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A JOURNEY THROUGH TIME. SPACE-TIME REPRESENTATION IN ADULTS AND CHILDREN

Surname: **Rizzi** Name: **Ezia**

Registration number: 809150

Tutor: Luisa Girelli, Ph.D.

Coordinator: Maria Teresa Guasti, Ph.D.

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Abstract

It is well known that the human mind often creates a representation of time through more concrete dimensions, such as space. Habitually, we talk about past referring to the space behind us and about future referring to the space in front of us. This doctoral thesis explores the origin and development of the association between time and space in childhood and adulthood.

The first section provides an overview of the theoretical background and discusses previous studies that have been focused on this topic. We outline the missing pieces of evidence and pinpoint that the type of information processed at hand (i.e., events referring to personal and non-personal memory) may impact on how the Mental Time Line is constructed and on the relative spatial frames of reference involved.

The second, empirical chapter investigates directly whether personal and non-personal events are differently mapped on space in adulthood, by involving native Italian speakers. The results described show that whereas personal events are preferentially mapped on the sagittal space, non-personal events are more likely mapped on the horizontal space. These findings were replicated in a sample of English adult speakers using a similar procedure and indicate that the type of content processed in memory affects how the individual represents time in space.

The third chapter aims to study, whether, in a paper and pencil task, we can obtain the same time-space representation of the personal and non-personal event obtained in the computerized tasks. The lines represent the Mental Time Line drawn on a paper (i.e., horizontal and sagittal). Results find the same time-representation for non-personal and personal events on the Horizontal axis.

The fourth chapter focuses on the ontogeny of the Mental Time Line. In the first study, Italian primary schoolchildren were involved in two tasks probing the linguistic and sensorimotor origins of the sagittal Mental Time Line. A second study explored the representation of personal and non-personal events on the sagittal space in native English primary schoolchildren, thus extending the main theoretical question underlying this thesis at the developmental level. Results indicate that the representation of time on the sagittal space strongly relies on sensorimotor processes already from a young age.

Together, this body of evidence provides new insights on the cognitive and sensorimotor mechanisms that would drive humans to represent time on spatial coordinates.

Abstract Italian Version

È noto che la mente umana spesso crea una rappresentazione del tempo attraverso dimensioni più concrete, come lo spazio. Abitualmente, parliamo del passato riferendoci allo spazio dietro di noi e al futuro riferendoci allo spazio di fronte a noi. Questa tesi di dottorato esplora l'origine e lo sviluppo dell'associazione tra tempo e spazio nell'infanzia e nell'età adulta.

La prima sezione fornisce una panoramica del background teorico e discute gli studi precedenti che sono stati focalizzati su questo argomento. Delineeremo le prove mancanti e individueremo che tipo di informazioni elaborate (ad esempio eventi riferiti a memoria personale e non-personale) può avere un impatto sul modo in cui è costruita la Mental Time Line e sui relativi frame spaziali di riferimento coinvolti.

Il secondo capitolo empirico indaga direttamente se eventi personali e non-personali sono mappati in modo diverso nello spazio in età adulta, coinvolgendo partecipanti di madrelingua italiana. I risultati descritti mostrano che mentre gli eventi personali sono mappati preferenzialmente nello spazio sagittale, è probabile che eventi non personali siano mappati nello spazio orizzontale. Questi risultati sono stati replicati in un campione di adulti di lingua inglese utilizzando una procedura simile e indicano che il tipo di contenuto elaborato in memoria influisce sul modo in cui l'individuo rappresenta il tempo nello spazio.

Il terzo capitolo si propone di studiare, se in un compito su carta e matita, possiamo ottenere la stessa rappresentazione spazio-temporale dell'evento personale e non personale ottenuto nei compiti computerizzati. Le linee rappresentano la Mental Time Line disegnata su un foglio (cioè orizzontale e sagittale). I risultati hanno trovato la stessa rappresentazione temporale per eventi non-personali e personali sull'asse orizzontale.

Il quarto capitolo si concentra sull'ontogenesi della Mental Time Line. Nel primo studio i bambini della scuola primaria italiana sono stati coinvolti in due compiti che esploravano le origini linguistiche e sensomotorie della Mental Time Line sagittale. Il secondo studio ha esplorato la rappresentazione di eventi personali e non-personali sullo spazio sagittale in bambini di scuola elementare madrelingua inglese,

estendendo così la principale domanda teorica alla base di questa tesi all’età evolutiva. I risultati indicano che la rappresentazione del tempo sullo spazio sagittale si basa fortemente su processi sensorimotori già in giovane età.

Insieme, questo corpus di prove fornisce nuove intuizioni sui meccanismi cognitivi e sensomotori che guiderebbero gli esseri umani a rappresentare il tempo sulle coordinate spaziali.

Chapter 1

Theoretical Background: theories, models, and cognitive processes on the Mental Time Line

«Time is not at all what it seems. It does not flow in only one direction and the future exist simultaneously with the past» (Albert Einstein). How does our mind make a Mental Time Travel? How does our mind represent and processes domains such as time and space? What are the factors that may influence such a spatial-time representation? What is the age at which the space-time representation appears? What are the differences between adults and children representation of time? Personal or non-personal memories, sentences with temporal references, an adjective, or different cultural aspects, can be represented along the time line differently? To provide some insights on these fascinating questions, this first chapter re-examines previous experimental works of the last decades and recent developments and findings on time-space representation. Within this theoretical framework, this chapter will discuss the notion of time-related to space, the origin, and ontogeny of time-space representation in the human mind and how they are related to memory ability. This chapter will also report studies on the neural correlates subserving in space-time processing. Finally, it will review in depth the Mental Time Travel ability and how personal and non-personal memories are represented (in space and time). Those questions that cannot be answered by the studies mentioned in this thesis or topics that need a target deepening will be outlined at the end of this chapter as possible guidelines for future empirical work.

1.1 The origin of time representation in the human mind

Among man's primary capacities, there is also the ability to estimate the passage of time, which in turn has the potentiality to influence other cognitive skills and, more generally, human behaviour. Tulving (2002) defines such an ability to estimate the passage of time as 'Chronesthesia.' Chronesthesia refers to how humans think about the passage of time and mentally travel through time. It is connected to other cognitive functions, such as planning and memory skills, it allows to recall events that occurred in the past and to think about the future. The association between temporal information and imaginative space led to hypothesize the existence of a 'Mental Time Line' (MTL) (Bonato, Zorzi, & Umiltà, 2012;

Borodisky, 2000; 2001; 2007; Clark, 1973; Torralbo, Santiago, & Lupiáñez, 2006). Time passes from one end to the other along a line like a representational continuum in which time concepts (e.g., before/after) and temporal durations (e.g., short/long) are projected. A period, or quantity of time, does not intrinsically correspond to a specific point along the MTL; rather, it is codified using a reference point or interval (Bonato et al., 2012). There are several theories concerning the representation of time in the human mind that has emerged in recent years, some of which will be reviewed in the next section of this chapter.

From McTaggart's Paradox to the cultural and linguistic studies about time representation

More than a century ago, John Ellis McTaggart (1908) wrote a thesis known as the 'McTaggart's Paradox' based on the theory called 'The Unreality of Time.' Time does not exist objectively, independently of the mind. McTaggart highlighted that the word 'time' indicates two different time orders, namely Series A and Series B. The Series A is composed by the moments and their 'contents', or events ordered according to the so-called 'Property A' (i.e., they are present, past or future). The second one is the series of moments or events ordered according to the so-called 'B Relations', such as simultaneity and temporal precedence (e.g., I am writing, and it is raining, and tomorrow is my birthday. They are simultaneous events and happen temporally before my birthday). McTaggart described the Series A as dynamic, continually is subject to change, present events become past, past moves away toward the present, and the future comes and will later become present. On the contrary, the Series B is static, and it is made of immutable relations. McTaggart considered the Series B depending on Series A, and it cannot be considered as temporal without the Series A, because the changes are crucial when talking about time. On the other hand, Series A assumes that each element must have all the A properties, but it is contradictory because an event cannot be present and past contemporary.

Nunez & Cooperrider (2013) recently harked back to the McTaggart's taxonomy. They talked about 'Deictic Time,' or 'Time-D' (Series A), referred to the events considered from the observer's point of view, and 'Time in Sequence,' or 'Series S' (Series B), referred to events ordered in sequence. Moreover, they proposed a further distinction between Internal Time-D and External Time-D. In the Deictic Time, the observer's point of view is connected to a specific place related to an event. "Internal D-time Ego has internal perspective on the series, Deictic center co-located with Ego; External D-time Ego has external perspective, Deictic center displaced" (Nunez & Cooperrider,2013:222) on the series In the Series S, the observer looks at an event from an external perspective, an external point of view. Things move towards the observer standing or the observer moves to something.

In many cultures, linguistic metaphors recall objects' and people's movements in the space and the passage of time (Núñez, 1999), such as in the expression 'Our friend has passed', when a person died, or 'winter is approaching' when a new season is coming. In the metaphor of Time as a movement, the future is represented forward us because we can see with our eyes and our face and we can project forward, and see future events, while the past, is behind and we cannot see and act because it happened. The second metaphor refers to TIME moving. The time is a river that moves the events from the future to the past. Thus, the past is forward and the future back.

Most languages conceptualize time along space, and the direction of its representation along an axis can change according to culture (Boroditsky & Ramscar, 2002; Núñez, Motz, & Teuscher, 2006; Torralbo et al.,2006; Miles, Nind, & Macrae, 2010; Tversky, Kugelmass, & Winter, 1991). For instance, different direction to spatialize time along the egocentric axis have been reported in English, Spanish, Hebrew or Mandarin, that have respectively a left/right (Chan & Bergen, 2005, Torralbo et al., 2006), right/left (Fuhrman & Boroditsky, 2010;2011), and up/down (Boroditsky, Fuhrman, & McCormick, 2010) representation that is related to their reading-writing system direction.

Núñez and Sweetser (2006) studied the Aymara Tribe of the Andes, a population without a reading-writing system. This population represents the past as the space in front and the future as space behind, but the sequence time is mapped like in other. Furthermore, linguistic differences influence non-verbal reasoning strategies, such as memory for spatial arrays (Majid, Bowerman, Kita, & Haun, 2004) and body movements (Cooperrider & Núñez, 2007;2009; Núñez, Cooperrider, Doan, Wassmann, 2012; Haun & Rapold, 2009; Núñez, & Cooperrider,2013).

Boroditsky and Gaby (2010) investigated the Pormpuraaw population, an Australian Aboriginal community. They documented a temporal representation along the east-west axis: the past is mapped to eastward and the future westward regardless of body orientation. This study shows that allocentric coordinates can be recruited for representing temporal information.

Time, a daily and fundamentally abstract domain, is conceptualized regarding space in most cultures of the world. Linguists and psychologists have presented evidence that past, present, and future deictic time is interpreted along the front/back axis, as a linear, ego-based construct. Núñez et al, (2012) examined deictic time in Papua New Guinea population to investigate the linear and ego-based aspects of deictic time related to their language (Yupno) and gestures. Results have shown that Yupno organize the deictic time spatially, considering allocentric topography: the past is downhill, the present as co-located with the speaker and the future is uphill. Consequently, as the first aspect, it is possible to assume that the spatial organization of time is linked to and, ultimately, shaped by cultural and linguistic aspects.

Direction and shape of mental time representations

Bender and Beller (2014) described another conceptualization concerning the representation of time. They identified four conceptualizations: Linear, Cyclic, Spiral, and Radial. Linear time is conceptualized as a line with a specific directional orientation and represents the flow of time, where the course of events cannot be reversed (i.e.; the irreversible course of events). Cyclic time, on the other hand, is represented as a circle that shows how events are repeated sequentially and cyclically (e.g., days, weeks, and seasons). Linear time and Cyclic time can be integrated into Spiral time. Spiral time indicates that events can be repeated following a non-reversible order and at different times. Finally, Radial time represents the passage of time on a bidirectional line oriented towards the past and the future; according to this conceptualization, it is possible to recall past events and imagine future ones. Radial time reflects memory and perspective abilities. Spatial metaphors and mental representations of space allow humans to imagine and manipulate time features (Clark, 1973). Some abstract knowledge could be constructed and modelled by language. Therefore, people often use metaphors considering multiple domains and (spatialized) experience to talk about abstract domains.

