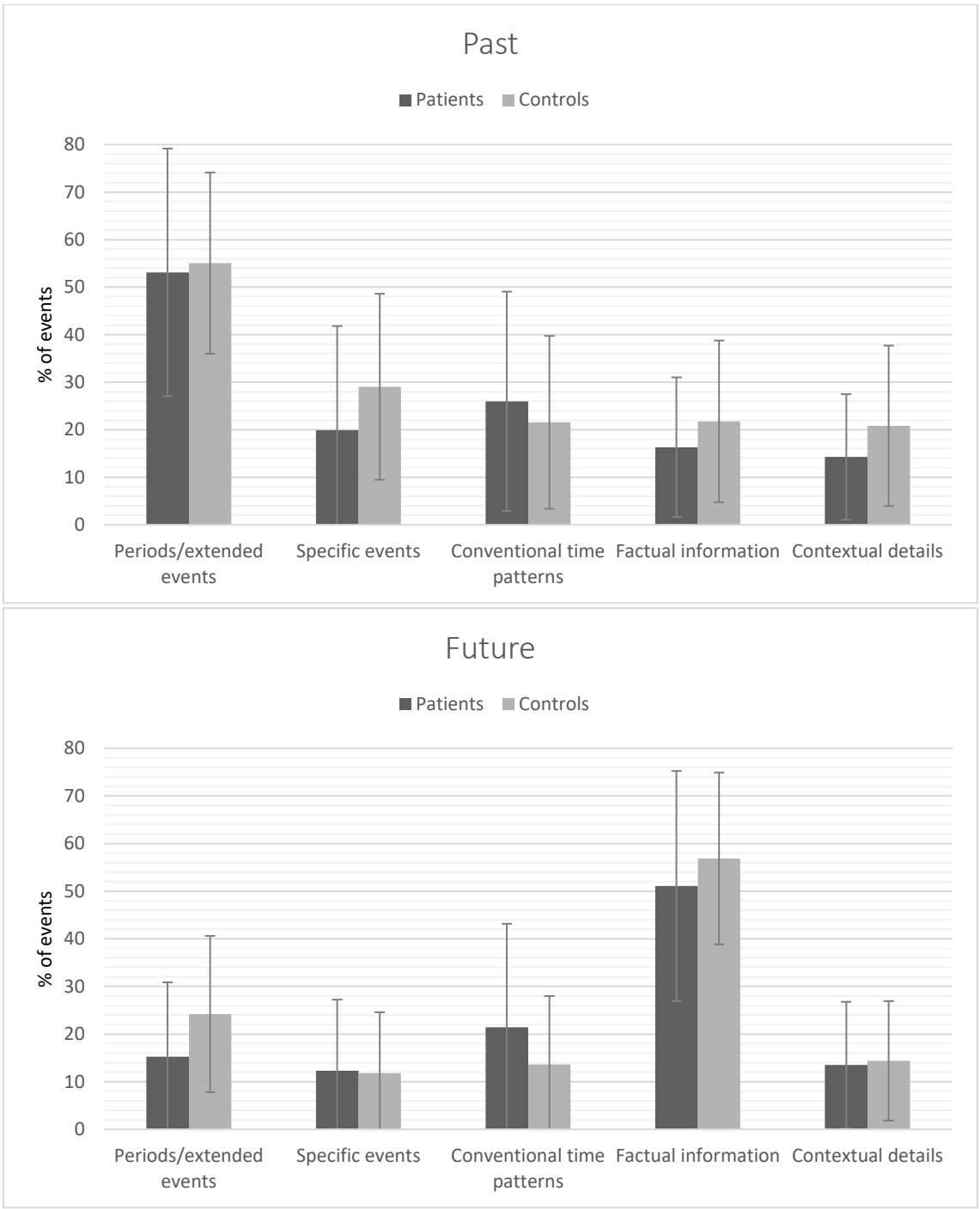

Figure 2. Mean percentages (and standard deviations) of temporal location strategies for past and future events, for patients with schizophrenia (n = 30) and controls (n = 30).

We also examined whether the use of multiple (i.e., two or more) strategies differed between groups and time orientations. Results showed that the use of multiple strategies was less frequent for patients than controls (OR=0.37, CI95%:0.17-0.70, *Pr*(OR>1) < .001), and less frequent for future than past events (OR=0.27, CI95%:0.17-0.42, *Pr*(OR>1) < .001). On average, patients with schizophrenia used multiple strategies for 26% (*SD* = 25) of past events and 13% (*SD* = 17) of future events, whereas controls used multiple strategies for 44% (*SD* = 22) of past events and 20% (*SD* = 21) of future events. No interaction between group and time orientation was observed (OR=1.43, CI95%:0.65-2.71, *Pr*(OR>1) = .78). The most frequently used combination of strategies was lifetime periods/extended periods and factual information for patients (used for 37% of events, *SD* = 36; vs. 18% of events for controls, *SD* = 20) and lifetime periods/extended events and contextual details for controls (for 32% of events, *SD* = 34; vs. 10% of events for patients, *SD* = 14). For percentages of use of each combination of strategies for patients and controls, see Supplementary material.

Event characteristics

The mean ratings of event characteristics are presented in Table 3, as a function of group and mode of location (directly located vs. reconstructed). Statistical analyses showed that patients provided lower ratings than controls for affective valence (OR=0.73, CI95%:0.59-0.90, *Pr*(OR>1) = .002), mental time travel (OR=0.75, CI95%:0.50-1.07, *Pr*(OR>1) = .05), and likelihood of future events (OR=0.64, CI95%:0.46-0.88, *Pr*(OR>1) = .003). There was no meaningful effect of group for subjective vividness, importance for personal goals, event and time rehearsal, subjective temporal distance and temporal location (all *Prs* (OR>1) > .11).

Concerning the mode of location, we found that directly located events received higher ratings on subjective vividness (OR=2.03, CI95%:1.60-2.56, *Pr*(OR>1) >.99), importance for personal goals (OR=1.33, CI95%:1.04-1.69, *Pr*(OR>1) >.99), mental time travel (OR=1.89, CI95%:1.50-2.36, *Pr*(OR>1) >.99), likelihood of future events (OR=2.07, CI95%:1.42-2.95, *Pr*(OR>1) > .99), and lower ratings on subjective temporal distance (OR=0.44, CI95%:0.34-0.56, *Pr*(OR>1) = <.001), compared to events that were located using reconstructive or inferential strategies. There was no difference between the two types of events for affective valence, event and time rehearsal, and temporal location (all *Prs* (OR >1) between .07 and .91).

Finally, there were meaningful interactions between group and mode of location for subjective vividness (OR=0.62, CI95%:0.44-0.87, *Pr*(OR>1) = .002) and subjective temporal distance (OR=1.42, CI95%:0.99-1.98, *Pr*(OR>1) = .97), showing that directly dated events were judged more vivid and less temporally distant than events whose dates were reconstructed, in controls but not in patients. There was also an interaction for mental time travel (OR=0.70, CI95%:0.41-0.96, *Pr*(OR>1) = .01), showing that mental time travel was lower in patients than controls for directly dated events, but not for events whose dates were reconstructed.

Table 3. Mean ratings (and standard deviations) of event characteristics for directly dated and temporally reconstructed events in patients with schizophrenia (n = 30) and controls (n =30).

	Control participants n=30				Patients with schizophrenia n=30			
	Direct		Reconstruction		Direct		Reconstruction	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Subjective vividness	5.9	1.2	4.8	1.1	4.9	1.3	4.5	0.9
Affective valence	1.6	1.3	1.5	0.6	1.3	1.3	1.2	0.7
Importance for personal goals	5.2	1.5	4.9	1.0	4.5	1.8	4.5	0.9
Mental time travel	5.5	1.2	4.6	1.1	4.5	1.1	4.2	0.9
Event rehearsal	3.7	1.0	3.6	0.8	3.4	1.3	3.3	0.8
Time rehearsal	3.6	1.1	3.3	0.9	3.3	1.5	3.1	0.8
Subjective temporal distance	2.7	1.0	3.9	0.7	3.2	1.2	3.8	0.7
Temporal location (months)	58.3	64.8	96.6	56.2	67.4	84.3	89.4	64.5
Likelihood (for future events)	6.1	0.9	5.3	0.8	5.7	1.2	4.9	0.8

Note. All dimensions were assessed on a Likert scale ranging from 1 to 7, except affective valence, which was assessed on a Likert scale ranging from -3 to 3, and temporal location from the present (which was assessed in months).

Temporal order

The percentage of events that were incorrectly ordered in time was compared between groups and time orientations. Results showed that order errors were more frequent in patients than controls (OR=1.80, CI95%:1.03-2.96, *Pr*(OR>1) = .98), but did not differ between past and future events (OR=1.34, CI95%:0.80-2.12, *Pr*(OR>1) = .86). No relevant interaction was found (OR=0.75, CI95%:0.35-1.14, *Pr*(OR>1) = .16). On average, patients with schizophrenia made order errors for 17% (*SD* = 16) of past events (vs. 7%, *SD* = 9, for controls) and 16% (*SD* = 16) of future events (vs. 10%, *SD* = 8, for controls).

Correlation analyses

We computed correlations between the percentage of use of each strategy/multiple

strategies and the PANSS scores. There was no association between the PANSS total score and the use of any temporal location strategies (all *Prs* (ρ>0) between .09 and .91). However, we found that a higher level of clinical symptoms was associated with a reduced use of multiple strategies (ρ =-0.31, CI95%:(-0.63)-(0.06), *Pr*(ρ>0) = .04). This association was mainly due to the level of negative symptoms (ρ =-0.31, CI95%:(-0.62)-(0.07), *Pr*(ρ>0) = .05), rather than positive symptoms (ρ =-0.16, CI95%:(-0.53)-(0.07), *Pr*(ρ>0) = .16).

Then we computed the correlations between the percentage of use of temporal location strategies and percentage of events that were incorrectly ordered in time. We found that a more frequent use of lifetime periods/extended events was associated with an increase of order errors in patients (ρ =0.42, CI95%:0.08-0.69, *Pr*(ρ>0) = .99). The four other temporal locations strategies were not associated with order errors and no relevant correlations were observed in controls (all *Prs* (ρ>0) between .11 and .90).

Finally, we computed correlations between the executive functioning (and other cognitive) scores, the percentage of use of temporal locations strategies, and the percentage of order errors. We found no association between executive functioning (and other cognitive functions) and temporal location and order processes, (all *Prs* (ρ>0) between .18 and .61).