Regarding the space-time congruence effect, two hypotheses have been formulated: the 'Weak Hypothesis' and the 'Strong Hypotheses' on metaphorical mapping (Boroditsky, 2000). These hypotheses assume that sensorimotor experiences obligatorily activate mental representations. The sensorimotor processes are involved in the perception of space, resulting consequently important to the mental representation of time. The Strong Hypothesis considers low-level sensorimotor mechanisms important to activate a mental representation; they are functionally involved whenever this mental representation is activated. The sensorimotor mechanisms activated in the interaction with space could be involved in the elaboration of temporal information and, consequently, in the spatiotemporal congruence effect observed. If the mental representation of time depends on low-level sensorimotor processes, the nature of the response to the stimulus can modulate the amplitude of the congruence effect. The Weak Hypothesis assumes that linguistic categories influence our patterns of thought. Thus, grammatical genders of objects may influence how they are perceived. There are some universal properties concerning linguistic aspects related to space that can be used to describe the time (Clark, 1973).

Numerous studies have shown that temporal aspects typically refer to some references such as the terms front/back and up/down. Studying native English speakers, it emerged that there are two systems of metaphorical space-time systems, the 'Ego-Moving Metaphor', and the 'Time-Moving Metaphor'. The first metaphor refers to the EGO and the observers, the future will be represented forward and the past backward, the Ego-Moving Metaphor shows a journey through time Findings that support both these two metaphorical mappings have been repeatedly reported in the literature. For instance, time is spontaneously mapped according to the Moving-Ego Metaphor.

Construal Level Theory (CLT) and psychological distance

Another line of research that has been implicitly grounded on the tight relationship between space and time is focused on perceptual biases. In recent years, Trope and Liberman (2010) proposed the Construal Level Theory (CLT) to define 'psychological distance', namely the distance between the stimulus and the observer making the direct experience. This distance is related to the observer's point of view and its experience; critically, psychological distance can influence mental representations, judgments, and actions. Psychological distance is self-centred, and it is composed of four dimensions: Temporal (e.g., how much time separates the observer from the stimulus); Spatial (how far the stimulus is from the observer); Social (the distinction between the observer perceived as self and the object perceived as something else); Probability (how probable it is that the event may occur in the observer's life). The bigger is the distance between the observer and the stimulus in one of their dimensions the more will be its representations and higher the level of cognition. High-level abstract constructs do not usually change if the distance on one of the four dimensions increases. They recall representations of more distant objects at a temporal, spatial, social, and probabilistic level. Thus, the link between distance and construct level is bidirectional: distant objects activate abstract representations, and nearby objects activate concrete representations, but it is also true that abstract representations recall distant objects and concrete representations close objects. These proposals are compatible with memories consolidation processes. Memory details are lost in time and usually become generic; while recent memories are more specific. The CLT assumes that events in the remote future require a more abstract representation, while events in the near future require a concrete representation. Psychological distance is important because it allows us to think about the past and make predictions while remaining in the present; it also allows us to consider the other's point of view and to make different hypotheses of reality. The representation is a hierarchical system; the abstract levels include the more concrete and are more schematic, simple and less detailed representation, therefore, distant events in time activates more prototypical representations than near events.

Liberman, Sagristano, and Trope (2002) studied the relationship between CLT and temporal distance to investigate whether humans used fewer but broader and more general categories to simulate future events. Participants took part in an imaginative task in which they imagined themselves making an action (e.g., going camping, moving, visiting a new city) or classifying the category of an object (e.g., soap, food, computers). The action was classified either in near (e.g., next weekend) or far future (e.g., next summer) using a time reference. Results confirmed the assumption of CTL relieving that to image action in the far future participants used few categories and more objects (i.e.; higher and abstract levels of cognition), to imagine the nearby future (i.e.; detailed information and low-level categories), they used more categories and fewer objects. Temporal and probabilistic dimensions of the Construal Level Theory (e.g., how much time separates the observer from the stimulus and how probable it is that an event will occur) can be related to the spatial dimension (Trope & Liberman, 2010).

Similarly, Bar-Anan, Liberman, Trope, and Algom (2007) investigated whether the psychological distance is activated automatically and whether psychological distance dimensions produce the same answer and are linked together, by using a modified version of the classic Stroop task. Participants looked at 13 landscape pictures with a word written on it; pictures served to create a distance between the words and the observer. Word can be referred to as Temporal psychological distance (e.g.; tomorrow, in a year), Social (e.g.; friend, enemy), and Hypotheticality (e.g.; sure, maybe). They administered a congruent and incongruent version: in the congruent version pictures and word with same meaning appear near or far from the observer; in the incongruent version, participants were presented with the opposite mapping. In the first task, they had to indicate whether the word was near or far, considering the meaning of the word, and subsequently classified the words, ignoring their distance. The results have shown a facilitative effect when the spatial distance was congruent. Also, results have shown that participants classified faster the spatial distance of words when the psychological distance was implicit and corresponded to spatial distance. Also, results have shown that psychological distance is activated automatically when words have a common meaning with spatial distance, temporal distance, social distance, and hypotheticality distance.

Distant stimuli require high-level representations, high-level representations are activated with distant stimuli, and high-level construct allows thinking to the present, past, and future (Trope & Liberman, 2010). To study the relation between psychological distance in the four dimensions and in the representation levels Bar-Anan, Liberman and Trope (2006) used an Implicit Association Test (IAT) proposed by Greenwald, McGhee and Schwartz (1998). Originally the IAT analyzed free associations between the concepts on an implicit level, where the information is not processing yet, and quick responses result from highly associated concepts. In the study, the psychological distance and the construct levels were compared assumptions of CLT. Eight tasks were administered included congruent and incongruent conditions. The results have shown that nearby spaces and objects associated with concrete low-level constructs, distant space, and objects are associated with abstract high-level constructs. These associations are implicit, and they are not related to the specific context or target since the processes of elaboration and construction of the stimulus representations are not activated. Therefore, it can be assumed that as specified by CLT, these aspects are related to each other and psychological distance, they have activated automatically.

Movement experience through time is analogous to the movement experience in the space. Therefore Caruso, Van Boven, Chin and Ward (2013) hypothesized that the spatial metaphor of events about time might produce an asymmetry in the psychological distance of past and future events. Future events are considered psychologically close to the present, while past events are considered more distant, essentially because of the spatial distance decrease with the future and increase with the past. Hence, the mental representation of time and psychological distance would depend on direct experience with spatial distance. Therefore, spatial distance is considered as a metaphor for psychological distance. Caruso et al. (2013) hypothesized that the associations of space and temporal movements, influence the psychological distance of the past and future through time, and the authors named this influence 'Doppler Effect' for the psychological distance. Usually, the Doppler Effect is associated with the auditory stimuli perception and explains a specific phenomenon, that loud noises are perceived with a higher tone when they approached and lower when they move away. Caruso et al., (2013) studied this effect asking their participants to perform a questionnaire, and to describe what they did a month before Valentine’s Day or what they would do in a month at Valentine's Day. After, they completed a survey and had to report how far they thought they were and measured the psychological distance using a scale from 1 (a really long time from now) to 10 (a really long time from now). In another task, the authors considered the hypothesis that psychological distance could be linked to the self-movement in space. The participants performed a virtual reality task and were asked to imagine themselves three weeks before and after three weeks. Results overall have corroborated the hypothesis that the future is perceived closer than the past.

Anxiety and depression condition change the way of thinking the past and the future; anxiety conditions mainly affect the way of thinking about future events processing them as threats, while depression conditions affect the way of thinking about past events categorizing them as sad. Rinaldi, Locati, Parolin and Girelli (2016), studied personality traits related to anxiety and depression to understand how the psychological distance of temporal events is perceived. Participants had to think about one month from today (future) and to think back to one month ago from today (past), and they had to report the psychological distance considering a scale from 1 (really close to now) to 10 (very far from now). Groups were classified considering personality traits of anxiety, depression, and a control group. Results have shown that participants with anxiety traits perceive future psychologically closer than the past, compared controls. On the contrary, participants with a depressive trait showed the opposite tendency. Therefore, this evidence confirms that personality traits change temporal orientation perception and temporal distance.

Representation on the Mental Time Line

Research on the mental representation of time has demonstrated systematic evidence that confirms an association between temporal information and imaginative space (Bender & Beller, 2014; Boroditsky, 2000; Boroditsky & Gaby, 2010; Nunez & Cooperrider, 2013; Núñez & Sweetser, 2006). About the time representation on the Mental Time Line, you can distinguish two hypotheses, the ‘Linguistic Hypothesis’, and the ‘Sensorimotor Hypothesis’. The Linguistic Hypothesis holds the metaphors used in the language to talk about space and time, cultural factors, proverbs, and words module the direction of the Mental Time Line. Time can be mapped along the sagittal, horizontal, or vertical axis. The Sensorimotor Hypothesis adopts the ME perspective, considering the

Mental Time Line as related to our sensorimotor experience, and primarily to the act of walking: a person leaves the past behind (e.g., events already happened) and goes forward to what will happen or what he will meet in the future. In this perspective, the Mental Time Line is projected along the sagittal axis, with the future forward and the past behind. Also, reading-writing is considered a sensorimotor practice and is linked to two axes: mainly the horizontal but also the vertical space (Núñez & Cooperrider, 2013; Rinaldi, Locati, Parolin, & Girelli, 2016).

Dobel, Diesendruck, and Bölte (2007) verified directly the Sensorimotor Hypothesis assumption in two German and Israeli groups of children aged three to six and adults, administering two tasks in the horizontal space. In these tasks, participants listened to some sentences and were asked to draw the meaning of the sentence, or they had to organize the order of the protagonist and objects to reproduce the order heard in the sentence. Tasks included two different types of sentences, in the first sentence type, the subject is always the first word (e.g., The mother gives the ball to the child); in the other type of sentence, the first word heard was the direct object (e.g., The child receives the ball from the mother). Results have revealed that German adults preferred to position the subject on the left, showing the left-right bias according to their writing system. On the contrary, Israelis showed the opposite pattern that is right to left. Crucially, children showed this bias only if they had already learned how to write younger children did seem to have such representation. These results confirm that the spatial representation of events is related to the writing system, and it can be developed after children learn to write.

Tillman, Tulgan, and Barner (2015a) investigated the possible automatic activation of Mental Time Line in English-speakers children aged three to six. This procedure was the same implemented by Tversky et al. (1991), who first demonstrated the existence of a Mental Time Line on the left-right axis. Moreover, they have shown that the reading-writing system influences MTL, and it is activated automatically in school-aged children. They asked to their participants, English and Hebrew children and adults, to paste chronologically on a sheet some stickers representing meals. Before starting the main experiment, children performed a pre-test: they had to name the days of the week in the correct order. In the experimental session, the experimenter placed a sticker representing one of the meals of the day (e.g., lunch) on the table. Consequently, children had to place stickers with adverbs of time (e.g., yesterday, today, tomorrow), considering the type of food presented. Results have shown a non-spontaneous activation of Mental Time Line in pre-schoolers (four aged), despite being able to arrange events correctly according to the prime. Children aged five-six, on the other hand, activated the Mental Time Line automatically in the left-right direction according to the reading-writing system direction, like adults. Differences in the left-right bias have found: the English speakers order the meals in left-right direction while Hebrew speakers, writing from right to left, have shown the opposite mapping. Therefore, the reading-writing system influences the temporal order of events.

Children aged four have been shown that place events on a left-right line accurately, with this skill improving consistently in the next three years (Hudson & Mayhew, 2011; Tillman, Fukuda & Barner, 2017). Critically, the order of events on the line would depend on the culture-specific direction. Recent studies (Dobel, Diesendrunk, & Bolte, 2007; Tillman, Tulagan, & Barner, 2015b), indeed, reported an automatic development of the MTL, with its direction becoming always more consistent through the school years likely because of the effects of literacy. Tillman et al., (2017) studied the development of mental associations between time and space in English pre-schooler-children in two experiments. In the first experiment, they presented them brief stories describing three-step event sequences (e.g., the experimenter placed two cards on the table in front of the child and asked: “Which card shows that story? Which one is better?”. After, the child pointed to their choice with a choice between two spatial depictions of each story left-right, right-left or bottom-to-top representations of events). In the second experiment, children had to choose between ordered and unordered sequences. In this way, the authors studied whether children were sensitive to the ordinality of the images. Results have shown that the Mental Time Line develops gradually in early childhood (Tilman et al, 2007; Tulagan, Fukuda, & Barner 20018), and it can strictly depend on writing direction and cultural factors.