Sensitivity analyses

We tested the robustness of the statistical analyses using non-informative and pessimistic priors (i.e. informative priors used in the opposite direction of the expected effect) for time orientation and mode of location, and our conclusions remained globally unchanged (for description of the few changes, see Supplementary material).

Discussion

The aim of the present study was to investigate temporal location and order processes for past and future events in schizophrenia. Our results showed that patients directly accessed to the temporal location of important events as frequently as control participants. However, when events were not directly dated, patients with schizophrenia less frequently relied on a combination of strategies and used contextual details and temporal landmark events less frequently than control participants to reconstruct or infer the dates of personal events. Moreover, patients with schizophrenia were less certain about the given dates and made more errors when they were later asked to temporally order events in time. Taken together, these results shed new light on the temporal location and order processes that are altered in schizophrenia.

In line with previous studies (Ben Malek et al., 2018; Ben Malek et al., 2017; Friedman, 1987; Skowronski et al., 1995; Thompson et al., 1993), we found that the majority of past and future events were located in time using reconstructive processes, and that only a minority of events were directly located in time. This preponderance of reconstructive strategies was observed in both groups of participants. However, we found that patients with schizophrenia relied on a single strategy (rather than a combination of strategies) more frequently than controls to reconstruct or infer the dates of past and future events. A possible explanation for the reduced use of a combination of strategies may be that patients have difficulties to use some of these strategies. Indeed, we found that the proportion of use of contextual details and temporal landmark events was lower in patients than in controls, and that patients mainly relied on the combination of semantic strategies (i.e., lifetime periods, factual information) rather than episodic strategies (i.e., specific landmark events, contextual details) as controls did. Contextual details are an

important source of information that is frequently used by healthy people to estimate the times of past events (Ben Malek et al., 2017). Temporal landmarks are meaningful and vivid events (such as one's graduation, children's birth, and so on) which date is known; such events contribute to structure past and future subjective times (Shum, 1998) and to determine the temporal location of other events (Friedman, 2004; Thompson et al., 1996). The less frequent use of these strategies and their combination to locate past and future events in time may be explained by patients' reduced ability to access episodic information in long-term memory (Berna et al., 2015; Riutort, Cuervo, Danion, Peretti, & Salamé, 2003). The lower feeling of mental time travel observed in patients corroborates this deficient access to episodic details, which could not be used to reconstruct or infer the times of past and future events. Correlation analyses revealed that patients' reduced capacity to combine strategies to date events was more marked in patients with higher levels of symptoms, in particular negative symptoms. This result aligns with previous studies showing an association between the severity of negative symptoms and the capacity to access episodic memory details (Raffard, D'Argembeau, et al., 2010; Raffard, D'Argembeau, et al., 2010). Our results further suggest that this association does not result from impairments of executive functioning, but may instead be due (at least partly) to the disturbance of self-continuity across subjective time in schizophrenia (Allé, D'Argembeau, et al., 2016; Chen et al., 2016; Danion et al., 2005; Danion, Huron, Vidailhet, & Berna, 2007).

Besides these differences in the use of contextual details and landmark events, patients relied on semantic and general knowledge (i.e., lifetime periods/extended events, factual information, conventional time patterns) to the same extent as controls to reconstruct or infer the times of past and future events. Previous studies have shown that knowledge about lifetime periods is frequently used to date personal events (Ben Malek

et al., 2018; Ben Malek et al., 2017). Indeed, lifetime periods contextualize specific events in one's personal life story (Conway & Pleydell-Pearce, 2000) and contain temporal knowledge that can be used to retrieve or envision the dates of past or future events (Ben Malek et al., 2017; Thomsen, 2015). Holm, Thomsen, & Bliksted (2016) showed that patients with schizophrenia are able to narrate and to date chapters of their life story. This preserved access to autobiographical periods indicates that some basic, easily accessible, and coarse temporal organisation of past and future thought may be preserved in schizophrenia.

Our results also showed that patients with schizophrenia were less certain than controls about the temporal locations of past and future events. This aligns with previous results showing that patients' ability to clearly remember when personal events happened is affected (Danion et al., 2005). However, it is worth mentioning that the certainty ratings of patients were still relatively high (M = 5.14 on a 7-point scale, compared to M = 5.67 in controls), suggesting that patients did not date events at random. Interestingly, we found that patients with schizophrenia made more errors than controls when they were later asked to temporally order the past and future events that had been previously dated. A possible explanation could be that the temporal locations provided by patients were not reliable, which lead to an increase of errors when they had to temporally order the same events. Another explanation would be that the provided dates were reliable, but that temporal order processes are altered in schizophrenia. A limitation of the present study is that we cannot distinguish between these two explanations because we did not collect independent information that would allow us to check whether the provided dates were accurate. Interestingly, however, we found that the use of lifetime periods/extended events to locate events in time was associated with an increase of order errors in patients, which suggests that the dates inferred from the knowledge of lifetime periods may not be

precise enough to correctly order the events in time. This is in line with previous findings showing that the use of lifetime periods was associated with a reduced accuracy of the dating of past events, compared to the use of specific landmark events (Skowronski et al., 1995; Thompson et al., 1993). Taken together, our findings suggest that the difficulty of patients with schizophrenia to order personal past and future events in time may at least partly relate to their propensity to use coarser temporal location processes, which might contribute to blur their representation of past and future times.

The present findings showed that patients with schizophrenia were able to directly locate past or future events in time as frequently as controls, and the proportion of directly dated events (between 15 and 25%) in both groups was similar to that reported in previous studies (Ben Malek et al., 2018; Ben Malek et al., 2017; Friedman, 1987; Skowronski et al., 1995; Thompson et al., 1993). It is worth mentioning that the minority of events that are directly located usually correspond to personally important and temporally close events (Ben Malek et al., 2017; Friedman, 1993, 2004; Thompson et al., 1996), and the direct access to temporal information for these events may be critical for successful goal pursuit (Ben Malek et al., 2018). In line with this view, we found that both patients and controls rated those events as more important for personal goals (and more likely to happen for future events) than events whose dates were reconstructed, suggesting that knowledge about personal goals may facilitate access to temporal information (Ben Malek et al., 2018) and supporting the view that time and goal processes are intimately linked (Etkin, 2018). Nonetheless, the subjective vividness and feeling of mental time travel were higher for directly located events compared to reconstructed events in controls but not in patients. According to the model of Self-Memory System (Conway, 2005), personal goals facilitate access to episodic information both when remembering the past and when imagining the future (Conway, Justice, & D'Argembeau, 2018). The lower

vividness of directly dated events in patients may reflect a reduced influence of goals on episodic access and/or a weakening of central control processes guiding the access to autobiographical memory in schizophrenia, an hypothesis discussed elsewhere (Berna, Potheegadoo, & Danion, 2014).

To conclude, the present study showed that patients with schizophrenia exhibit some alterations of temporal location processes. They less frequently use combinations of strategies and strategies based on episodic information to reconstruct or infer the times of personal past and future events, in comparison to controls. They also exhibit greater difficulty to order personal events in time. These findings suggest that the temporal component of mental time travel is blurred in schizophrenia and point to possible therapeutic implications. For instance, training patients to better access episodic information (e.g., by providing relevant cues or using visual imagery) and helping them to better specify and organize future times may contribute to improve personal goal pursuit.

Supplementary material

Sensitivity analyses using pessimistic priors for time orientation (i.e., past vs. future) showed that the group effect for the use of specific events to locate events was no longer meaningful (OR=0.73, CI95%:0.45-1.13, *Pr*(OR>1) = .07). In contrast, conclusions remained unchanged regarding the group effect for the use of factual information (OR=0.57, CI95%:0.35-0.88, *Pr*(OR>1) = .006), and the interaction effect for the use of contextual details (OR=2.66, CI95%:1.28-4.97, *Pr*(OR>1) = .99), for the use of lifetime periods/extended events (OR=0.53, CI95%:0.29-0.90, *Pr*(OR>1) = .01), and for the use of factual information, (OR=1.69, CI95%:0.95-2.88, *Pr*(OR>1) = .95).

Table S1. Mean percentages (and standard deviations) of combinations of temporal location strategies for patients with schizophrenia (n = 30) and controls (n =30).

	Controls n=30		Patients n=30	
	M	*SD*	*M*	*SD*
Lifetime periods/extended events – Specific landmark events	14.76	18.38	18.58	32.83
Lifetime periods/extended events – Conventional time patterns	8.63	13.56	9.21	24.04
Lifetime periods/extended events – Factual knowledge	17.82	20.53	36.88	36.57
Lifetime periods/extended events – Contextual details	31.64	33.65	9.82	13.84
Specific landmark events – Conventional time patterns	3.85	8.16	9.52	25.01
Specific landmark events – Factual knowledge	3.30	6.31	13.03	26.96
Specific landmark events – Contextual details	3.30	6.31	2.63	11.47
Conventional time patterns – Factual knowledge	6.34	11.13	3.95	12.53
Conventional time patterns – Contextual details	1.72	5.61	5.26	13.38
Factual knowledge – Contextual details	11.48	21.09	4.26	10.75

Table S2. Non-informative and pessimistic priors parameters for time orientation (i.e., past vs. future) for the analysis of the frequency of temporal location strategies (based on the results of Ben Malek, Berna & D'Argembeau, 2017).

	Non-informative		Pessimistic	
	Alpha (precision)	Beta (precision)	Alpha (precision)	Beta (precision)
Lifetime periods/extended events	0 (0.01)	0 (0.01)	-0.064 (0.5)	-0.168 (8)
Specific landmark events	0 (0.01)	0 (0.01)	0.006 (0.5)	-0.028 (8)
Conventional time patterns	0 (0.01)	0 (0.01)	-0.009 (0.5)	-0.201 (8)
Factual information	0 (0.01)	0 (0.01)	0.041 (0.5)	0.113 (8)
Contextual details	0 (0.01)	0 (0.01)	-0.155 (0.5)	-1.681 (8)

Note. The regression equation was defined as following: Y = Alpha + Beta * Time orientation

Table S3. Non-informative and pessimistic priors parameters for time orientation (i.e., past vs. future) for the analysis of event characteristics (based on the results of Ben Malek, Berna & D'Argembeau, 2017).

	Non-informative		Pessimistic	
	Alpha (precision)	Beta (precision)	Alpha (precision)	Beta (precision)
Subjective vividness	0 (0.01)	0 (0.01)	0.579 (0.01)	2.166 (0.784)
Affective valence	0 (0.01)	0 (0.01)	-1.654 (0.01)	3.696 (0.512)
Importance for personal goals	0 (0.01)	0 (0.01)	0.360 (0.01)	2.804 (0.574)
Mental time travel	0 (0.01)	0 (0.01)	0.487 (0.01)	2.611 (0.781)
Event rehearsal	0 (0.01)	0 (0.01)	-0.027 (0.01)	4.455 (0.239)
Time rehearsal	0 (0.01)	0 (0.01)	-0.338 (0.01)	2.902 (0.642)
Subjective temporal distance	0 (0.01)	0 (0.01)	-0.283 (0.01)	1.300 (1.921)

Note. The regression equation was defined as following: Y = Alpha + Beta * Time orientation

CHAPTER 5

DISCUSSION

Summary of the results

The role of inferential processes in the temporal location of future events

The direct dating of future events

The role of personal goals in the temporal location of future events

Is the temporal location of past and future events supported by similar mechanisms?

A dual process model of temporal location for autobiographical events

Temporal location and order processes of autobiographical events in schizophrenia

Temporal location and order processes: implications for goal-pursuit in schizophrenia

Limitations

Perspectives

Conclusion

Summary of the results

The three studies of the present thesis shed new light on the mechanisms involved in the temporal location of autobiographical events and on the alteration of temporal location and order processes in schizophrenia. First, we identified how people envision when future events would likely occur. Second, we determined how the representation of personal goals influenced temporal location processes for future events. Third, we found that patients with schizophrenia exhibited some alterations of temporal location and order processes for past and future personal events.

Concordant with our expectations, we found, in Study 1, that the strategies used to locate past and future events in time were highly similar, suggesting that the temporal location of both past and future events mainly relies on reconstructive and inferential processes. References to lifetime periods/extended events and factual knowledge (about the self, others, or the world) were most frequently used to determine the temporal location of both past and future events. However, contrary to the other strategies, the use of contextual details was more frequently used to date past events than to envision when future would likely occur. Interestingly, a minority of future events (and of past events) were directly dated, and these directly located events presented some features that distinguished them from events that were located in time using reconstructive/inferential strategies. Indeed, directly dated events were judged as more vivid, associated with a stronger feeling of mental time travel, more important for personal goals, and less temporally distant than events located in time using reconstructive strategies. Time information of directly dated events was also reported as more frequently rehearsed. However, some of these event features tended to co-vary (e.g., vividness and personal

importance), therefore further investigation was needed to specify the contribution of each feature (and in particular, personal goals) to direct dating process.

To address this question, in Study 2, we investigated the role of personal goals in the temporal location of future personal events. Confirming the results of Study 1, we found that most events were located in time using reconstructive or inferential strategies, regardless of the nature of the event (i.e., events related to goals, familiar places or experimenter-provided scenarios). Interestingly, the results showed that goal-related events were directly located in time more frequently than scenario-related (but not place-related) events. We also found that the perceived importance of events for personal goals was a predictor of the direct access to temporal information. When the events were not directly located in time, we showed that participants relied on lifetime periods/extended events more frequently to infer the times of goal-related events, than place- and scenario-related events. The perceived importance of events for personal goals predicted the use of lifetime periods/extended events and of specific landmarks, whereas it was negatively related to the use of conventional time patterns to locate events in time.

In Study 3, we sought to examine whether the processes involved in the temporal location and order of past and future events are altered in schizophrenia. The results showed that patients with schizophrenia directly accessed to the temporal location of important events as frequently as control participants. However, contrary to controls, directly dated events were not judged as more vivid and more associated with a feeling of mental time travel than events whose dates were reconstructed or inferred. When the events were not directly dated, we found that patients with schizophrenia less frequently relied on a combination of strategies and used contextual details (e.g., persons, places, activities, weather conditions) and temporal landmark events less frequently than control participants to reconstruct or infer the dates of personal events. Patients used lifetime

periods/extended events, factual information (about the self, others or the world), and conventional time patterns as frequently as controls to determine the times of personal events. Nonetheless, patients with schizophrenia were less certain about the given dates and made more errors when they were later asked to temporally order events. Correlation analyses showed that a greater severity of negative symptoms was associated with the reduced use of a combination of temporal location strategies, and that the use of lifetime periods/extended events was associated with an increase of order errors in patients.

The role of inferential processes in the temporal location of future events

People spend much of their time thinking about what will happen in their future life. These thoughts represent future events that can more or less specific, embrace various themes (e.g., work, relationships) and serve a range of functions (e.g., decision making, action planning). While the contents and functions of future-oriented thinking are well investigated (D'Argembeau, Renaud & Van Der Linden, 2011), it remained poorly understood before conducting this thesis, how people proceed to locate imagined events at particular points in time. Similarly to previous work showing that memory for the times of personal past events is mainly based on reconstructive and inferential processes (Friedman, 1993, 2004, Thompson et al., 1996), we found that the temporal location of future events is mainly determined using inferential processes. Our three studies showed that about 75-80% of future events were located in time using various information (or what we call 'strategies') available to reconstruct or infer the times of events, whereas about 20-25% of future events were directly located in time (i.e., without the use of any strategy).

Among the events whose dates were located using temporal location strategies, about 45% of future events (vs. 40% of past events) were located in time using reference to lifetime periods/extended events, which was the strategy most frequently used to determine the times of both past and future events. The proportion of use of lifetime periods/extended events was similar between Study 1 and 2[7], which suggests a convergence of our findings. In Study 3, however, while the proportion of use of lifetime

[7] When the proportion of use of lifetime periods/extended events to determine future times is averaged between goal-related, place-related and scenario-related events.

periods/extended events to date past events was similar to the other studies, the use of this strategy was reduced for the future (i.e., used for 25% of future events). This may be explained by a difference of participants recruitment in Studies 1 and 2, compared to Study 3. Indeed, our participants in the first two studies were mostly young undergraduate students (about 22 years old), whereas participants in Study 3 were older (about 38 years old). The relevance of lifetime period/extended events to infer the times of events (mostly in the future) may evolve along the course of life. Perhaps because expectations of environmental change (for example in work or personal life) decrease with age, this strategy may be less useful to discriminate future times in middle-aged adults. In contrast, information regarding others or the society may be more accessible and useful to organize future times in this age group (see pages 160-161, 169-171). It is worth noting that other factors than age *per se* (such as level of education, richness of social, personal or work life) may also contribute to explain differences between studies in the frequency of use of anticipated lifetime periods/extended events to organize and discriminate future times. Be that as it may, the use of lifetime periods/extended events remains an important means for inferring future times, and may be especially important to infer the times of events that are highly related to personal goals (see the section entitled 'The role of personal goals in the temporal location of future events').

How to explain why people frequently relied on this knowledge to infer temporal locations of future events? Based on a prominent conception of the architecture of autobiographical memory (Conway & Pleydell-Pearce, 2000; Conway, 2005, 2009), it has been recently proposed that episodic future thoughts are contextualized in an individual's life by higher-order autobiographical knowledge (i.e., anticipated lifetime periods and extended events; Conway et al., in press; D'Argembeau, 2015). Our findings give support to this view by showing that anticipated lifetime periods play a major role

in the temporal location of future events. A lifetime period is defined as a representation that contains knowledge about people, places, activities and objects that are common to that period (Thomsen, 2015). People can both remember and anticipate periods and perceive their beginnings and endings. It has been suggested that the boundaries of such periods are defined by transitions that bring about significant changes to life circumstances (e.g., relocation, Brown, 2016), and there is indeed evidence that such transitions play a key role in locating specific past events in time (Brown et al., 2016; Zebian & Brown, 2014). Our results suggest that mental representations of autobiographical periods can not only be formed following actual changes in material conditions (e.g., changes of job, house, partner), but also in response to expected changes in the future (e.g., when I will have graduated, when I will be living in Paris, when I move in with Claire). Expected transitional events (which may be idiosyncratic or governed by cultural life scripts; Bernsten & Rubin, 2004) may play a key role in structuring future times, with the ensuing structure of anticipated life periods being frequently used to estimate when future events would likely occur.

Paralleling the use of lifetime periods/extended events, we found that about 30-40% of future events (vs. about 30% of past events) were located in time using factual knowledge. More specifically, participants referred to general information about the self (e.g., I know that I will be busy next month), others (e.g., my friend will not be able to join me next summer because she got an internship abroad), and the world (e.g., the concerts generally take place in September) to estimate the temporal location of envisioned future events. While the frequency of use of factual information to determine future times was similar in Studies 1 and 2, participants of Study 3 used this temporal location strategy to a greater extent (for about 55% of future events). This increased use of factual knowledge in middle-aged people may be a compensation of the less frequent

use of anticipated lifetime periods/extended events to infer the times of future events. Indeed, the amount of general information about others and the world may increase along with the accumulation of life experiences. Taken together, our findings suggest that personal and general semantic knowledge (about the others or the world) provides relevant information that contribute to structure imagined events in future times, and the use of this knowledge may increase with age.

Another strategy was the use of some events whose dates were known (landmark events) to infer the times of future events. This strategy was used for about 10-15% of future events (vs. 15% of past events), and we found similar proportion of use in all three studies. Previous work has shown that temporal landmarks are meaningful events that are frequently used as reference points to retrieve the times of past events (Shum, 1998; Thompson et al., 1993; Skowronski et al., 1995; Friedman, 1987). In the same vein, our studies show that landmark events can be used to envision when future events would likely occur. These landmark events can represent personal or cultural reference points that have already been anticipated and can be used to structure and temporally organize future times. For example, landmark events can represent transitional events that announce beginnings or endings of lifetime periods (Thomsen, 2015; Brown, 2016), which may play an important role in the temporal location of future events, especially for goal-relevant events.

Conventional time patterns were also used to reconstruct or infer the times of both past and future events, although to a lesser extent (around 10% of past and 10% of future events). The use of this temporal location strategy was similar across the three experimental studies. Reasoning using the calendar (i.e., days, weeks, months, years) or natural time patterns (e.g., seasons) may be useful when no other information is available to infer the times of future events. Interestingly, in Study 2, we found that scenario-related

events (that were weakly related to personal goals) were more frequently located in time using conventional time patterns (for about 20% of events) than goal- and place-related events (for less than 5% of events). Furthermore, the certainty associated with the estimation of dating was judged lower for scenario-related events, and these events were rated as less likely to occur than goal-related events. These findings suggest that future events that were less easily embedded in an autobiographical context (i.e., scenario-related events) were more frequently located in time using the calendar or natural time cycles, probably because other information (e.g., anticipated lifetime periods) was lacking to infer the dates of these events. The temporal location of these events may be more labile and uncertain because they are less contextualized within the individual's life story.