Several studies compare these hypotheses to validate their assumptions. Rinaldi et al. (2016) demonstrated how the Mental Time Line influences movements in the sagittal space during mental information processing. In their study, participants were blindfolded, and standing and body movements were measured using optoelectronic sensors. Participants listened to some words, and they had to categorize them as referring to the past or the future. Results have shown the influence of temporal processing on the motor programming of the active movement of the body in the early stages of response. They have found a congruency effect (past associated with backward movements and future with forward movements) limited to the beginning of the movement. This experiment highlights that time is represented on the sagittal mental line and recruits sensorimotor representations.

Sell and Kaschak (2011) have demonstrated the existence of the motor component in time-space representations and how it appears in the execution of motor responses in space. Participants read a mix of meaningful and meaningless sentences that indicated a temporal shift in the future or the past. In front of a keyboard, participants pressed a start button and had to respond whether a sentence had a meaning or not by moving to another button (left or right). The sentences were referred either to the past or the future, and the participants had to press the button far or close from the middle of the keyboard (e.g., future-forward and past-backward). The experiment was performed in two conditions: movement and no movement. In the first condition, the participants moved the hand from the start key to the response key matched to the correct answer; in the second condition the left hand pressed the start key, and the right hand was already positioned on the response key. The effect of motor compatibility appears only in the movement condition, highlights the importance of the movement to represent time. Furthermore, in the first condition of this experiment, participants had to move their arms to respond, and the effect of motor compatibility was modulated by the amplitude of the temporal shift to the past or the future. According to embodied cognition, these results suggest that time representation involves sensorimotor simulation. The neural systems involved to comprehend concrete objects are used to simulate abstract concepts (Barsalou, 2008). Thus, the understanding of abstract concepts is based on the real experience domains mediated by the bodily perception systems and planning of actions. According to Walsh's theory (2003), the inferior parietal regions are involved in understanding space, time, and quantity, and they are also involved in the planning of actions in the peri-personal space.

When people engage in types of spatial thinking, it changes the way of thinking about time. Movement in space is not necessary or enough to lead people to think about time; experience has an important role, and it can amplify the effect. Moreover, the construction of this representation is influenced by language. Dimensional Overlap Model (Kornblum, Hasbroucq, & Osman, 1990) assumes that the amplitude of the congruence effect is proportional to the number of characteristics shared by response and stimulus. Sell and Kaschak (2011) support this hypothesis specifying that the congruency space-time effect is present only in movement condition and not in the no movement condition. The Weak Hypothesis, on the other hand, considers the sensorimotor experiences necessary to establish the mental representation of time. And crucially, the MTL would not be functionally linked to low-level sensorimotor processes. Thus, the spatiotemporal congruence effect reflects only the conceptual associations between time and space at higher cognitive levels, and the response modalities should not modulate the space-time congruence effect. To test these different hypotheses Eikmeier, Hoppe, and Ulrich (2015) investigated whether the response modalities modulate the amplitude of the space-time congruence effect. Participants carried out a task in which they responded to some words referred to the past or the future using manual or vocal modality. The authors presented stimulus-response congruent mapping (i.e.; past/backward, future/forward) or incongruent mapping (i.e.; past/forward, future/backward). The results showed a similar congruence effect in both response modalities, compatible with the Weak Hypothesis: space-time mapping is at a higher level of cognition.

Eikmeier, Schröter, Maienborn, Alex-Ruf, and Ulrich (2013) investigated the breadth of the space-time congruence effect to understand how strongly our cognitive representation of time is related to our space representation. Following this model, Eikmeir et al. (2013) compared two conditions: in the experimental condition the sets of stimuli and responses: stimuli-time and responses-space, or stimuli-space and response-time; in the control condition, they had stimuli-time and response-time, or stimuli-space and responses-space. In the first experiment, each participant read on the screen some sentences related to the past or the future; vocal TRs were recorded. In the control condition, they had to pronounce the word 'Past' if the sentence referred to the past and 'Future' if the sentence referred to the future. In the experimental condition, they had to pronounce the word 'Front' whether the sentence referred to the future and 'Behind' whether it referred to the past. Participants were asked to perform an incongruent version as well. In the second experiment, the experimenter in front of or behind the participant emitted the sound, and the procedure was the same, with a congruent or incongruent condition. In both experiments a strong SRC effect was found, the SRC effect for temporal and spatial stimuli was independent of if the answers were related to time or space, that meaning the time and space dimensions are strongly linked.

Ulrich and Maienborn (2010) studied the left-right Mental Time Line. They examined whether the Mental Time Line has involved in the sentences elaboration. Also, their study tried to demonstrate whether a Mental Time Line is activated automatically and whether it is involved in sentence context processing. This study includes administering three experiments on sentences processing, referred to the past or the future. In the first experiment, they used an implicit task to cause automatic activations of MTL. They asked whether the sentences made sense or not. They used 120 sentences regarding an imaginative situation and people (40 past, 40 future, 40 neutral). Participants responded, pressing a button to the left (past) and the right (future) in the congruent condition and the opposite side in the incongruent condition. They presented a neutral sentence, as well. Stimuli were referred to an imaginary person (e.g., Yesterday, Hanna repaired the bike; Karl has signed the contract; Mona and Diana danced the whole night through). In the second experiment, they used 240 sentences (including also 60 referred to past, 60 referred to future) and they added 60 non-sense past, 60 no future sense than the first experiment. In the third experiment they used 320 (including also 60 past, 60 future, 60 non-sense past, 60 non-sense future) and they added 80 sentences with temporal information in the middle of the sentence (20 past, 20 future, 20 non-sense past, 20 non-sense future). The sentences have the same number of words. They divided it into two lists: A and B, in this way, the same sentence was not presented to the participants twice. As explained congruent condition in the task considering the past to the left and the future to the right: they responded with the left shift key and left index finger for the sentences of the past and shift and index finger right hand for the sentences of the future. In the incongruent, condition participants used keys and opposite fingers. Participants changed the answer key in each block, and they did not respond to the non-sense sentences. Task duration was 45 minutes. In the long sentences, they did not find a congruence effect. Temporal reference identification is early in the brain, and if the sentences are long participants lost it. For these reasons in the third experiment, they added another stimuli category that contained a time reference in the middle of the sentence. This study has shown a response in the congruent condition (left-right timeline) quickly. Also, results have shown faster reaction time in the congruent condition of left-right mapping and automatic mapping of temporal elements in the sentence.

Mental Number Line and SNARC effect

Until now in this chapter is reported evidence about Mental Time Line on sagittal and horizontal mapping considering words, sound, metaphors. Our mind tends to create a spatial representation of different types of ordered information among these types of information; there are also the numbers.

Dehaene (1992) proposed that the magnitude representation of numbers could be represented on a Mental Numerical Line (MNL). The spatial-numerical association of response is described as an index of automatic access to the spatial representation of the numerical quantity. The numbers are represented on a Mental Number Line according to the numerical quantity, in the left-right or right-left direction, depending on the reading-writing system. The association between number and space has been mainly indexed by the so-called ‘Spatial-Numerical Association of Response Codes’ (SNARC). Several factors influence the SNARC Effect, such as the direction of reading-writing, working memory demands, numbers position, task instructions, and cognitive deficits (e.g., a deficit of spatial attention). Spatial organization of time is demonstrated in ‘temporal intervals categorization’ tasks, and Dehaene, Bossini and Gireaux (1993) as well as Dehaene, Dupoux, and Melcher (1990) explained this evidence with the SNARC effect. Participants in their studies performed a task about timed odd–even judgments examined how parity and number magnitude are accessed from Arabic and verbal numeral. They highlight a relation between the numerical magnitude and the spatial position of the stimulus. Participants responded faster to small numbers when using the right hand and big numbers with the left hand. Magnitude information was automatically activated in the Arabic numerals. The SNARC effect is related to only one number magnitude and was weaker or absent with letters or verbal numerals.

Other evidence of an inverted SNARC effect was found related to the Arab language, which indeed has a right-left reading-writing system (Fischer, Shaki, & Cruise, 2009; Shaki &Fischer, 2014; Shaki, Fischer, & Petrusic, 2009).

On a very related line of research, Ishihara, Keller, Rossetti and Prinz (2008) investigated the horizontal spatial representations of time reporting evidence about the Spatial-Temporal Association of Response Codes Effect (STEARC), thus in analogy to the classic SNARC effect. Time is represented on horizontal space along the left to the right direction, and they assume the existence of a Mental Time Line in space. This study was designed to investigate whether the evidence considering time information mapping on spatial coordinates along the vertical and horizontal axis. In this task, the authors used eight auditory stimuli (clicks) for each trial, and the participants had to decide whether the interval before the last click was longer or shorter than the other seven heard before. They had to respond with the left key when the interval was 'early' and the right key when the period was ‘late,’ and on the contrary in the incongruent condition. They were faster when the shorter sound was on the right side and the longest sound on the left side. These results provide the existence of a spatiotemporal association in which the sensorimotor process mediates the perception of the stimulus and the preparation of the response. The results revealed no spatiotemporal association on the vertical axis. It also demonstrated that spatial and temporal information congruence along the "timeline" facilitates manual responses, eliciting the STEARC effect.

A tight association between number, space, and time were reported by Vicario, et al. (2008), who presented numbers to their participants in two different conditions. In the first condition, the numbers were lateralized on the left or right side on the screen with the fixation point in the middle. In the second condition, the numbers were presented centrally. Results have shown that healthy participants underestimated the temporal duration of the numbers presented on the left and overestimated the stimuli to the right. In the second condition, however, participants overestimated the duration of bigger numbers and were more accurate in estimating the duration of the smaller numbers. In summary, they performed better the task when the small numbers were presented on the left, and the durations were longer, as well as the bigger numbers were presented on the right. These data have suggested a spatial organization of numerical magnitude and a time spatialization on a Mental Number Line. More recently, studies have assumed that this effect depends on Working Memory. Abrahamse, van Dijck, and Fias (2016) explained the SNARC effect using numerical quantities processing and serial order. According to this hypothesis, the SNARC Effect could depend on the activation of pre-existing number positions on the MNL, on Long-Term Memory, and the serial order in Working Memory (Ginsburg & Gevers, 2015).

Van Dijck, Abrahamse, Majerus and Fias (2013) have assumed that recalling information in WM induced a shift of cover attention based on the information stored in WM. These findings assume that the serial order in verbal WM is intrinsically processed spatially. Recently it has been shown that short sequences of words stored as series in WM are linked to the space, and the elements at the beginning facilitate the answers with the left hand, while the elements at the end facilitate the answers with the right hand, also when the serial position was not relevant during storage of this information (Torralbo et al. 2006). Wang, Liu, Shi, and Kang (2018) showed that the SNARC effect appeared simultaneously in numerical quantity processing and the temporal sequence when a time sequence was induced. The SNARC effect disappeared during the timeline processing; however, the SNARC effect appaired in the processing of numerical magnitude, temporal sequence, and spatial sequence when the spatial sequence was inducted, and the participants performed a relevant task. Children seem to have precociously multiple representations of number size based on logarithmic representations (representations of magnitude affect estimation) and representations to subsequently acquire.

According to the Gibbon Accumulator Model (Gibbon, 1977), an object is represented as a central nervous system impulse accumulated by the cognitive system; afterward, information is transferred to Long-Term-Memory (LTM). In LTM information is categorized and represented at different levels; in this way, a number would be represented as a continuous quantity, which mirrors the discrete quantities that it represents. Traditionally SNARC effect studies have always focused on numbers, Gevers, Reynvoet and Fias (2003) investigated the association between order and space and extended to the study of ordinal sequences. Numbers transmit implicit and hierarchical ordinal meaning from their real meaning encoded spatially (Gallistel & Gelman, 2000). Gevers et al. (2003) investigated the possible spatial organization of two ordered sequences, namely months of the year and letters in native Dutch speakers. In the task concerning the months of the year, it was asked to judge the position of eight months, from January to April and from September to December, and participants judged whether these months were before or after July. During the task, they performed an irrelevant task, judging whether the presented month ends with the letter "R" or not. The participants were given the task twice: once participants had to answer with the left hand, and once they had to answer with the right hand. In the second condition to obtain spatial effects without of numerical encoded Gevers et al. (2003) used the letters of the alphabet, therefore participants compared the letters to detect the order, and they judged whether a letter in the alphabet was before or after the O, they also performed a task in which they classified the letters as vowels or consonants. The irrelevant task allowed investigating the spatial encoding of the ordinal structure with a completely different stimulus-response mapping. The results showed that the mental representation of the ordinal sequences is spatially codified. Specifically, in the experiment concerning the months, the authors showed that the participants responded more quickly to the months of the beginning of the year with the left hand and with the right hand to the months at the end of the year. Besides, it occurred when the participants had to indicate whether the month ended with the letter R, that requires superficial processing and not of the ordinal position. This result shows that spatial encoding is activated automatically. Moreover, Gevers, Reynvoet and Fias (2004) studied ordered sequences processing concerning the days of the week and observed a similar effect as reported in the former study. Gevers et al. (2004) concluded that the ordinal and numerical information share the same characteristics, and they are functionally separate, the ordinal information allows to require magnitude notion (Fuson, 1988).

Probably a common system allows to process ordinal and numerical information that differs later in life with learning. The ordered and numeric information has common characteristics that are spatially organized, and the serial information is represented in the memory according to cultural factors. Cultural factors influenced serial information representation in Working Memory and ordered and numeric and information has common characteristics spatially organized. Previtali, de Hevia and Girelli (2010) studied whether the sequences of newly acquired information could be mapped spatially linked to cultural factors and investigated in Italian speakers whether learning a list of words induced a spatial organization as a SNARC effect. Participants performed one of three tasks, two concerning order-relevant and other an order-irrelevant. In their study, the authors presented first a learning test, participants learning a list of nine words after they asked them to say whether the word presented visually was before or after a specific word presented in the list. In another task, they had to decide whether a picture was presented before or after, pictures appeared instead of words. In the third task, Previtali et al. (2010) administered an irrelevant order task using some letters to investigate whether the processing of the ordered information can be activated automatically. They asked to decide whether pictures and word contained the letter ‘R’. They responded using the left or right key. Participants responded fast with the left hand when they had to classify words presented on the top of the list and fast with the right hand when the words were at the end of the list. Results have shown that newly acquired information was spatially organized along a mental representation, showing a SNARC effect. This distance effect looked like the primacy and the recency effect demonstrated by Atkinson and Shiffrin (1968), while results obtained using the pictures have confirmed the hypothesis of a spatial mental representation of recently oriented series acquired from left to right. Also, the letters task has confirmed that spatial characteristic is activated automatically.

de Hevia, Girelli and Vallar (2006) administered a bisection task to investigate the relationship between numerical and spatial representations. The authors argue that the meaning representation of the number is organized spatially as a mental line of the number. Participants performed four tasks, a string bisection task, a line bisection task with distractors, in which numbers were used on the line, a task to bisect an empty space, and a bisection line task with distractors and empty spaces. This study aimed to analyze how numerical information influence participants' performance in the bisection tasks. In the present study, spatial biases emerged primarily when numerical distractors were arranged in a left-to-right orientation (smaller left/larger on the right) following the convention direction of the Western reading system. In the numerical domain, cultural factors are critical to acquiring skills, such as arithmetic and numerical transcoding, and the relations between space and numerical representations can appear related to spontaneous strategy to organize spatially ordered information from left to right (e.g., the sequence number) or information related to analogical representation of numerical quantity (Moyer & Landauer, 1967). Also, it was relieved that with the right side of a mental space representation are associated large number.

The Mental Time Travel

The ability to mentally move from one event to another, from the past to the future and to consciously think about the passing of time is called Mental Time Travel (MTT). A journey through time allows us to imagine new situations, what could happen in the future, relive or pre-create times and places, projecting the self over time (Atance & O'Neill, 2001; Tulving 1985, 2002).

Mental Time Travel is linked to our memory abilities, to episodic memory (personal and non-personal) and perspective memory (Anelli, Ciaramelli, Arzy & Frassinetti, 2016). Perspective Memory is considered as the ‘memory of intentions’ and is used when we must remember to act at a future time (Baddeley, 1990; Kvavilashvili, 1987). To this end, perspective memory involves the mechanisms of working memory, such as planning action schemes, semantic, and episodic knowledge. Autobiographical episodic memory organizes knowledge about the events of a person's life: past events, self-knowledge about goals and aspirations (Tulving, 1972). Each event is associated with a space-time context and has an emotional connotation. Non-personal episodic memory, on the other hand, organizes knowledge concerning the events that happen in the surrounding world, but which do not concern us personally. Mental Time Travel is related to Chronesthesia process (Tulving, 2002), and it is a detached mental construct that can be represented in sensorimotor systems that regulate movement. Therefore, chronesthesia involves thoughts and actions and thinking of retrospective and perspective events, and they can be appaired by backward or forward movements.

Miles et al., (2010), considering this hypothesis, indeed chronesthesia linked to the movement, so they measured spontaneous fluctuations of the postural oscillation of the body using a motion sensor applied over the left knee while participants imagined a mental journey through time, to the past or the future. They used an eye patch for making images more vivid. Participants evaluated the value of their retrospective or prospective thoughts on a 9-point Likert scale (1 very negative and 9 very positive). Significant effects were found between the temporal dimension and the movement direction. They moved backward when they thought the past and forward when they thought the future. These results show that Mental Time Travel has a behavioural correlation, the direction of body movements in space and the chronesthesia seems to be based on perception-action systems that support socio-cognitive functioning.

Arzy, Collette, Ionta, Fornari, and Blanke (2009) studied subjective Mental Time Travel and the ability to project self to the past and the future. Our ability to judge as past or future an event might not depend on event type or perceptive input to categorize (i.e., our ability to self-projection over time), it could be depending on different mechanisms. They presented to their participants some faces or event on the screen, illustrating participants' faces or a famous person (e.g., George Clooney). Faces were aged and rejuvenated using specific software. Participants had to judge whether faces or events were past or future. Participants had to place themselves in an egocentric perspective in three moments: in the present, in the past (i.e.; eight years ago) and in the future (i.e.; in eight years). The results showed better performance when the subjects performed the task of imagining themselves in the present concerning the past and the future and when the participants had to judge the events as future rather than passed. The concept of an Absolute Time (aMTT) refers to location of the self in the different moments of mental time (past, present, and future) and a Relative Time (rMTT), that is the relationship between the temporal location of an event and the point in which our self is mentally positioned. In the absolute position all that has already happened is part of the past, while all that has yet to happen refers to the future; when we speak of relative position we must understand the past and the future with respect to an event and the view of our self (Type A and Series B as McTaggart hypothesized).

Experimental manipulations of visuospatial attention, as well as spatial attention alterations after brain damage, can influence time processing. Patients with damage to the right hemisphere show a significant temporal undervaluation in a temporal bisection task, compared to patients with neglect. In other hands, patients with right hemisphere damage and neglect shows a contralesional distortion in the visuospatial attention and a temporal duration underestimation (Calabria et al., 2011). These patients have a normal score in the paper and pencil tasks, but they have more difficult to perform the task when words presented are referred to the future, and they had to detect targets in the contralesional space (Pun, Adamo, Weger, Black, & Ferber, 2010). This finding also supports the hypothesis about the role of spatial attention in temporal elaboration (Bonato et al., 2012).

Bonato, Saj, and Vuilleumier (2016) studied patients with right hemisphere damage and Neglect syndrome, to see whether the processing of events ordered considering time characteristic is spatialized. Patients had to read a story until they had memorized it. Then, patients had to seat in front of the screen and watched images that illustrated George's story. The main event of the story was ‘George on top of the mountain’, and the patients had to decide whether the image that appeared on the screen was referred to an event that occurred before (images -3, - 2 and -1) or after (images 1, 2, and 3) this reference event. Patients with neglect syndrome showed slower responses, and difficulty to imagine events that happened before the main event. These results demonstrate that the representation of the order of the events is spatialized and provides strong evidence that the order is processed in the same way in time and numerical sequences, with a left-right representation. This spatial preference is determined by hemispherical asymmetries, linguistic metaphors, and reading-writing system. Mental Number Line (MNL) studies involving patients with right-hemisphere damage and neglect syndrome have shown a key role of spatial attention to access in numerical magnitude on MNL.

Spatial concepts and MTL characteristic in blind people are perceived differently. Therefore, it can cause changes in representation of time along the sagittal space (Rinaldi, Merabet et al., 2018; Rinaldi, Vecchi et al, 2018).

Crollen and Collignon, (2012) have shown that the mental organization of non-visual reference spatial frames (FoR) in blind people who have lost their sight before aged three is qualitatively different compared to people who have lost their sight later. Studies that used a tactile stimulation localization paradigm, and sensory controls on the action (Collignon, Charbonneau, Lassonde, & Lepore, 2009; Röder, Kusmierek, Spence, & Schicke, 2007;Röder, Rösler, & Spence, 2004) highlighted as sighted people perform the task based on an external spatial FoR (i.e., positions are represented within a frame outside the body). On the contrary, the blinds at the beginning preferentially use an anatomical FoR (i.e., positions are represented with respect to the position of one's body and the position of one's limbs), to represent the relationship space.

Italian blind participants took part in a study (Bottini, Crepaldi Casasanto, Crollen & Collignon, 2015). The aim was to study whether their MTLs are represented as in the sighted. Blind people read in Braille. Thus, they can use an external FoR and show a congruence of space-time similar effect through the postures. In this way, they would present a left-right mapping with the past on the left and the future on the right, or whether early blindness can lead to the default use of an anatomical FoR to map abstract concepts on space (as in the case of numbers), without any spatiotemporal congruence effect. They asked to their participants to classify words referring to the past, or referring to the future (e.g., before, yesterday, after) verbally, as fast as possible. In the task, there was also an incongruent condition in which the future was on the left and the past on the right. The blind participants seem to conceptualize the time using a horizontal Mental Time Line.

1.2 The ontogeny of time representation

The previous section has been focused on describing how our mind organizes space-time representation and how some factors, such as metaphors, reading-writing system, and the action of walking can influence its direction. It is crucial now to dwell on the ontogeny of space-time representation and deepen our understanding of how our mind develops this ability in childhood. There are various findings testifying that the infant's mind spontaneously organized ordered information, such as number and time, in a spatial format. For instance, de Hevia, Girelli, Addabbo and Macchi Cassia (2014) studied the association between numerical order and left-right spatial orientation in childhood. The authors administered a numerical spatiotemporal sequence to seven months old children in which numbers arrays appeared along the horizontal space, on left-right and right-left axes. The results have shown that the discrimination of ordinal number sequences is influenced by their spatial information. First, a spatial representation of numerical information is constructed, and then a preference to organize the numerical order from left to right.

Casasanto, Fotakopoulou, and Boroditsky (2010), conducted an experiment involving Greek-speaking children in three tasks, about the main Distance-Time interference, that is the ability to judge duration independent of spatial interference, and ability to judge distance independent of temporal interference. They aimed testing the relationships between space and time in the minds of kindergarten and school-aged children. Their results have shown that children were more skilled to ignore irrelevant temporal information when they judge space information than vice versa. Hence, children seem to have the same adult's cross-dimensional asymmetry: they could ignore irrelevant temporal information when they judgment some stimuli about space. On the contrary, they have more difficulty to ignore irrelevant spatial information when they judgment some stimuli about time.