Finally, participants sometimes relied on contextual details of events (e.g., locations, activities, persons, weather conditions) to infer their temporal location. However, the use of contextual details was more frequent for determining the times of past (about 20% of events) than of future events (less than 5% of events), particularly in young adults. Indeed, we found that the use of contextual details to infer the times of future events was more frequent for middle-aged adults (about 15% of events in Study 3), which might compensate the reduced use of anticipated lifetime periods. Contextual details can provide clues for determining the temporal location of past events, whereas this is less frequently the case for future events. Giving support to this idea, we examined in Study 1 which contextual details were more frequently used, and we found that details that helped participants to determine the times of future events were mainly details about the weather conditions (70% of the reported event details) suggesting that the other contextual details (e.g., as locations, activities, persons) may not provide relevant information for inferring temporal locations. This difference in the use of contextual details for locating past and future events in time may be related to fundamental

asymmetries between remembering and future thinking (see the section entitled ‘Is the temporal location of past and future events supported by similar mechanisms?’)

In summary, our research showed that to determine when events would likely occur, people most frequently infer dates using a variety of information about anticipated futures. This information can be episodic (i.e., contextual details, landmark events) and/or semantic (lifetime periods/extended events, factual knowledge, conventional time patterns), and people frequently combine different types of information to infer future times. Together, these different strands of information may structure the representation of a personal timeline that is used to place envisioned events in future times.

The direct dating of future events

Although the majority of future events were located in time using inferential processes, it is worth noting that about 15-25% of future events were dated directly (i.e., without the use of any temporal location strategy). This proportion slightly differed across the three studies and this may be explained by an influence of certain event features (for example, goal-relevance or rehearsal frequency, see below). A similar proportion of past events (about 20-25% of events) were directly located in time, confirming previous findings suggesting that the dates of a minority of events can be directly accessed (Friedman, 1993, 2004; Thompson et al., 1996, 1993; Skowronski et al., 1995). The findings of the present thesis are the first to highlight the existence of such direct dating for future events and they further bring some insight into the mechanisms that may support the direct access to the dates of personal events.

What are the characteristics that would allow events to be directly dated? In Study 1, we found that directly dated events were judged as more vivid, more important for personal goals, associated with a stronger feeling of mental time travel, and were less temporally distant than events located in time using inferential/reconstructive strategies. Time information of directly dated events was also reported as more frequently rehearsed. Confirming these results, we found in Study 3 that directly dated events were judged with a greater vividness, importance for personal goals, and mental time travel than events whose dates were inferred. However, contrary to Study 1, time and event rehearsals did not differ as a function of mode of location in Study 3. Directly dated events were more temporally distant in Study 3 (M = 58 months) than in Study 1 (M = 29 months), and this increased distance may explain why time information of directly dated events was not more frequently rehearsed than events whose dates were inferred in Study 3. These

findings suggest the direct dating concerns events that are highly vivid, temporally close, and personally important—features that likely make these events particularly accessible. Adding support to the association between the personal relevance of events and the direct access to their dates, Study 2 showed that goal-related future events were more frequently directly located (20% of events) than goal-unrelated future events (i.e., scenario-related, 5% of events). Furthermore, we found that the perceived importance of events for personal goals predicted their direct dating and that this association may be mediated by the rehearsal of event dates. Taken together, the findings of Studies 1, 2 and 3 suggest that goal-relevance and rehearsal may be two key processes which favour a direct dating of envisioned events. This increased accessibility of temporal locations for important future events may in turn facilitate future planning and contribute to goal-pursuit.

A question that remains is how people directly date some personal events? For past events, a possible explanation is that some episodes might be time-tagged at encoding, such that time information can be later directly retrieved from memory (Friedman, 1993, 2004). Another explanation would be that temporal information was not encoded in memory during the initial episode but instead had been reconstructed during a previous retrieval attempt. The reconstructed date might then be encoded in memory along with the event representation, such that it can be directly accessed during subsequent retrieval occasions. In the same vein, a direct access to the temporal location of future events might occur because people have already thought about these events as well as their possible dates on a previous occasion (which is supported by our findings, as discussed above), such that this information has been encoded in memory as part of "memories of the future" (i.e., memory for previous future event simulations; Jeunehomme & D'Argembeau, 2017; Szpunar, Addis, McLelland, & Schacter, 2013). Recent findings have shown that previously imagined future events can be directly

accessed in response to relevant cues (Cole, Staugaard & Berntsen, 2016; Jeunehomme & D'Argembeau, 2016), and a similar phenomenon might thus occur for the temporal location of imagined events.

The role of personal goals in the temporal location of future events

Personal goals are defined as personally important objectives that people pursue in their daily lives (Emmons, 1986; Klinger, 2013; Little, 1983; McAdams, 2013). Goal-related knowledge is represented in a hierarchical structure that organizes higher-order goals (e.g., having a successful academic career) in sequences of sub-goals (e.g., receiving a PhD degree with highest honors, finding postdoc positions in competitive laboratories) that specify how to attain desired states (Austin & Vancouver, 1996; Wadsworth & Ford, 1983). The ability to locate goal-related events at specific times may be critical for planning and goal-pursuit, and in turn, goal-achievement often requires a sequence of actions that need to be ordered and carried out at specific times (e.g., on a given day or within a particular temporal window). However, whether and how personal goals influence the temporal location of future events was poorly understood before this thesis.

As described earlier, our results suggest that the goal-relevance of events may have influenced the accessibility of their temporal locations. Indeed, the findings of Study 1 and 3 showed that directly dated events are judged as more important for personal goals than events whose dates were reconstructed or inferred. Suspecting their key role, we decided to focus our research on how personal goals contributed to the temporal location of future events. The results of Study 2 highlighted that personal goals influenced not only direct dating but also inferential processes. First, we found that the dates of goal-related events were directly accessed more frequently than the dates of goal-unrelated events (i.e., scenario-related). Furthermore, the perceived importance for personal goals was a strong predictor of the direct dating of events. It is also worthy to note that the

association between the goal-relevance of events and their direct dating seems to be mediated by the rehearsal of dates. These findings emphasize the idea that personal goals may facilitate the access to temporal information (probably by enhancing the rehearsal of time information), which may contribute to successful planning and goal-pursuit.

Second, when goal-related events were not directly dated, they were more frequently located in time using anticipated lifetime periods. Moreover, the use of anticipated lifetime periods was predicted by the perceived goal relevance of events (and not mediated by time rehearsal). These findings support the view that personal goals contribute to the temporal organization of imagined future events because they are closely associated with higher-order autobiographical knowledge (D'Argembeau, 2015, 2016; Conway et al., in press). In fact, the construction of lifetime periods may in part be determined by personal goals (Thomsen, 2015). For example, the goal of getting married will delineate a period of married life in one's mental time line, which can then be used to determined when associated (i.e., goal-relevant) events will likely happen. Thus, goals may drive the construction of a personal timeline, composed of anticipated lifetime periods, that serves to temporally organize and locate episodic future thoughts. In addition, the perceived importance of events for personal goals also predicted the use of anticipated landmark events, suggesting that these events (which could constitute beginnings and endings of lifetime periods) are part of the timeline that structures the future. There is strong evidence that personal goals guide the construction and the organization of episodic future thoughts (D'Argembeau & Mathy, 2011; D'Argembeau & Demblon, 2012; D'Argembeau, 2015) and the present findings further suggest that personal goals may also play a central role in the temporal location and temporal organization of episodic future thoughts.

Is the temporal location of past and future events supported by similar mechanisms?

The results of the present thesis provide novel insights into the similarities and differences in the cognitive mechanisms that support the temporal location of past and future personal events. Extensive research over the last decade has shown that episodic future thinking and episodic memory are closely linked and share (at least partly) common cognitive and neural mechanisms (for reviews, see D'Argembeau, 2012; Schacter et al., 2012, 2017; Szpunar, 2010). Interestingly, a recent functional magnetic resonance imaging (fMRI) study has shown that judgements of temporal order recruit a common neural network for past and future events, suggesting that (at least partly) similar processes are used to order events in past and future times (D'Argembeau et al., 2015). The findings of Study 1 & 2 support this view by showing that the strategies used to reconstruct or infer temporal locations are mostly similar for past and future events, suggesting that (at least partly) similar mechanisms are involved in estimating the times of past and future events.

Surprisingly, however, the findings of Study 3 contrast with this view. Indeed, participants relied more frequently on lifetime periods/extended events, specific landmark events, conventional time patterns and contextual details to date past than future events. On the other hand, the use of factual knowledge was more frequent to infer the times of the future than to reconstruct the times of the past. These differences reflect a distinct pattern of use of strategies for the future, compared to the one we found in our previous studies. The availability of information used to infer the times of events (and mostly of future events) may evolve along the course of life. For example, the reduced use of anticipated lifetime periods in middle-aged adults (Study 3) may be explained by less

expected changes of the environment (for example in one's social, personal or work situation), such that this strategy may not be relevant enough to discriminate future times, whereas general knowledge about others or the world may be more stringent and distinctive to envision future times. Differences in the age of participants between studies may thus explain differences in the strategies used to infer the times of future experiences. Furthermore, other factors may also contribute to influence temporal location processes. In Studies 1 & 2, participants were mostly undergraduate students whereas they were mostly employed in Study 3. Differences in socio-professional status (along with the level of education) and richness of socio-personal life may influence the use of temporal location strategies. For example, a higher richness of socio-personal life may increase the elaboration of knowledge about others, which could then be more frequently used to infer the times of future experiences. However, these interpretations remain speculative and the hypothesized roles of age, socio-professional status, and richness of social and personal life in the use of temporal location strategies require further empirical investigation.

An alternative hypothesis that may explain asymmetries in temporal location processes between the past and the future is that remembering the past and imagining the future are different in kinds (Perrin, 2016). For example, Studies 1 & 3 showed that the use of contextual details was more frequent to determine the dates of past than future events. A possible explanation is that details of past events are constrained by what happened and thus can be used as clues for dating events, whereas details of future events are more malleable and influenced by imagination processes, thus being less relevant for inferring the dates of events. Moreover, previous studies showed that children are able to reliably differentiate distances of events at an earlier age for the past (4 years old) than for the future (5 years old), and the earlier development of this capacity may be due to the

vividness of memories, which provide a clue to their distance (Friedman, 2000). These differences between temporal location processes for past and future events may be (at least partly) explained by the epistemic status of remembering and future thinking (Perrin, 2016). For example, in remembering, there is some (albeit imperfect) correspondence between the individual's representation of a past event and the actual occurrence of this event in the past, whereas future thoughts are about events that have not yet occurred and thus may or may not actually occur. Moreover, "a past event can have present effect, while a future one cannot […] it will possibly have causal effects as it will become present" (p. 47). This fundamental difference in the *actuality* events and in its causal effects may (at least partly) explain some observed differences in the temporal location processes for past and future events. It may also contribute to explain why participants made more errors in ordering future than past events.