McCormack and Hoerl (1999) described the temporal representation development phases and related cognitive abilities. Temporal representation is formed through different steps: time frames, temporal decentralization, scripts, and imitation. In the first phase, prospective or non-retrospective pictures are created, representing repetitive sequences or times that do not yet form an episodic memory. In this phase, children cannot think about events as occurred at specific moments in time. Later, children develop the ability to adopt a temporal point of view different from their own (i.e.; this process is called ‘temporal decentralization'). This is a cognitive prerequisite to understand linguistic descriptions of action sequences in which the order of the events as described is different from the order in which they actually occurred. Temporal decentralization allows us to locate events in the past, regardless of whether these events led to a present observable situation. Weist (1989) suggests that children's ability to move in time is developed when they show episodic memories. At this stage, children aged two or three may be able to represent events that happen at different times, but their reasoning is still limited, therefore they consider the effects of an event just related to the present situation (Harris & Kavanaugh, 1993; Jarrold, Carruthers, Smith, & Boucher, 1994; Perner, 1991). For example, they can switch from a representation like ‘This is a banana’ to an imaginative representation like ‘This is a telephone’, they simulated that banana was a telephone, without representing the nature of the relationship between these representations (i.e., I think and want that banana represents a phone).

We often try to localize an event in time by creating inferences or by using other contextual information (e.g., who was there). A child can recall information related to a single episode, but this information remains generic. This information, called a script, is recurrent in a child's life (e.g., some examples would be going to the pediatrician, going to a birthday party, or eating in a fast-food restaurant) (Nelson, 1986; Schank & Abelson, 1977). Scripts function as frameworks, and they provide the way to represent the position of new events over time. A child forming a sequence may be able to recognize a new sequence of events as belonging to a script, despite it containing a new element or one of its features being different or missing. The use of a script requires a minimal understanding of time localization, and therefore, some integration ability. Deferred imitation of action sequences, on the other hand, allows a child to represent events as fixed elements. Young children can represent sequences of events in the early stages of development, but they may not work as temporal structures. For this reason, children may find it challenging to use representations flexibly (e.g., to represent an event's position in a story).

McCormack and Hoerl (2005) assessed the causal, temporal reasoning ability in a working memory task. The aim was to verify whether children could consider two past events order accurately to infer on the current, or whether the information that could conclude on the correct past events order. Furthermore, the authors wanted to provide an empirical distinction between temporal updating and temporal causal reasoning. A way to measure temporal causal reasoning was to make the child unaware of the events during the task. The events were not directly observable, and they were listed to the child in a different order from the one in which they happened. Authors in their study used two dolls named Sally and Katy; in each condition, Sally performed the actions before Katy. During the task, they used a shelf, pressing two buttons they could appear a machine or the shelf rotating showed a new object. The aim of this task was to understand who pushed the button and which toy was associated with the dolls. They told children a story where Sally and Katy pressed a button each to move the shelf, and they asked children which toy was on the shelf, considering the doll that had pushed the button as first. The results showed that four-year-olds children could perform neither of the two tasks because they have difficulty to make causal, temporal inferences. Instead, children aged five years had a better performance in the agent's inference task and demonstrated a better understanding of the causal relevance of the temporal order of events. They understand better which doll pressed the button and which toy appeared. The object inference task requires acquired information to recall the dolls' position, their action order, and the objects linked with them. In the agent inference test, children can focus on the dolls immediately, and the task results easier. Therefore, younger children can keep up information and can track events as they occur, or if they are informed of events at the same time focusing just meaningful information. However, children may have found Sally more salient because she was biggest than Katy or because she always performed the first tasks. Another possible issue was that to explain the task the authors used the word ‘before': this could represent a problem for this age children, as it could be an informative cue.

Pre-schoolers have difficulty planning sequences of future events, although they can remember sequences of similar events (Atance & O'Neill, 2001; Benson, 1997; Bauer, Schwade, Wewerka, & Delaney, 1999). Such difficulties depend on explicit reasoning ability, about causal connections between events. A further study on the reasoning of children on the order of past events was carried out by McCormack and Hoerl (2007) and as shown in previous studies, children aged four can verbally describe both routine and history in sequences of events in the correct order (Fivush & Hudson, 1990; Nelson, 1986). Four-year-olds children can also correctly order representations of familiar sequences of events, such as the main events of daily (Friedman & Brudos, 1988; Fivush & Mandler, 1985). Children of this age can code and remember the temporal order of information and judge whether events are ordered correctly or not. Povinelli et al., (1999) have suggested that young children have temporally ordered representations of the world, but they do not understand the bases and significance of this chronological organization completely. Three or four-year-old children have some planning skills (Atance & O'Neill, 2001; Hudson, Sosa, & Shapiro,1997), and can make some simple hypothetical and counterfactual judgments (Beck, Robinson, Carroll, &Apperly, 2006), can use structured temporal scripts to drive their behavior (Nelson, 1986, 1996).

McCormack and Hoerl (2007) have carried out a study of simple hypothetical and counterfactual judgments and structured temporal scripts using scripts in four-five-year-children. Participants saw two dolls, John and Peter, in a wooden house; one of them was taller and dressed in a different way than the other. In the story, these two dolls go to the bathroom; the experimenter closes the door and begins to tell John's and Peter's actions, such as washing their hair. Afterward, they asked children about the order of actions: "Which of the two dolls do you see brushing their hair first?". There were three conditions: in the first condition they did not see what the dolls were doing in the bathroom, in the second, dolls went in the bathroom one at a time, and the experimenter left the bathroom door open, and children saw what happened. The results of the study have confirmed McCormack and Hoerl (2005) results; also, they have shown as four aged children are not able to use the information of two events to understand the order when they occur. This ability is defined as causal-temporal reasoning. It requires to understand the causal meaning of information and understanding of temporal order. However, children have not knowledge of the event yet, and their working memory fails during the performance of the task, and they do not understand or use in their reasoning, the relationships between events over time. Children can remember action sequences when a task requires a simple observation of the dolls' actions, to perform this task; they need to plan the actions. There is the failure to fully understand or use in their reasoning the nature of the relationships between events over time.

In another study, McColgan, and McCormack (2008), make use of a doll named

Molly. In the story, Molly visited a Zoo and took a picture of a kangaroo using a Polaroid brought in a backpack. The study was divided into two conditions, the Past Zoo, and the Future Zoo. In the Past condition, Molly lost her camera in one of the lockers behind the animal cages, where she had placed his backpack. The experimenter told to the children at the end of the story when Molly finished visiting the zoo. Children had to choose a position to look for the camera, considering just the cages of the animals that Molly saw. In the Future condition, to a different children group, they told of a doll, Molly and her intention to visit the zoo and to want to take a picture of a kangaroo. Children knew the doll could not bring her bag, and she had to leave it in a place where she could take it when she was approaching the kangaroo cage. Children chose a place to leave the camera. During the task, children performed a distracting task (taking the doll's coat out of the test area), and in the meantime, the experimenter replaced Molly's bag with the camera with a bag without a camera. When the children went back, the experimenter told them the camera was missing and let them check. They suggested to children that the Polaroid could have fallen into one of the lockers behind each cage. Later they showed children the pictures of the kangaroo took during the task, and the experimenter asked them if they thought the doll had lost the camera before taking the picture to the kangaroo. He asked them in which lockecould is the Polaroid and to help Molly to find it.

McColgan and McCormack (2008) have shown more difficult to performance of the tasks for four years old children and better performance in five years old children three-four years old Children chose the first and the second position when they responded with wrong answers. These results suggest the possibility that some children may have tried to use a serial and sequential search strategy rather than looking for the position logically. Children could have chosen the location just one time, and they would not be able to complete such a serial search. Young children have adopted over-thinking strategy when looking for the solution effortlessly; they use an unproductive serial research strategy and worsening their performance. In the planning task, four aged children had not a position preference (first position), and their failure could be caused by a memory error rather than a failure in reasoning.

1.3 Cognitive processes and brain areas involved in the memory ability and space-time processing

The consciousness process related to the passing of time is linked to memory ability (Lewis & Miall, 2006). Tulving (2002) considers episodic memory as made of two separable components, named the memory of ‘What' and ‘When.' These components are temporal and spatial aspects of the experience that is when and where an event occurred. The component ‘When’ instead is the ‘Autonoetic Consciousness', that is the awareness of oneself since the event in the past was experienced, and this component involves Mental Time Travel. Fivush (2011), assumed that autobiographical memory is based on the representation of episodes (e.g., recall) including the memory of the self (e.g., a person as an actor who lived that event, Autonoetic Consciousness), a series of individual past events. Instead, the autobiographical memory connects past events into a personal story where they are connected between them through the past, present, and future, forming a narrative story of life. Specific autobiographical memories are integrated with a personal timeline that represents the past, the presen, and the future (Habermas & Bluck, 2000, McAdams, 2001). As previously described in this chapter, Tulving (2002) linked the Chronestesia to the memory ability as well as to personal and subjective aspects. Therefore, memory processes can change in childhood and adulthood. Passage of time is overall linked to memory function and planning and decision making. Many behavioural, injurie, and neuroimaging studies investigated the neural basis of memory and the ability to project the self in the future.

The brain changes continuously in lifespan and reorganizes itself. These changes depend on environmental, genetic, social factors, rehabilitation program, or traumatic brain injury that model the synaptic connections of the nervous system.

In the 50s Montalcini and Hamburger identified a protein named Nerve Growth Factor (NGF) produced by neuronal stimulation; this protein allows the development and increase of connections between cells, especially in the hippocampus, the brain area related to memory and learning functions. Magnetic resonance studies on cerebral development in children and adolescents have found profound changes, especially in the prefrontal cortex. These changes are due to myelination processes, synaptic priming or plasticity processes (Gogtay et al, 2004; Hensch, 2004; Sur, & Rubinstein, 2005; Lenroot, & Giedd, 2006). In adolescence, there is a linear increase in white matter and the myelination of the axon; this increase allows greater neuronal signals conduction (Casey, Getz, & Galvan, 2008). There is an increase in the myelination processes of cortico-cortical fibers; they connect different areas of prefrontal cortex and cortico-subcortical fibers to limbic and paralimbic regions, such as the amygdala, nucleus accumbens, and hippocampus. Frontal lobes reach their peak growth at 12 years for males and 11 years for females; parietal lobes reach their peak at 12 years for males and ten years for females; temporal lobes are the last to reach their peak, at about 17 years in both gender types (Giedd, 2008).

The prefrontal cortex is one of the last cortical areas to achieve its final conformation. It is involved in many cognitive functions such as language and movement, but above all the high-level processes, such as working memory, selective and sustained attention, attentive shifting, planning, problem solving, and plays a crucial role in the self-monitoring and detection of errors to inhibit automatic responses, decision-making skills and self-regulation (Alvarez & Emory, 2006). A shared network of activation that includes the prefrontal cortex and medial temporal lobe has been described. The dorsolateral prefrontal cortex is involved in working memory process as well as in time processing (Gibbon, 1977; Staddon and Higa, 1999). One of these studies (Addis & Schacter, 2008) using event-related fMRI, found one common neural network related to the elaboration of past and future events in medial temporal lobes and the frontopolar cortex. Whether events are referred to the past, or the different future areas respond differently. The hippocampus is the area more involved in the temporal distance elaboration: the bilateral hippocampus is more active when the distance from future events increases and the past event is more recent. Neuroimaging studies point out that thinking to past and future requires common cerebral regions, especially the medial prefrontal cortex, medial temporal lobe (Addis, Moscovitch, Crawley & McAndrew, 2004; Marshuentz, et al., 2000). Dorsolateral and ventromedial prefrontal cortex are involved in Mental Time Travel and to plan future events (Fellows & Farah, 2005). Moreover, prefrontal cortex and medial temporal lobe are activated to relive past events and imagine the future (Batzung, Denkova & Manning, 2008). The left and posterior part of the hippocampus is more activated when details are related to the past than when they are related to the future; the left and anterior part of the hippocampus, on the other hand, responds more to future events.

As already mentioned, Torralbo et al., (2006) highlighted how the representation of time in space is mediated by attentive mechanisms that interact with working memory. They hypothesized that this mechanism occurs online in working memory as a result of the simultaneous activation of time and space. Also, a conceptual mapping may exist in long-term memory, and it can be used to guide conceptual projection into working memory based on numerous factors, such as language and cultural. Therefore, a mapping is stabilized in long-term memory, and it can be activated in the future. Attention is a critical component: it influences the information that will enter working memory as well as the choice of a deictic point of view, a focus, and an overall perspective. It can be guided either automatically linked to immediate changes (e.g., highly salient tasks) or voluntarily (e.g., endogenous control factors). The authors have shown that people have two possible mappings available in long-term memory, but that they use just one. The chosen mapping will be the only one generating a representation in the most coherent working memory.

Long-term memory, on the other hand, works on the information that has been stored and consolidated for a long time. Theoretically, according to the characteristics of the information stored, long-term memory can either be declarative or non-declarative. Declarative memory records personal and general facts verbally and has conscious access. Sometimes it is considered as explicit memory. Tulving (1972) further divided declarative memory into episodic memory and semantic memory. Episodic memory contains traces of personal experiences about our lives and what, who, where, and when they happened. Episodic memory always includes the self as the agent or recipient of some actions, places, feelings, or people that took part. Episodic memory is the result of rapid associative learning of thing, where, when, and who of a single episode, and its context, become associated and bound together. They can be recalled from memory after a single episode.

Semantic memory, on the other hand, is the objective knowledge of something that has happened. It is not associated with a context, such as a news item it is something, we learned but do not remember where. Semantic memory reflects the knowledge of the facts and concepts of the world. Non-declarative memory is implicit, and we do not have conscious access to it. It includes some learned behaviour such as priming, conditioning, habituation, sensitization, and procedural memory, such as a motor or cognitive ability in learning. This form of memory is detected when previous experiences facilitate performance in a task that does not intentionally require the re-evocation of experiences. It involves other brain structures, including basal ganglia, cerebellum, amygdala, and neocortex. A non-declarative form of memory is the procedural memory used when we learn motor skills, and when we recall learning skills such as driving or cycling. It does not require conscious or minimal awareness.

The development of autobiographical memory is allowed by the development of language and narrative skills, which are an essential ability for gaining experience and organizing knowledge (Bruner, 1990; Fivush, 2008; Nelson, 1996; Vygotsky, 1978).

Thanks to the language, it is possible to connect to the single memory aspects related to the intentions, motivations, thoughts, and emotions related to the social and cultural contest. Episodic and semantic memory appears at different ages in human development. Two-year-olds can demonstrate the re-enactment of things they saw at 13 months (Bauer & Wewerka, 1995). As highlighted by Piaget and Andreani Dentici (1969), the development of autobiographical memory follows specific phases. At two years of age, there is a routine memory linked to general events. Between three to five years of age, events are related to specific episodes that can be recalled. From the age of six, children can recall memories from a less fragmented organization of their own 'story'. From preadolescence, as we develop and construct our identity, we begin to raise interest in the significant episodes of our life story in perspective. Children under three years have a semantic memory more developed than their autobiographical memory. In fact, between one and two years a child learns many words, linguistic rules, information on objects, animals, people, places, but can rarely recall an event of his life wholly and accurately. Children can more easily recall a script memory, such as routine activities, rather than something that has happened and is not habitual (Nelson, 1973). Two-three-year-old children can remember the activities and the information they have been exposed to several times, but they cannot organize their memories. Children cannot remember the events that precede their second year of life because they lack a cognitive self; the brain structures responsible for the conscious recovery of long-term memories are still too immature. Life events are deeply coded because they are better known. Short-term memory capacity increases with age, from four to 12 years of age. In this time range, the ability to use the strategies for review and the speed of information recall from memory increase.

Working Memory (WM) skills are developed in childhood; this is also made possible by the increase in the amount of information that can be stored, the memory span increased that allows to maintenance information during execution of other activities. An essential component that helps the development of this ability is the attentional skills that develop more around seven years. Multiple mechanisms contribute to children's WM development, influencing all processes involved in coding, maintenance, and recall. They are related to the development of skills such as the increased capacity for attention, process automatic, increased knowledge, and mnemonic strategies. In lifespan, there are changes in the acquisition and storage of information in memory, and they behave greater processing speed, efficient storage strategies, and basic knowledge. Therefore, autobiographical memories become more resistant. Over time, experience details can be forgotten, and the memory altered becoming more coherent with children's information, related to what usually happens. If the event is consistent with the script, the knowledge gained over time can influence our memory of it even long after the event.

Children have mental states that are necessary for them to think about their past experiences as the origins of their memories. Therefore, they not even have episodic memory. Having a temporal perspective implies possessing mentalization skills, that is the ability to conceive the self as a possessor of mental states depending on someone's temporal perspective; such abilities are necessary for episodic memory development (themselves as occupants of these different perspectives) (Neisser, 1991; Povinelli & Simon, 1998). Social sharing of memories is essential to develop narrative memories (Haden, Haine, & Fivush, 1997; Hudson, 1990; Reese, Haden, & Fivush, 1993). Social sharing of memories and mentalization allows children to develop time concepts. In children aged two or three, there is no understanding of systematic temporal relationships between thematically unrelated events. Povinelli et al. (1999) showed that three-year-olds could not understand events that occurred in the more recent past. They occurred at a time in the farthest past, and they develop this skill at five years of age. According to Povinelli et al. (1999), children fail to understand the causal significance, the temporal order in which past events took place, to elaborate the current state of the world around them.

Numerous and previous works have highlighted the role played by culture in autobiographical memory development, that is how the adaptation of the first memories and the characteristics of the autobiographical information depend on the culture (Conway, Wang, Hanyu, & Haque, 2005; Han, Leichtman, & Wang, 1998; Leichtman, Wang, & Pillemer, 2003). In western culture, autobiographical memories contain more self-focused information: self-assertion and personal identity are in the foreground. On the contrary, in cultures with a collectivist orientation, in which people are instead considered as an integral part of the surrounding environment, they develop an interdependent self. In this case, people remembering episodes of their own life, they focus more on information related to social interactions and tend to pose the self in the background (Wang, Hutt, Kulkofsky, McDermott, & Wei, 2006).

In the socio-relational context, emotions are linked to people, when they are the cause of emotional experience and when they have a role in supporting modulation or emotional regulation. Emotions are more easily related to objects or events in the physical world, for example, how to receive a gift (Fivush & Wang, 2005). Over time learning allows them to better understand the experiential difference between the various emotions and, in the specific case, children learn that emotional experience can help them to detect danger. More generally, they develop awareness and understanding of one's emotional states. Moreover, the more intense is the emotion linked to the memories, the easier it will be to remember them.

Christianson and Safer (1996) argue that events related to strong emotions are remembered with greater ease and are stored in memory for longer than others. Episodic memory integrates information regarding contextual details and information about the event (Davies & Thomson, 1988). This type of memory involves self-conscious reasoning processes defined as Autonoetic Consciousness (that is, the ability to mentally represent and become aware of one's own experiences in subjective time) (Perner & Ruffman, 1995). On the other hand, there is a Noetic awareness that accompanies semantic memories that involve the recovery of knowledge, but not the revisiting of someone's past.

Therefore, authors, as Tulving (2002) redefine episodic memory as a form of Mental Time Travel (MTT). In a Mental Time Travel, a person re-experiences past events (episodic memory) and imaginatively ‘pre-experience’ future events (Michaelian, Klein & Szpunar, 2016) in future-oriented Mental Time Travel (FMTT). Episodic memory and FMTT have some common points, and some differences constituted by their distinct temporal orientations. Two current theories explain their different point of view about episodic memory and FMTT. According to the Continuists, there is no fundamental difference between episodic memory and FMTT, and there is a single general ability, a unique system (Suddendorf and Corballis, 2007). Also, a moderate Continuists' point of view considers the ability to imagine a future event more cognitively difficult than to recall a past event. According to the Discontinuists considers the episodic memory and FMTT involve constructive episodic simulation of event, but there are two different ability, two different processes: episodic memories of past events and episodic imaginations of future events. The debate is still on whether (Bernecker & Michaelian, 2017).

1.4 Travelling through our memories: Mental Time Travel in personal and non-personal

A growing body of literature has examined Mental Time Travel ability referred to specific personal and non-personal events, despite evidence about of how our mind maps personal and non-personal events along the Mental Time Line through a Mental Time Travel is still poor and need to be dealt in depth.

Ansuini, Cavallo, Pia, and Becchio (2016) measured the duration of the journey through time, and how far the participants moved in time. In this study, they asked participants to imagine themselves at a specific point in time, such as their middle childhood or middle adulthood, and to judge temporal distance. A co-experimenter of about the same age as the participants sits in front of them. Participants had to imagine events according to their own or the co-experimenter's perspective (e.g., your fiftieth birthday/the co-experimenter's fiftieth birthday). They watched a dark screen with small white points that resembled a sky full of stars. The stars moved in a backward or forward flow to simulate a journey into the past or the future, respectively. The results showed there was higher sensitivity in the representation of time and events in the egocentric perspective compared to the allocentric perspective. Participants took more time to mentally travel the same distances when they had to imagine themselves in the past or the present rather than in the future. These results were not replicated in the allocentric perspective when they had to imagine the same events according to the co-experimenter's point of view. The authors explain these results by considering future events as less detailed and simpler to elaborate than past events that may require higher cognitive functions and processes. As also highlighted by Trope and Liberman (2003) and D'Argembeau and Van der Linder (2004), when a future event is more distant, it is represented as less clear either positive or negative experiences that a person expects to live in the future. Also, travel duration increased as a function of the length of time, and participants were faster and more accurate in the relative future than the relative past. As humans, we frequently engage in Mental Time Travel, reliving past experiences, and imagining possible future events. This study examined whether similar factors affect the subjective experience associated with remembering the past and imagining the future. Participants mentally 're-experienced' or 'pre-experienced' positive and negative events that differed in their temporal distance from the present (i.e.; close versus distant), and then rated the phenomenal characteristics (i.e., sensorial, contextual, and emotional details) associated with their representations. For both past and future, representations of positive events were associated with a greater feeling of re-experiencing (or pre-experiencing) than representations of negative events. Also, representations of temporally close events (both past and future) contained more sensorial and contextual details and generated a stronger feeling of re-experiencing (or pre-experiencing) than representations of temporally distant events. It is suggested that the way we both remember our past and imagine our future is constrained by our current goals. Self-projection ability allows the human mind to project itself through time, in the past or the future, detaching itself from the present.

Arzy, Molnar-Szakacs, and Blanke (2008) employed an imaginative task to investigate the relation between Mental Time Line and Mental Time Travel. They asked their participants to imagine moving toward the future or the past. Participants imagined themselves ‘now’, ‘10 years ago’ and ‘in 10 years’, and they had to indicate whether events happened in the past or would happen in the future. The stimuli were sentences which described personal events (e.g., the birth of a first child) or non-personal events (e.g., the passage of Katrina hurricane). They used the index and middle fingers of the left and right hand, alternating in the block to respond. Participants were faster and more accurate when they categorized events as future or past while imagining themselves in the present, thus not changing their self-location. A ‘Self-Effect’ was recorded in other conditions: participants performed better with personal than with historical events.

Schurr, et al., (2018) studied Mental Time Travel in three epileptic patients. The task was the same as in Arzy et al. 2008. Participants imagined themselves ‘now, ‘in 10 years’ and ‘10 years ago’ and they had to indicate whether an event was past, or future based on their position in time: before or after the moment imagined. The events were personal (e.g., the birth of a first child) or non-personal (e.g., Obama's election). Participants used the index and middle fingers of the left and right hand, alternating in the block to respond. EEG data were collected during the task and examined according to the fMRI and EEG classifications of anatomical localization. The results showed that the lateral temporal cortex and the hippocampus were involved in MTT. The lateral temporal cortex was involved at the beginning of the MTT process, in which the participants projected themselves over time; the hippocampus instead activated later to connect the different events to the projected self.