A dual process model of temporal location for autobiographical events

Based on previous research on memory for the times of past events and our novel findings, we propose a theoretical model which aims to account for the processes involved in the temporal location of autobiographical events in both past and future times. In this model (see Figure 2), we suggest that two independent, but complementary processes are involved in the temporal location of personal past and future events: reconstructive/inferential and automatic processes.

The first process, which is used to date the majority of personal events, is defined as a strategic/controlled process which allows people to reconstruct or infer the dates of personal events from a variety of available information. It is an effortful, slow process that (most of the time) lead to imprecise time locations. The nature of information that serve to reconstruct or infer dates can be semantic and/or episodic. The semantic subsystem includes the use of lifetime periods/extended events, general information (on the self, others or the world) and knowledge of natural (e.g., seasons) or conventional (e.g. parts of the day, week, month, and year) time patterns. The episodic subsystem includes information regarding contextual details (e.g., locations, activities, persons, weather conditions) of the event to date and other specific events whose dates are known and play the role of temporal landmarks. These two subsystems may be accessed in parallel, and play complementary roles since people frequently combine semantic and episodic information to reconstruct or infer the times of autobiographical events. The use of multiple strategies may be more frequent to determine the times of events in the past than the future, as multiple information may be required to check the accuracy of reconstructed dates.

The second process, which is used to locate around 25% of autobiographical events, is defined as automatic and allows a direct access to temporal information of past and future events. It is a non-controlled, perhaps effortless, process that leads to a fast access to precise time locations. The direct dating generally concerns events that are highly vivid, important for personal goal, frequently rehearsed, and close to the present time. The exact mechanism of the direct dating of events is not fully understood yet. However, our studies suggest that goals and rehearsal processes may contribute to the direct access to temporal information of personal events. A direct dating may be possible because events are 'time-stamped' at encoding, such that temporal location can be directly and automatically retrieved from memory. Another possibility is that time information is not encoded in memory during the initial episode but is instead reconstructed or inferred during a subsequent retrieval attempt; this reconstructed date may then be encoded in memory along with the event representation, such that it can directly be accessed during subsequent retrieval occasions.

Although the two types of temporal location processes are independent, it is possible to move from one process to the other to determine an event's date on different occasions. A specific event whose date has been reconstructed or inferred may be later directly located because its temporal location has been mentally rehearsed at multiple occasions and no longer needs to be reconstructed or inferred. On the other hand, an event that has been directly dated may be progressively forgotten, for example, when its temporal location is not enough mentally rehearsed, or when the event is no longer important. At a latter attempt to date this event, it would be inevitable to use reconstructive or inferential processes to determine the date of that event.

Personal goals may play a key role in the organization of temporal location processes. Personal goals influence both direct dating and reconstruction/inference

processes. First, personal goals influence the accessibility of goal-related events, so that their dates could be directly accessed more easily and frequently. Second, personal goals favor the use of lifetime periods to reconstruct or infer the times of events that could not be directly accessed. It has been proposed that personal goals and autobiographical knowledge are strongly inter-connected (Conway & Pleydell-Pearce, 2000; Conway, 2009; Conway et al., in press; D'Argembeau, 2015, 2016), so that personal goals constitute a relevant cue to access past and future event representations. Our findings support this view by showing that personal goals foster the access to autobiographical knowledge to infer the times of personal events.

Beyond or in addition to personal goals, other event features (e.g., affective valence, temporal proximity), socio-demographic characteristics (e.g., age, level of education) or clinical conditions (e.g., schizophrenia) may also differently influence temporal location processes and their subsystems, and these factors need to be empirically examined to enrich the model.

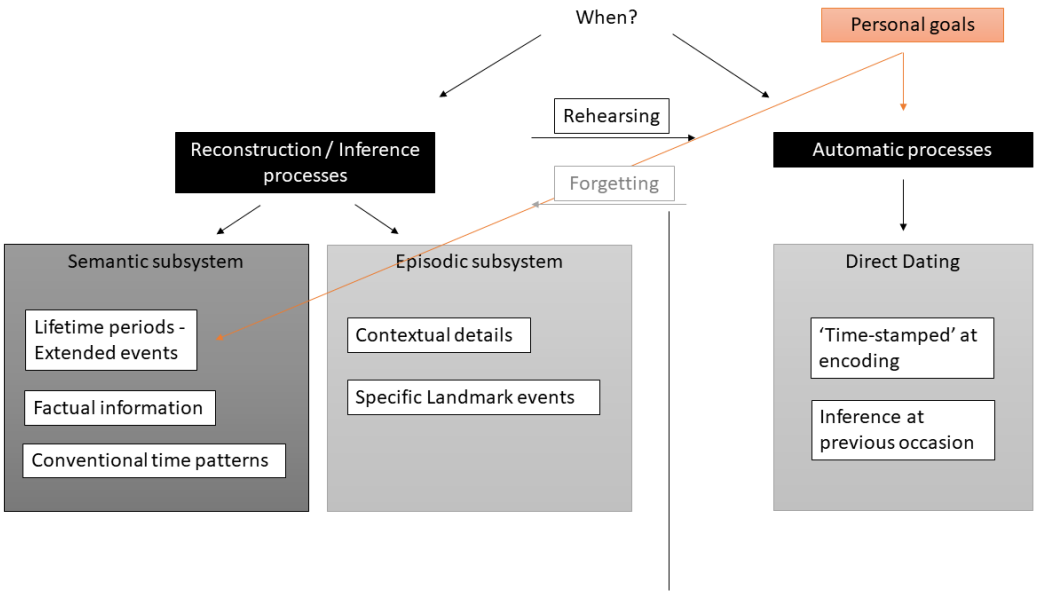

Figure 2. A dual process model of temporal location of autobiographical events

Temporal location and order processes of autobiographical events in schizophrenia

Reconstructive/inferential processes

The present thesis brought new insight regarding the mechanisms involved in the temporal location of autobiographical events in schizophrenia. Although patients relied mostly on reconstructive or inferential processes to determine the times of past and future personal events and acted similarly to controls on this aspect, we found both similarities and differences between the two groups. Regarding similarities, patients with schizophrenia mainly used lifetime periods/extended events to reconstruct the times of past events (about 55% of events for patients and controls), and factual knowledge (about the self, others or the world) to infer the times of future events (about 50% of events for patients *vs.* about 55% of events for controls); and these proportions did not differ between the two groups. Patients with schizophrenia also relied on conventional time patterns (about 20% of events) but to a lesser extent, as did control participants (17% of events). This indicates that patients with schizophrenia are able to rely on semantic and general knowledge (i.e., lifetime periods/extended events, factual information, conventional time patterns) to locate personal events in time. Recent findings align with ours which found that patients are able to narrate and to date chapters of their life story (Holm et al., 2016). This preserved access to personal semantic knowledge at least for dating events indicates that some basic, easily accessible, and coarse temporal organisation of autobiographical memory and future thought may be preserved in schizophrenia.

Nonetheless, the statistical analyses also showed some differences between patients and controls. For instance, the proportion of use of temporal landmark events and

contextual details was lower in patients (about 15%, and 15% of events, respectively) than in control participants (about 20%, and 18% of events, respectively). Furthermore, we found that patients with schizophrenia relied on a combination of strategies (26% of past events, 13% of future events) less frequently than controls (44% of past events, 20% of future events). The reduced use of a combination of strategies may be explained by the inaccessibly of certain strands of information to determine the times of events. In favour of this idea, we found that patients less frequently relied on contextual details (e.g., persons, places, activities, weather conditions) and temporal landmark events than controls, and mainly relied on the combination of semantic strategies (i.e., lifetime periods, factual information) rather than episodic strategies (i.e., specific landmark events, contextual details) as controls did. The less frequent use of these episodic strategies and of their combination to locate personal events in time may be explained by impairments of accessing episodic details in autobiographical memory (Berna et al., 2015; Riutort et al., 2003) and future thinking (D'Argembeau et al., 2008) (for further hypotheses regarding the mechanisms involved, see pages 181-182).

Direct dating

Although the majority of future events were located using reconstructive or inferential processes, we found that patients with schizophrenia were able to directly locate 25% of past events, and 15 % of future events in time. This proportion did not differ from that of controls (25% of past events, 17% of future events). The minority of events that are directly located usually correspond to events that are close in time, personally important and frequently rehearsed, and the direct access to temporal

information preserved in patients with schizophrenia may be critical for successful goal-pursuit.

However, we found some differences regarding the characteristics associated with event representation between the two groups. Indeed, directly dated events were judged more vivid and more associated with a feeling of mental time travel than events whose dates were reconstructed or inferred in controls, but not in patients with schizophrenia. This suggests that the disease may alter the strength of event representation of events whose dates are directly accessed. According to the Self-Memory-System model (Conway & Pleydell-Pearce, 2000; Conway et al., in press), personal goals facilitate access to episodic information both when remembering the past and envisioning the future. The lower vividness of directly dated events in patients may reflect a reduced influence of goals on episodic access and/or a weakening of central control processes guiding the access to autobiographical memory in schizophrenia (Berna et al., 2014). Interestingly, however, we found no differences regarding the ratings of importance for personal goals, suggesting that the deficient access to episodic information was not explained by the selection of goals by the patients that were trivial (this explaining also that goals also facilitated direct dating of events) but rather by a weakened influence of goals on the access to episodic memory details. Moreover, event and time rehearsals did not differ either between groups, this reinforcing our hypothesis of a deficient access to episodic information.

Temporal Order

To investigate whether temporal order processes are altered in schizophrenia, we asked patients and controls to temporally order the events that had been previously dated.

The results showed that patients with schizophrenia made more order errors than controls: 17% of past events (vs. 7% for controls) and 16% of future events (vs. 10% for controls). This finding is concordant with previous observations of an alteration of temporal order for non-personal events (Schwartz et al., 1991; Rizzo et al., 1996; Waters et al., 2004; Elvevag et al., 2000; Zalla et al. 2006) and a weakened chronology of event and life story narratives (Raffard et al., 2010a; Allé et al., 2015, 2016b), but contrasts with recent evidence suggesting that sequencing personal events that happened one week before testing are preserved in schizophrenia (Allé et al., in prep). This discrepancy may be explained by a difference of temporal distance, the events being more remote in our study and thus more complex to order temporally for patients (in both past and future times).