Anelli, Ciaramelli, Arzy and Frassinetti (2016) investigated Mental Time Travel through the lifespan using personal and non-personal events. Participants were young adults and adults, and they imagined moving themselves to the future or the past (10 years ago and in 10 years). Considering the imagined perspective, 10 years earlier or later, they indicated whether the target events happened in the past or would happen in the future (e.g., personal events: 10th birthday; non-personal events: Chernobyl disaster). Participants responded with the right index when the events would take place in the future and with the left index when they had taken place in the past. Anelli et al. (2016) have shown a relation between Mental Time Travel changes, in the aging and memory functions as well as between self and memory. Older participants had greater difficulty in judging the future rather than past events, relative to their self-location. Both the younger and older groups showed greater emotional involvement for personal than non-personal events, for young adults, personal events represented past wishes and future goals. The authors also showed that older participants had a reduced ability to pinpoint events in time, probably because the task requires recovery strategies and recall abilities to access contextual details of autobiographical memory and these abilities deteriorate with age. The ability to predict the future has highly adaptive value, as it allows one to anticipate the consequences of a choice.

As mentioned before, adults in Western societies tend to map future and past events either on a lateral (left/past, right/future) spatial axis, or on a sagittal (backward/past, forward/future) axis (Nunez & Cooperrider, 2013). Embodied approaches to cognition believe that concepts are understood through sensorimotor simulations in which neural systems are involved in understanding the actions of objects and events in the real world, it depends on whether in our mind actions and movements are simulated.

Vigliocco and Vinson (2009), Borghi and Cimatti (2009) underline that sensorimotor information is integrated with information related to the language and sensorimotor representations. Thus, sensorimotor simulation can help to understand concepts.

Sell, and Kaschak (2010) performed a study on time and text comprehension to test if time was represented spatially. Participants read sentences about past or future events and decided whether events should move towards or away from their body by pressing keys. Participants read texts and phrases and pressed the key that was nearest to or farthest from the body. It was an implicit task that asked the participants whether the sentences made sense or not. There were two conditions. In the movement condition, the keyboard was not cantered but moved outwards to move the X key away while the P key remained close to the right index of the participant. In the no movement condition, the keyboard was cantered, and participants responded with both the right and the left index. The thought of past or future events influence motor responses along the sagittal axis: participants were quicker to produce a 'distant' response when they were elaborating forward-looking phrases, and they were quicker to perform movements close to their body when sentences were addressed to the past. The no-movement condition showed no effect (Sell & Kaschak, 2010; 2011).

Walker, Bergen and Núñez (2017) studied space-time mapping along a horizontal and sagittal axis, using deictic time and time sequences regarding personal events (e.g., Starting to crawl/Your birth or Tomorrow/Writing your will). In the first experiment, participants held in each hand one mouse. In the deictic time task, they had to decide whether an event had happened in their past or could occur in the future. In the time sequence task, they heard the description of two events, and they had to decide whether the second one happened before or after the first one. In the sagittal condition, participants held their hands behind their back. Results suggest a representation of deictic time along the sagittal axis, future forward, and past backward. In the second task, Walker at al. (2017) used two different adjectives in the sentences: ‘her’ and ‘your’ to introduce a different classification of the events. They considered the possibility that the type of pronoun influences the space-time mapping pattern. In this experiment, the procedure and stimuli were the same as in the first. Results have shown that ‘your’ points to an internal perspective, and we use the body as a reference to think about the sentence (deictic time/sagittal axis), whereas ‘her’ points to an external prospective and we use language as a reference to think about the sentence (lateral axis).

There are scarce evidence and studies involving children to investigate personal and non-personal memory in a Mental Time Travel task and space-time representation. As we have seen, studies focused on this chronological organization of events, planning sequences of events, and temporal reasoning ability. An in-depth analysis of literature highlight few and old studies about the ability to respond to the questions about the past and the future related to children's life events (i.e., events considered as personal)(Busby-Grant & Suddendorf, 2005; Friedman, 1991;2000;2002;2003;2005; Friedman, Gardner & Zubin, 1995; Friedman & Kempo, 1998). The studies mentioned describing children three aged as unable to order chronologically past event in the specific time point in which happened and children aged four to nine can recall memories from the past accurately, (e.g., yesterday, last weekend, last summer, and holidays). Also, children four aged are unable to distinguish future distances compared to five-year-old children, who can identify events that would occur in the coming weeks and months, as well as events that would not happen for many months.

Previous studies (adults and children) reveal that there are different and distinct psychological processes that contribute to the perception of the sense of the past and future. Adults have representations of multiple time patterns, and these representations take different forms. The memory related to the timing of the past events is based on the reconstruction of temporal places, notion about the distances in the past. The timing of future events activates propositions in memory that contain information due to the fact that the events are going to happen. Young children have difficulty to distinguish whether some events are past or future, and this shows that basic memory processes do not allow this distinction. Studies on adult representations concerning days of the week and months of the year revealed that there are two distinct types of representations: the verbal list processes that concern the connections between each element and its successor and allow us to move forward through the order. These processes are suitable for determining the exact temporal distance (e.g., which month is three months after another month). The second type of process is based on the images, allowing us to detect the spatial relationships between the elements of a time model. Friedman (1986) asked the children in judgment tasks whether, for example, "Does Saturday or Monday come after Thursday?". In the first condition, children counted the days or months.

The results have shown that nine and ten-year-old children could respond correctly when they think about the future, while 15-year-olds were more accurate in backward activities. The results highlight the existence of a two-stage model, in which children at first know the order of days of the week and months of the year as a sequence of verbal labels and later integrate it with image representations. Therefore, probably, the representations of verbal lists related to temporal patterns appear in childhood, in children aged nine-ten, while the representations of images appear in adolescence. Children aged four-five can select and order cards that represent the main events of the day, such as walking, having lunch, having dinner, and going to bed at night. Children aged six can judge which of the two activities will occur later, thinking backward in time, considering some reference points (Friedman, 1990). This ability is similar to the use of images by adolescents to judge the days of the week and months of the year. These differences in developmental trends are probably related to the underlying mental stages. It is likely that four-year-old children often think about where they are during the day, while the orientation about the week and the year rarely happen before the nine-ten year of age. Also, sometimes, children learn the days and months during primary school, and this could actually hinder the spontaneous development of image representations about days, weeks, and months.

Further, four-year-old still cannot think of time relative to longer distances more than a day, and they have an approximate sense of the distances about some events in the past.

Other basic memory processes allow children to link specific memories to temporal names (e.g., weekend, summer), although they do not know when these events occurred compared to another. The perception of some future events appears before children start to use these representations to think about the future. Young children are often confused about the past-future of events; around six ages, the distinction seems clearer. The representations of temporal models and basic memory properties, fully mature in adulthood, allow traveling in time. The studies in the literature, as well as the studies mentioned in this chapter, explored the ability to represent time in terms of both past and future. No study has so far explored the origin of the spatial representation of time along the sagittal axis.

As we have seen, previous studies employ many different stimuli (and diverging methods to investigate time-space mapping. In particular, there is scarce evidence and few studies in the literature that have dealt with the space-time mapping of personal and non-personal events along the timeline (for example, horizontal or sagittal). In addition to this, the mechanisms and nature of such representation are not well understood. Therefore, we still miss a deep understanding of the factors that may influence such a spatial representation. Whether these aspects are the same reported in Linguistic Hypothesis or Sensorimotor Hypothesis and Moving Ego (ME) will be one of the focuses of this thesis. Also, it is important to verify whether the ability to travel through time (Mental Time Travel) and time-space representation changes in lifespan. The hypothesis of this thesis is that event typology influences time-spatial mapping on the axis. With this in mind, personal events could be preferentially represented along the sagittal axis, because individuals can make direct and sensorimotor experience of them (e.g., walk to the future). Instead, non-personal events (e.g., historical events) could be preferentially represented along the horizontal axis, as this mapping may be related to the reading-writing system.

Therefore, in the second chapter, it will be explored the space-time representation of personal and non-personal events in Italian and English adult speakers along sagittal and horizontal space. A new methodology is introduced, concerning stimuli selection and devices employed in computerized task.

Furthermore, the careful selection was made of the stimuli with ad hoc survey administered to a sample designed, an aspect not considered in other previous studies. In the third chapter, the same topic is analysed using a pencil-paper task with timeline drawings in Italian speakers, i.e., the same sample of the first experiment. We tested whether the same space-time representation of personal and non-personal events recorded in the computerized task could also be obtained in this different task. In the fourth chapter, a study will investigate the origin and development of time and space association in Italian schoolchildren in both a motor and linguistic task (using the implicit association test). In the same chapter, a second study will assess the ontogeny of personal and non-personal events representation in schoolchildren native English will be presented. Here are numerous studies about children's space-time representation, but in most of the cases, they performed very difficult and different tasks. For instance, in most previous studies, the tasks employed required a considerable effort of visuospatial, motor, and working memory skills. Hence, the origin of the sagittal MTL will be explored in a sample of English children.

Chapter 2

Spatial representation of personal and non-personal memories in native Italian and English speakers

2.1 Introduction

Converging evidence points to a crucial role of reading and writing habits in the setting of the horizontal Mental Time Line (MTL) (Boroditsky, 2001). Accordingly, individuals from Western countries tend to associate past and future events with the left and right space, respectively (Nunez & Cooperride,2013; Tversky, Kugelmass, & Winter, 1991). In turn, the Mental Time Line seems to be oriented oppositely in those participants who read and write from right-to-left, such as in Hebrew speakers (Fuhrman & Boroditsky,2010). A similar effect of reading habits has been documented in the vertical space in Mandarin speakers, who show a top-to-bottom MTL (Boroditsky, Fuhrman & McCormick,2011; Casasanto & Boroditsky, 2007).

Interestingly, despite the great interest on the horizontal MTL, testified by a large number of studies published on this issue, in a broad range of cultures, time is often conceptualized on the sagittal space. Indeed, many languages share a prototypical spatial metaphor mapping past events with spatial locations beyond the body and future events with locations in front of it. This is reflected in some linguistic expressions, such as when encouraging someone else to *take a step* (in time) to reflect about some past events. According to the so-called 'Ego-Moving Metaphor', time would be conceived as a stationary line extended through the sagittal space with the speaker moving forward along it.

Empirical research in recent years has provided support to the view that this linguistic representation would be more than just a metaphorical mapping. That is, effects compatible with the direction of the MTL have been observed at the level of the motor system, using response-side compatibility tasks. For instance, Rinaldi et al. (2016) found a congruency effect in the sagittal axis between whole-body movements and words related to the past and the future. In particular, participants in this study were faster in responding to past-related words by making a step backward, whereas to future-related words by making a step forward. This corroborates the view that time is represented along with the sagittal space and that a Mental Time Line is activated at the level of motor output.

Interestingly, in these two representations of time (i.e., horizontal and sagittal), the participants' ego would 'view' the timeline (i.e., as referred to past and future times) from different perspectives. In particular, in the horizontal MTL, the ego may preferentially assume an external perspective on the time sequence, with the deictic center displaced to an external locus. On the contrary, in the sagittal MTL, the ego is inherently collocated with the moment "now" in the series. Unfortunately, despite these two different perspectives are taken for granted in different theoretical frameworks (Bender & Beller, 2014; Núñez & Cooperrider, 2013), no empirical study has so far explored whether the type of material at hand can facilitate the processing of time information along a privileged axis (i.e., horizontal or sagittal) and, hence, the adoption of such perspectives on the MTL. Here, we reasoned that the specific memory content processed during the task at hand might facilitate such observation. In particular, the processing of personal and non-personal information may elicit a preferential activation of the sagittal and horizontal MTL, respectively. In other words, it is likely that processing non-personal information may activate the horizontal space, as the ego primarily takes an external perspective when representing time on this spatial axis. In turn, the processing of personal information would be likely activated the sagittal space, as the ego here takes an internal perspective on the timeline.