However, since the temporal locations that were previously provided by participants were taken as reference to score temporal order performance, two alternative hypotheses may explain our findings. Either the temporal locations provided by patients were not reliable, which led to an increase of errors when they had to temporally order the same events. Or the provided dates were reliable, but temporal order processes are altered in schizophrenia. A limitation of this study was that we cannot distinguish between these two explanations because we did not collect independent information that would allow us to check whether the provided dates were accurate. Interestingly, however, we found that the use of lifetime periods/extended events to locate events in time was associated with an increase of order errors in patients, which suggests that the dates inferred from the knowledge of lifetime periods may not be precise enough to correctly order the events in time. This is in line with previous findings showing that the use of lifetime periods was associated with a reduced accuracy of the dating of past events, compared to the use of specific landmark events (Thomspson et al., 1993; Skowronski et al., 1995; Thompson et al., 1996). Taken together, our results suggest that the difficulty

of patients with schizophrenia to order personal past and future events in time may at least partly relate to their propensity to use coarser temporal location processes, which might contribute to blur their representation of past and future times.

However, more research is needed to tackle precisely the processes involved in the alteration of temporal order processes. For example, to address the limitation described above, a diary procedure in which patients would be asked to report personal events in a notebook would provide evidence about the actual occurrence of (past) events. We could imagine asking patients to order personal events that happened even several years before testing. Furthermore, to better understand the mechanisms involved, we could adapt the think-aloud procedure (used for the temporal location task) to the temporal order task. Indeed, patients would be asked to verbalize all their thoughts while ordering events in time, and we could analyse the content of thoughts flow. Finally, since ordering past and future events in time involves common neural substrates (most notably, the left posterior hippocampus, intraparietal sulcus, dorsolateral prefrontal cortex, dorsal anterior cingulate, and visual cortex) suggesting that similar processing operations are engaged for ordering past and future times (D'Argembeau et al., 2015), functional neuroimaging studies involving patients with schizophrenia may highlight which brain areas (and corresponding cognitive processes) are affected during temporal order. In particular, reduced activity (at rest and during memory retrieval) in the hippocampus (Heckers et al., 1998; Heckers, 2001) may be involved in the temporal order deficits of past and future events in schizophrenia.

Mechanisms involved in the alteration of reconstructive/inferential processes

Our findings pointed out that patients with schizophrenia have difficulties to rely on episodic information to reconstruct or infer the times of personal events. According to the dual process model of temporal location for autobiographical events (see Figure 2), our findings suggest that the episodic subsystem is affected in schizophrenia. The alteration of this subsystem may prevent patients to mentally relive and prelive personal experiences (Chen et al., 2016; Danion et al., 2005), and to accurately locate personal events in past and future times. The impairment of the episodic subsystem may be due to a dysfunction of strategic processes during encoding (Elvevag et al., 2003; Danion et al., 2007; Berna et al., 2015). Indeed, patients with schizophrenia favour a superficial level of information processing, and fail to engage efficient organisational strategies and associations, which may impact encoding in memory (Achim et al., 2005). Even if we did not find any correlation between the use of episodic information to locate events in time and cognitive functioning in our study, the impairment of executive functions in patients may likely contribute to disturb encoding in schizophrenia.

In addition, the weakening of central control processes (e.g., goal processes) guiding the access to autobiographical memory (Berna et al., 2014; Conway & Pleydell-Pearce, 2000), in interaction with lower executive functioning, may also contribute to alter the use of the episodic subsystem to determine the times of events. Corroborating the idea of a deficient access to the episodic subsystem, it has been found that providing specific cues to patients improved the memory specificity and richness of episodic details (Potheegadoo et al., 2014). However, even after the cueing procedure, the richness of contextual details (and of temporal details) was still lower in patients than in controls, suggesting that a dysfunction of retrieval processes is not the only factor involved in patients' difficulties. Most likely, alteration of both encoding and retrieval processes may

lead to a defective use of episodic information for inferring temporal locations of personal events. In turn, the lower use of episodic information might also contribute to disturb the organisation of past and future times in schizophrenia.

Finally, we found that the reduced use of multiple strategies was correlated with higher levels of clinical symptoms (and particularly of negative symptoms). Furthermore, preliminary results from a recent study conducted on a non-clinical population showed that individuals with attenuated psychotic symptoms less frequently rely on contextual details to infer the times of future events, in comparison with individuals who are less prone to experience psychotic experiences (Ben Malek et al., in prep). Taken together, these findings suggest that alterations of temporal location processes may be present upstream the disease and may evolve as a function of the severity of psychotic symptoms.

Conclusion

In summary, our findings showed that patients with schizophrenia exhibit some alterations of temporal location and order processes for autobiographical events. While they less frequently relied on episodic information, they were capable of using semantic and general knowledge to reconstruct or infer the times of personal events. Their propensity to use coarser temporal location processes, however, may disturb temporal order processes and blur the temporal component of mental time travel in schizophrenia.

Temporal location and order processes: implications for goal-pursuit in schizophrenia

The ability to locate events at specific times in the future may play a critical role in planning and goal-pursuit. Indeed, successfully achieving a goal often requires a sequence of actions that need to be ordered and carried out at specific times (e.g., on a given day or within a particular temporal window). Although it is widely shared by physicians and psychologists that patients with schizophrenia have much difficulties to pursue goals in their daily life, no empirical finding has completely unraveled yet which specific mechanisms of goal-pursuit are altered in schizophrenia. The alteration of temporal location (for example, due to a defect access to the episodic subsystem) and order processes in schizophrenia may likely account for goal-pursuit disturbance, since the representation of future times is blurred. However, more research is needed to tackle the links between goal-pursuit, temporal location and order processes of episodic future thinking, which remain poorly understood. Be that as it may, determining the dates of future events is also critical to remember to carry out an intended action at a particular point of time in the future (an ability also known as prospective memory). Research showed that all types of prospective memory are severely impaired in schizophrenia, with time-based prospective memory being even more impaired (Wang et al., 2018; Wang et al., 2009). The alteration of temporal and order processes of future events may contribute to explain time-based prospective memory, and thus may impact successful goal-pursuit. A possible therapeutic implication of our research could be to enhance access to episodic information (e.g., by providing relevant cues or using visual imagery) and help patients to better specify and organize future times.

Limitations

In the present thesis, we used the think-aloud procedure (Fox et al., 2011) to unravel the mechanisms engaged in the temporal location of autobiographical events. Our experimental tasks were inspired by previous work on past event dating that used a similar procedure (Brown, 1990; Brown et al., 2016; Nourkova & Brown, 2015). The validity of this procedure could legitimately be discussed. One could argue that thinking aloud might alter temporal location processes and that verbalization might not accurately reflect the underlying location processes because participants might not report some thoughts or, conversely, might report mental events that did not occur (Russo, Johnson & Stephens, 1989). Although these validity issues cannot be totally ruled out, Fox et al. (2011) have shown in a meta-analysis that thinking aloud does not alter task performance, provided that participants are instructed to simply verbalize their thoughts (as was the case in our studies) rather than directing them to give explanations for their thought processes. Furthermore, our results about past events using the think-aloud procedure yielded similar conclusions as previous studies that used other methods (Arbuthnott & Brown, 2009; Friedman, 1987; Skowronski et al., 1995; Thompson et al., 1993), thus providing evidence for the validity of think-aloud protocols for investigating strategies involved in representing the times of autobiographical events.

Another issue regarding the use of the think aloud procedure specifically with patients suffering from schizophrenia could be acknowledged. Considering the disturbance of cognitive (Nuechterlein et al., 2004) abilities in schizophrenia, one could legitimately argue that these deficits could have interfered with the verbalization, and thus disturb the analysis of the temporal location strategies. Although our patients showed impairment of executive functioning, there was no difference between groups regarding

the verbal fluency abilities. Also, patients partly used similar temporal location strategies (lifetime periods/extended events, factual knowledge, conventional time patterns) to determine the times of autobiographical events. In addition, the temporal order task did not require any verbalization, since patients had to place each event on an arrow of time drawn on a blank sheet of paper. These arguments suggest that temporal location and order processes might not have been influenced by verbal expression deficits. However, we acknowledge that reduced metacognitive abilities (Dimaggio & Lysaker, 2014) could have influenced patients' ability to rate event characteristics (e.g., personal relevance, event and time rehearsals, mental time travel), since it is difficult for patients to clearly analyze their mental states. In future studies, it would be relevant to add a measure of metacognition to examine the putative role of metacognitive impairment in the evaluation of event characteristics in patients with schizophrenia.

Another limitation is that we did not collect independent information that would allow us to check whether the provided dates of past and future events were actually accurate. A first reason is that it would be difficult to check the precision of remote memories, and even impossible to check if the expected events would happen at the dates given. A second reason is that our aim was to unravel the mechanisms engaged in the temporal location of autobiographical events, and not whether these mechanisms influence the precision of the dating. Some researchers investigated in detail the association between the use of particular temporal location strategies and precision of dating, but only for past events (Thompson et al., 1996). It would be interesting for future studies to explore whether the use of certain temporal location processes would alter the precision of future event dates, similarly to past event dates.

Finally, it is possible that in Study 3 the temporal location task interfered with the temporal order task. To address this issue, future studies could counterbalance the order

of presentation of the temporal location and order tasks. Concretely, participants would first be asked to order events in time (without any other instructions), and then after having ordered all events, to locate them in time. This procedure would prevent temporal location processes to influence temporal order processes, at least in part (but note that temporal location, order and distances may be strongly associated to give people a sense of past and future times; Friedman, 1993, 2004). This procedure, however, would not resolve the issue of the validity of the dates provided. A diary protocol in which participants would be asked to record personal events in a notebook would constitute an alternative to investigate the accuracy of location and order processes, at least for past events.

Perspectives

Our work brings new insight into the mechanisms involved in the temporal location of past and future personal events. It will be important in future research to obtain converging evidence using other measures (e.g., response times, self-rating of the use of strategies) of temporal location processes. In this perspective, we recently conducted an online study in which we asked 200 participants to think about 3 events that are likely to happen in their future, and to try to determine their dates (Ben Malek et al., in prep). Participants were asked to be attentive to their mental processes while they were attempting to locate events in time and then had to rate on 7-point scales the extent to which they directly dated the events or used inferential strategies (i.e., lifetime periods/extended events, factual knowledge, landmark events, conventional time patterns, contextual details). Interestingly, preliminary data confirms the preponderance of inferential processes in the temporal location of future events, since about 28% of future events were reported to have been directly dated (i.e., mean ratings above 5 on the 7-point scale). A pattern of use of dating strategies similar to our previous studies was found. Indeed, participants relied on anticipated lifetime periods/extended events for 60% of events, on factual knowledge for 37% of events, on landmark events for 24% of events, and on contextual details for 35% of events. Surprisingly, participants reported having frequently relied on the use of the calendar to infer future times (for 46% of events), which was higher compared to what we found in our previous studies. However, overall the results were very similar and this converging evidence using a different methodology gives further credence to the findings of the present thesis.

An important question for future research is the need to better understand factors that contribute to the direct dating of personal events. In Study 2, we experimentally

manipulated the contribution of personal goals in the imagination of events to investigate the role of goals in the temporal location of future events. However, goal-related and goal-unrelated events differed not only in terms of goal-relevance, but also on other dimensions (i.e., event and time rehearsals, affective valence, mental time travel, feeling of pre-experience, temporal proximity, likelihood) that might influence temporal location processes. Most notably, our findings suggest that the rehearsal of time information seems a key factor in explaining the direct dating of goal-relevant events. However, the respective roles of goals and rehearsal need further investigation. For example, it would be interesting to investigate temporal location processes for goal-relevant but unrehearsed events (i.e., events that people imagine for the first time) which would allow to disentangle the role of goals and rehearsal in the direct dating of future events. Moreover, more study is needed to investigate the role of personal goals in other aspects of temporal representation, such as temporal order and distances (Friedman, 2005, 2004, 1993). For example, it would be interesting to determine whether goal-relevance would ease the temporal order performance of goal-related events. Also, it has been suggested that vividness of memories may influence people's ability to judge temporal distances (Friedman, 2000), however other factors, such as goal-relevance, may also influence distance processes, and this needs to be further investigated.

In Study 3, we found that patients with schizophrenia had greater difficulties than control participants to temporally order the past and future events that had been previously dated. Interestingly, a more frequent use of lifetime periods/extended events was associated with more order errors, which suggests that temporal location and order process may be related to each other (at least partly, because the use of other strategies was not associated with order performance). Besides alteration of temporal location and order processes (which are the two components that we targeted in the present thesis, as

part of the classification of Friedman, 1993, 2004), previous research suggested that patients with schizophrenia have a distorted perception of the subjective temporal distance of events (Potheegadoo et al., 2012). While the present thesis provides some evidence for a link between location and order, further research is needed to explore the association of distance-based processes (the third component of the classification of Friedman) with the other aspects of temporal representation, and particularly in schizophrenia.

Be that as it may, our results suggest that a reduced access to episodic information in long-term memory may contribute to blur the representation of subjective times in schizophrenia. Therapeutic programs targeting the altered access to the episodic system may help patients to better envision and organize future times, which may contribute to improve goal-pursuit. Another promising research would be to implement intention to instigate behavior in the form "if situation Y is encountered, then I will initiate the goal-directed behavior X" (Gollwitzer, 1999; Gollwitzer & Sheeran, 2006) in order to favor prospective memory and goal-achievement. Few but interesting evidence showed that implementation intention improved performance of prospective memory in individuals prone for schizotypal personality disorder (Chen et al., 2014), and goal-achievement in individuals with schizophrenia (Brandstätter et al., 2001).

Finally, we proposed a model that aims to explain the mechanisms at play in the temporal location of past and future personal events. Once converging evidence would give more support to this theoretical representation, this dual process model could be used as a reference to better understand the alterations of temporal location processes in other pathological conditions. For example, it has been recently shown that psychopathology is strongly related to specificity and episodic details with which individuals can mentally envision future events (Hallford et al., 2018). Our theoretical model may help determine

whether (and if yes, which aspects of) temporal location processes are altered in depression, bipolar disorder or autism spectrum disorder, and to understand if distinct mechanisms are involved according to psychopathological dimensions.

Conclusion

To conclude, the experimental findings that constitute the present thesis shed new light on the cognitive mechanisms involved in people's ability to locate future events in time. First, the results showed that people mostly rely on reconstructive/inferential processes to determine when envisioned events would likely occur. We identified that people use most frequently anticipated lifetime periods/extended events and factual knowledge (about the self, others or the world) to infer the times of future events. They also rely on temporal landmark events, contextual details (i.e., persons, places, activities, or any other content), and conventional time patterns (i.e., the calendar or natural time cycles) but to a lesser extent.

Second, although reconstructive/inferential process are predominant, we showed that people are able to directly date some events (i.e., without any use strategies) that are defined by specific features. Directly dated events are more vivid, more important for personal goals, and more frequently rehearsed than events whose dates are inferred. Interestingly, we found that personal goals influence temporal location processes, on the one hand by easing the direct access to dates of goal-related events, and on the other hand by facilitating the accessibility of strands of information that are part of autobiographical knowledge (i.e., lifetime periods/extended events), when events cannot be directly dated.

Third, our findings showed temporal location and order processes for autobiographical events are (at least partly) altered in schizophrenia. Patients with schizophrenia less frequently rely on episodic information (i.e., contextual details, temporal landmark events) to date events, compared to control participants. However, they are able to compensate by using semantic information (i.e., lifetime periods/extended events, factual knowledge, conventional time patterns) to the same extent than controls.

Moreover, while the proportion of directly dated events did not differ between the two groups, the representation of these events appears to be less vivid and less associated with mental time travel. Finally, the results showed that patients make more errors when they are asked to order the past and future events previously dated. The alteration of temporal location and order processes for autobiographical events may blur the representation of past and future times in schizophrenia.

Résumé détaillé de thèse

En tant qu'êtres humains, nous sommes capables de voyager mentalement dans le passé pour nous souvenir d'événements personnels. Nous pouvons nous souvenir de ce qui s'est passé, où et quand. Cependant, nos souvenirs ne sont pas des enregistrements exacts de ce qui s'est réellement produit et la localisation temporelle des événements est souvent erronée ou imprécise (Thompson et al., 1996). Essayez de penser à des expériences passées qui ne se sont produites qu'une seule fois dans votre vie. Bien que les dates exactes de certains événements importants puissent être directement rappelées (par exemple, l'obtention de votre diplôme, votre mariage ou la naissance d'un enfant), vous aurez peut-être du mal à vous rappeler exactement des dates d'autres événements. Pour la majorité de nos expériences passées, nous n'accédons pas directement à la date des événements mais nous nous remémorons plutôt diverses informations pour tenter de reconstruire ou d'inférer leur localisation temporelle (Friedman 1993, 2004). Par exemple, nous pouvons nous rappeler de la période de vie au cours de laquelle un événement s'est produit (par exemple, pendant mes années de lycée) ou nous rappeler d'un autre événement pour lequel nous connaissons la date et qui peut servir de point de repère temporel (par exemple, l'événement s'est produit une semaine après le jour de mon accident de voiture).

Bien que l'étude de la mémoire du temps des événements passés ait attiré beaucoup d'attention, on en sait peu sur la manière dont les événements envisagés dans le futur sont localisés dans le temps. Savoir comment les événements futurs sont localisés dans le temps est important pour comprendre les mécanismes impliqués dans l'anticipation des temps futurs. La recherche scientifique axée sur la représentation du futur a suscité beaucoup d'intérêts dans le domaine de la psychologie et des neurosciences

cognitives. À ce jour, toutefois, les processus cognitifs impliqués dans la localisation temporelle des événements futurs sont mal compris. De nombreuses données montrent que se souvenir du passé et imaginer le futur partagent des similitudes (par exemple, leurs fonctions et contenus) et sont sous-tendus par un réseau neuronal commun (D'Argembeau, 2012 ; Schacter et al., 2012 ; Szpunar, 2010). Cependant, on ignore encore dans quelle mesure des processus cognitifs similaires sont utilisés pour déterminer le moment des événements dans le passé et dans le futur.

Dans ce contexte, le premier objectif de ma thèse doctorale était d'examiner les processus cognitifs impliqués dans la localisation temporelle d'événements envisagés dans le futur. Pour cela, dans une première étude, nous avons comparé les processus de localisation temporelle utilisés pour dater les événements passés et futurs. Ensuite, dans une deuxième étude, nous avons examiné l'influence des buts personnels dans la datation d'événements futurs. Le second objectif de ma thèse était de déterminer si une altération des processus de localisation temporelle pouvait être impliquée dans les difficultés rencontrées par les patients avec schizophrénie d'envisager l'avenir et de s'engager avec succès dans la poursuite de buts. La schizophrénie est une maladie mentale grave qui frappe lourdement la trajectoire de vie des patients car elle débute à une période critique où les projets personnels se mettent en place. Comprendre comment les personnes ayant une schizophrénie se représentent et anticipent leur avenir pourrait aider les médecins et les psychologues à améliorer la prise en charge des patients et les aider à mieux ancrer leurs projets de vie.

Comment dater les événements futurs ?

L'objectif de l'Etude 1[8] était d'investiguer comment les personnes localisent les événements futurs dans le temps. Pour répondre à cette question, nous avons cherché à déterminer les stratégies que les personnes utilisent pour dater les événements passés et futurs, en utilisant la méthode de réflexion à voix haute (Fox et al., 2011). Concrètement, les participants ont généré une série d'événements personnels passés et futurs, et pour chaque événement, ils ont ensuite verbalisé tout ce qui leur venait à l'esprit en tentant de déterminer quand cet événement s'est produit (pour la condition 'passé') ou pourrait se produire (pour la condition 'futur'). Les stratégies utilisées pour déterminer les localisations temporelles ont été analysées selon une grille de cotation créée sur la base de précédentes recherches sur la mémoire du temps des événements passés (Friedman, 1987 ; Thompson et al., 1996 ; Thompson et al., 1993 ; Skowronski et al., 1995 ; Brown, 1990). Cette grille de cotation comprenait cinq catégories de stratégies : périodes de vie/événements étendus, événements spécifiques, références temporelles conventionnelles, connaissances factuelles (sur soi, les autres ou le monde) et détails contextuels.

Sur base de la littérature montrant que la localisation temporelle des événements passés est en grande partie déterminée par des processus de reconstruction/d'inférence (Friedman, 1993, 2004 ; Thompson et al., 1996 ; Shum, 1998), nous nous attendions à ce que les participants s'appuient fréquemment sur des stratégies de reconstruction pour localiser les événements passés dans le temps. En outre, compte tenu des travaux de recherche suggérant que se souvenir du passé et imaginer le futur partagent (au moins en grande partie) des mécanismes communs (D'Argembeau, 2012 ; Schacter et al., 2012 ; Szpunar, 2010), nous avons fait l'hypothèse que la localisation temporelle des

[8] Ben Malek H, Berna F & D'Argembeau A (2017). Reconstructing the times of past and future personal events. Memory, 25(10), 1402-1411. https://doi.org/10.1080/09658211.2017.1310251

événements passés et futurs s'appuient sur des stratégies similaires, consistant essentiellement en des processus de reconstruction et d'inférence. En plus d'examiner les stratégies de datation, nous avons également cherché à déterminer si les dates de certains événements futurs peuvent être directement déterminées, comme cela a déjà été démontré pour les événements passés (Friedman, 1987 ; Thompson et al., 1993), et dans quelle mesure ces événements directement datés présentent des caractéristiques distinctes. Notre hypothèse était que les événements localisés directement dans le temps seraient jugés comme plus importants pour les buts personnels que les événements localisés dans le temps avec l'utilisation de stratégies de reconstruction.

Confirmant nos attentes, les résultats ont montré que les stratégies utilisées pour dater les événements passés et futurs étaient similaires, suggérant que la localisation temporelle des événements passés et futurs repose en grande partie sur des processus de reconstruction/d'inférence. Les références aux périodes de vie/événements étendus, et aux connaissances factuelles (sur soi, les autres ou le monde) ont été les plus fréquentes pour déterminer la localisation temporelle des évènements passés et futurs. Cependant, contrairement aux autres stratégies, l'utilisation des détails contextuels a été plus fréquente pour les événements passés que pour les événements futurs. De façon intéressante, une minorité d'événements futurs (et d'évènements passés) ont été datés de façon directe, et ces événements présentaient des caractéristiques distinctes des événements localisés grâce aux stratégies de reconstruction ou d'inférence. En effet, les événements datés directement ont été jugés comme plus vivaces, associés à un plus fort sentiment de voyage mental dans le temps, plus importants pour les buts personnels et moins distants que les événements datés à l'aide de stratégies de reconstruction du temps. L'information temporelle des événements datés directement a été jugée également comme plus fréquemment remémorée dans des épisodes précédents. Toutefois, certaines

caractéristiques des événements avaient tendance à covarier (par exemple, la vivacité et l'importance personnelle) et il s'avérait dès lors nécessaire de préciser la contribution de chaque caractéristique (et en particulier, celle de l'importance par rapport aux buts personnels ; voir Etude 2) au processus de datation directe des événements.

Pour conclure, les résultats de l'Etude 1 ont montré que pour dater des événements envisagés dans l'avenir, les personnes se repose souvent sur des connaissances autobiographiques et générales pour inférer le moment où ces événements pourraient vraisemblablement se produire. Une minorité d'événements futurs qui sont notamment importants et proches dans le temps peuvent être datés directement, et cet accès direct à la localisation temporelle semble critique pour l'anticipation des temps futurs et la poursuite de buts.

Le rôle des buts personnels dans la localisation temporelle des événements futurs

Dans l'Etude 2[9], nous avons cherché à étudier l'influence des buts personnels dans la localisation d'événements futurs. Pour répondre à cette question, nous avons demandé aux participants d'imaginer une série d'événements futurs liés à des buts personnels, à des lieux familiers ou à des scenarios imposés par l'expérimentateur. Nous avons ensuite demandé aux participants de verbaliser à haute voix tout ce qui leur venait à l'esprit en tentant de déterminer quand chacun des événements futurs pourrait se produire.

Sur base des résultats de l'Etude 1, nous nous attendions à ce que les participants s'appuient fréquemment sur des stratégies de reconstruction ou d'inférence pour localiser les événements futurs dans le temps, quelle que soit leur nature (liée aux buts, lieux ou

[9] Ben Malek, H., Berna, F., & D'Argembeau, A. (2018). Envisioning the times of future events: the role of personal goals. *Consciousness and Cognition*, 63, 198-205. https://doi.org/10.1016/j.concog.2018.05.008

scénarios). De plus, en considérant le rôle des buts personnels dans la construction et l'organisation de la pensée future épisodique, nous avons émis l'hypothèse que les événements liés aux buts seraient plus fréquemment localisés dans le temps de façon directe que les événements liés aux lieux et aux scénarios. Enfin, étant donné que les buts personnels contribuent à l'organisation des connaissances autobiographiques (et en particulier des périodes de vie), nous avons prédit que lorsque les événements futurs ne sont pas directement datés, les périodes de vie futures seraient plus fréquemment utilisées comme stratégie de localisation temporelle pour les événements liés aux buts que pour les événements liés aux lieux ou scénarios.

Confirmant les résultats de l'Etude 1, nous avons trouvé que la majorité des événements futurs étaient localisés dans le temps à l'aide de stratégies de reconstruction/d'inférence, quelle que soit la nature des événements (liée aux buts, lieux ou scenarios). De façon intéressante, les résultats ont montré que les événements liés aux buts étaient plus fréquemment datés directement que les événements liés aux scenarios (mais pas que ceux liés aux lieux). Nous avons également constaté que l'importance perçue des événements par rapport aux buts personnels était un facteur prédictif de l'accès direct à l'information temporelle. Lorsque les événements n'étaient pas localisés directement dans le temps, nous avons montré que les participants s'appuyaient plus fréquemment sur des périodes de vie/événements étendus pour inférer le moment des événements liés aux buts que celui des événements liés aux lieux ou scénarios. L'importance perçue des événements par rapport aux buts personnels prédisait l'utilisation de périodes de vie/événements étendus et d'événements spécifiques jouant le rôle de marqueurs temporels, alors qu'elle était négativement liée à l'utilisation des références temporelles conventionnelles pour localiser les événements dans le temps.

Pour conclure, les résultats de l'Etude 2 ont montré que les buts personnels influencent la localisation temporelle des événements envisagés dans le futur. Les buts personnels facilitent l'accès direct aux événements particulièrement importants, et quand la date des événements ne peut être directement déterminée, les buts augmentent l'accessibilité des connaissances autobiographiques qui sont plus fréquemment utilisées pour inférer le moment des événements futurs.

Les processus de localisation et d'ordre temporels des événements personnels passés et futurs dans la schizophrénie

L'objectif de l'Etude 3[10] était d'étudier l'intégrité des processus de localisation et d'ordre temporels des événements personnels passés et futurs dans la schizophrénie. Pour cela, nous avons utilisé la même procédure que dans l'Etude 1, appliquée à deux groupes de participants : un groupe de patients avec schizophrénie, et un groupe de témoins (appariés sur l'âge, le genre et le niveau d'éducation). Après avoir localisé les événements dans le temps, nous avons demandé aux participants de classer dans l'ordre chronologique les événements passés et futurs qui ont été précédemment générés et datés.

Sur base des résultats des Etudes 1 & 2, nous nous attendions à ce que les deux groupes de participants utilisent principalement des stratégies de reconstruction/d'inférence pour localiser les événements passés et futurs dans le temps. Cependant, en prenant en compte les recherches antérieures montrant que les personnes avec schizophrénie éprouvent des difficultés à localiser des événements historiques dans le temps (Venneri et al., 2002) et que la chronologie des récits de vie et d'événements personnels est désordonnée (Raffard et al., 2010a ; Allé et al., 2015 ; 2016a), nous nous

[10] Ben Malek, H., D'Argembeau, A., Allé, M., Meyer, N., Danion, J-M., & Berna, F. How do patients with schizophrenia locate and order personal events in past and future times (submitted to *Scientific Reports*, April 8, 2019)

attendions à ce que les processus de localisation et d'ordre temporels soient affectés. Plus précisément, nous nous attendions à ce que les patients avec schizophrénie manifestent des difficultés à s'appuyer sur des informations épisodiques (mais pas sémantiques) pour dater les événements et fassent davantage d'erreurs lors du classement chronologique des événements, relativement aux témoins.

Les résultats ont montré que les patients avec schizophrénie accédaient de façon directe à la localisation temporelle d'événements importants aussi souvent que les participants témoins. Cependant, contrairement aux témoins, les événements directement datés n'étaient pas jugés plus vivaces et plus associés au voyage mental dans le temps que les événements dont les dates étaient reconstruites ou inférées. Lorsque les événements n'étaient pas datés directement, nous avons constaté que les patients avec schizophrénie utilisaient moins souvent que les témoins des combinaisons de stratégies. De façon intéressante, les patients s'appuyaient moins fréquemment sur les détails contextuels (relatifs aux personnes, lieux, activités, ou conditions météorologiques) et les événements spécifiques jouant un rôle de marqueurs temporels que les participants témoins pour reconstruire ou inférer les dates des événements personnels. Les patients ont toutefois utilisé les périodes de vie/événements étendus, les connaissances factuelles (sur soi, les autres ou le monde) et les références temporelles conventionnelles aussi souvent que les sujets contrôles. Néanmoins, les patients étaient moins certains des dates fournies et commettaient davantage d'erreurs lorsqu'on leur demandait par la suite de classer dans l'ordre chronologique les événements passés et futurs. Des analyses de corrélations ont montré que la sévérité des symptômes négatifs était associée à la réduction de l'utilisation d'une combinaison de stratégies de localisation temporelle et que l'utilisation de périodes de vie/événements étendus était associée à une augmentation des erreurs d'ordre temporel chez les patients.

Pour conclure, les résultats de l'Etude 3 ont montré que les patients avec schizophrénie présentent une altération des processus de localisation et d'ordre temporels des événements personnels passés et futurs. Plus précisément, les patients éprouvent des difficultés à se reposer sur des informations épisodiques (c-à-d., les détails contextuels et les événements spécifiques jouant le rôle de marqueurs temporels) pour reconstruire ou inférer le moment des événements dans le passé et dans le futur. Cette altération des processus de localisation et d'ordre temporels brouille l'organisation temporelle des événements personnels et pourrait représenter un des facteurs impliqués les difficultés de poursuite de buts retrouvés dans la schizophrénie.

Conclusion

En résumé, les résultats expérimentaux qui constituent cette thèse doctorale ont apporté un nouvel éclairage sur les processus cognitifs impliqués dans la localisation temporelle d'événements futurs. Sur la base de nos découvertes résumées précédemment, nous avons proposé un modèle à double processus pour la localisation des événements autobiographiques (voir Chapitre 5, page 154) qui articule les mécanismes cognitifs engagés dans la datation des événements personnels passés et futurs. De plus, cette thèse a permis de mettre en évidence certaines altérations des processus de localisation et d'ordre temporels des événements autobiographiques dans la schizophrénie qui pourraient contribuer à brouiller la représentation mentale des temps passés et futurs chez les patients.

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