In our study, therefore, we asked whether the type of information processed at hand (i.e., personal and non-personal events) affect the mental construction of the MTL in different spatial axes (i.e., horizontal and sagittal). Only one previous study has investigated whether associations between sequence time and sagittal space are sensitive to person-perspective, offering preliminary and indirect promising evidence to our hypothesis (Walker et al., 2017). In their study, indeed, Walker and colleagues (2017) reported that space-time mappings recruited for temporal relationship (e.g., earlier/later) involving 'her' were different than those recruited for 'your'. This suggests that the particular perspective from which a person interprets an event in time influences how the individual construes sequence time along the sagittal axis. On these grounds, here we explored the personal and non-personal events time-space mapping in a group of Italian adults. In this study, we asked whether adults represent personal and non-personal events differently, considering spatial mapping along the horizontal (left-right) or sagittal (forward-backward) axes. The underlying assumption is that personal events should be represented along the sagittal axis, which is centered on the body – that is, the ego - (Núñez & Cooperrider, 2013; Rinaldi, et al.,2016). Historical/public/non-personal events, however, should be represented on the horizontal axis, as they are not experienced directly, and further may be related to information mainly contained in texts, thus being referred to reading habits (Borodisky 2000; Tversky et al., 1991). In this chapter, two different studies will be presented. The first study involves Italian adult speakers; the second study aimed to replicate the first experiment on English adult speakers, using procedure slightly different response setting. In this chapter, the terms *Axis*, *Mapping*, or *Space* will be used as synonyms, and the same applies to the terms *Memory* and *Events*.

2.2 Preliminary pilot experiments

Before conducting the main experiments, two preliminary pilot experiments were performed. The first experiment aimed to validate the Makey Makey (Makey Makey LLC © 2012 -2018), a device that simulates a standard keyboard but allows keys to be freely put in space. Indeed, this device was then used in our main experimental task. Purpose of the second preliminary experiment was to select the stimuli for the main task, using an interview and an online survey. We decided to choose the (personal and non-personal) events precisely so that all participants would likely know the stimuli presented in the main task. We involved two different samples for each preliminary study.

2.2.1 First preliminary experiment: device validation

In this first preliminary experiment, participants had to perform manual movements along the sagittal and horizontal axes, moving their dominant arm forward and backward or right and left from a central starting position, respectively. Participants had to respond using both a standard computer keyboard and the Makey Makey device. This latter device is composed of sensors connected to an electronic circuit, which is itself connected through a USB cable to the laptop. In our study, the sensors were plugged on three metal plates positioned on a wooden board.

Materials and procedure

Participants

Fifteen Italian participants (10 females; mean age 22.87 ±1.89 years), all right-handed, were recruited at University of Milano-Bicocca among Ph.D. students and volunteers. All participants had normal or corrected visual acuity.

Procedure

The experiment was built using E-Prime, version 2.0 (Psychology Software Tools, Pittsburgh, PA, USA). Participants seated in front of a personal computer and had to indicate the direction of an arrow presented on the screen. Participants had to perform two blocks, one in which they had to answer utilizing the Makey Makey device, and another one through a standard keyboard. In the Makey Makey (Figure 1) condition had to release the starting point plate, move toward and press the right plate when the arrow pointed right, whereas they had to move toward and press the left plate when the arrow pointed left. In the other block, participants used keyboard button: key number 6 as the central starting key, key number 2 to answer when the arrow was oriented to the left and key number 0 when the arrow was pointing to the right. For each task condition, there was just one block of 30 trials each. Each arrow lasted on the screen for 1200 ms, but participants had no time limit for responding. After the participant's response, a

Figure 1. Makey Makey device.

blank screen was presented for 500 ms before another trial started. In both blocks, we measured accuracy (i.e., whether the direction of the movement was correct with respect to the arrow's direction), the time to release the starting sensor/button (Choice RT), and the time to press the second response sensor/button (i.e., computed from the release of the starting sensor/button; Answer RT). The order of conditions was counterbalanced between the participants.

Data analysis and results

No statistical analysis was performed on accuracy because participants obtained 99.55% of correct answers in the task performed with the Makey Makey and 99.77% of correct answers in the task performed using the keyboard. We carry out a dependent *t*-test using IBM SPSS Statistic 25 software to compare participants' reaction time recorded using Makey Makey device and Keyboard. No significant difference was found in Answer RT [t (14) =-.012, p = .991] between two devices: Makey Makey (M = 167.24, SD = 69.79) and Keyboard (M = 167.58, SD = 72.07) (Figure 2).

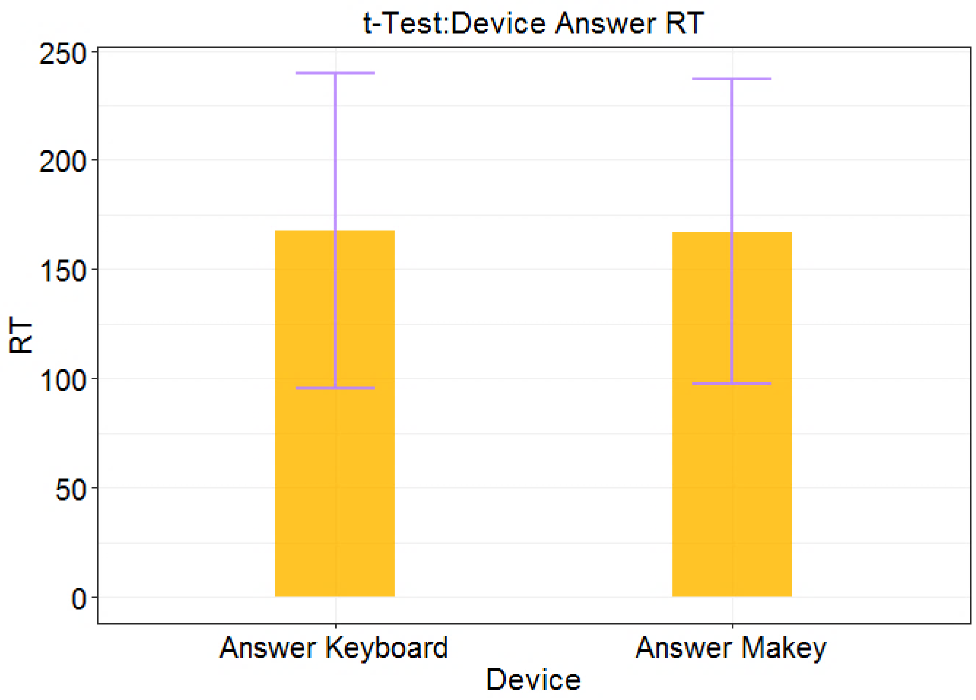

Figure 2. Makey Makey validation, t-Test results. Mean and SD of Answer RT recorded with Makey Makey and Keyboard.

The comparison on Choice RT almost reached significance [*t* (14) = -2,112, *p* = .053]: Makey Makey (*M* = 305.93, *SD* = 32.33) and Keyboard (*M* = 362.85, *SD* = 108.95) (Figure 3).The lower Choice RT in the Makey Makey condition, as compared to the standard Keyboard, may be related to the fact that with the former device (i.e., plates) participants only touched the plates (i.e., and hence not pressed the starting button). In other words, by pushing and releasing the central button, participants may have been slower with the keyboard than with the Makey Makey device. Therefore, the new device was considered reliable for our experiment, and we chose to use it.

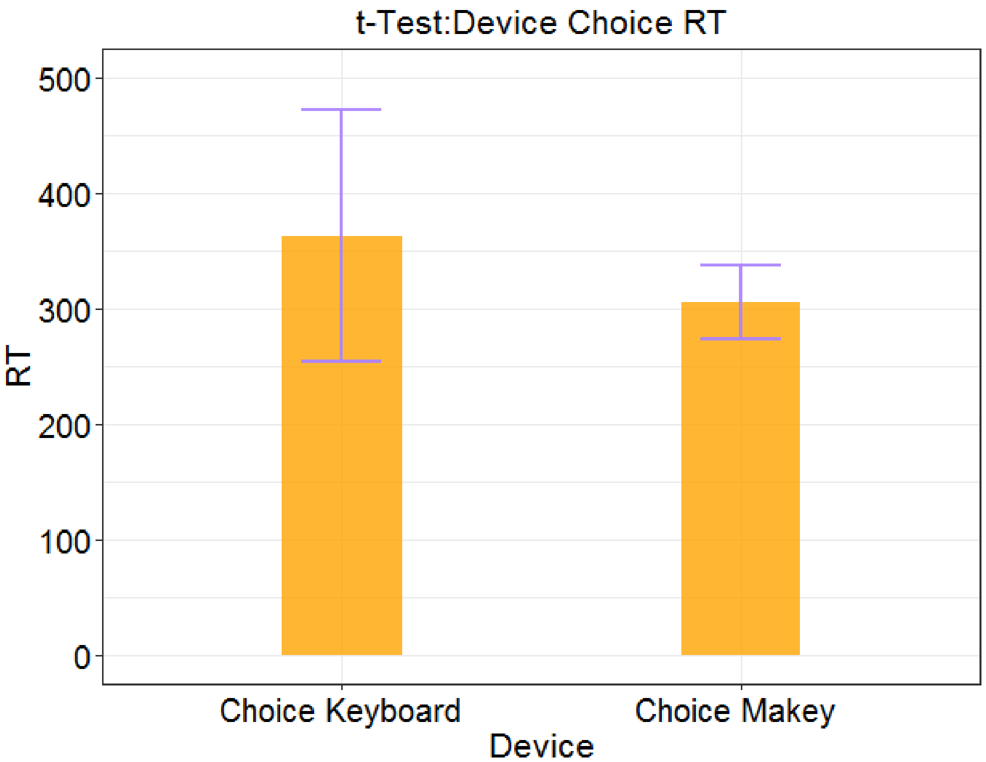

Figure 3. Makey Makey validation, t-Test results. Mean and SD of Choice RT recorded with Makey Makey and Keyboard.

2.3 First Experiment: spatial representation of personal and non-personal events in Italian adult speakers

2.3.1 Preliminary experiment: stimuli selection

We administered an interview first, and later a survey to select the most common and realistic personal and non-personal events. The aim of this selection was the reliability of the individual events so that the participants could remember them very well and consider them as probable events in the future.

Methods and Procedure

Participants

Ten university students (7 females, mean age 25.1 ± 2.17 years) took part to the interview and sixty university students (47 females; mean age 24.1 ± 3.07 years) were recruited for the events survey.

Task and Stimuli

Interview: We first asked participants to: "Write 10 historical events, that you remembered clearly, happened in Italy or around the world"; "Write 5 historical events that could happen in the future, in Italy or around the world"; "Write 5 significant autobiographical/personal events of your past"; "Write 5 autobiographical/personal events that may occur in your future". Non-personal events were carefully compared with the most important and significant events, reported in the newspapers and considering participants' age, and selected based on this rationale. For the future non-personal events, we picked them based on their likelihood to occur given current news and state of the art in general knowledge. Instead, personal events were chosen among the events that can commonly happen during the lifespan.

Survey procedure: after the interview, a survey was created and posted online through the Qualtrics Experience Management Software. In this survey, participants were asked to evaluate personal events that commonly happen during the lifespan, as well as non-personal events. For each event, they could rate how clearly they could remember the past events and how likely they will occur in the future on a 7-point

Likert scale (1 ‘Not at all’ to 7 ‘Extremely well’ to happen). For instance, for the personal past events we asked: “Based on your life experience, please indicate on a scale from 1 (Not at all) to 7 (Extremely well) how you remember each of the following events from your past" (see Appendix A). Participants were also asked to specify when these events happened in the past, or when they will supposedly occur in the future.

Data analysis and stimuli selection

We carried out a descriptive statistical analysis (frequency and average) of Likert values for each personal and non-personal event with SPSS Statistics 25. Only those events that obtained a Likert value between 4 (fair) and 6 (very good) were chosen. The stimuli referred to personal events did not contain possessive adjectives (e.g., last trip) and were selected based on the number of syllabus and letters, for both temporal references (e.g., First Exam/*Primo Esame* in the Personal memory experimental block and Last Sanremo/*Ultimo Sanremo* in the Non-Personal block). Forty-eight events, 24 personal and 24 non-personal, half of which referred to the past (6 targets and 6 distractors) and the other half to the future (6 targets and 6 distractors) (see Appendix B to consult the table of the stimuli).

2.3.2 Main study: Mental Time Line Task

To study Mental Time Line in the sagittal and horizontal space, we used a go/no-go paradigm to measure response time (RT) in a two-choice design. In particular, participants had to decide whether the presented event referred to the past or the future using two different movements (e.g., leftward and rightward in the horizontal plane, backward and forward in the sagittal plane). Whereas they had to refrain from answering to the non-relevant dimension (e.g., non-personal events when they were instructed to classify personal events and vice versa). In the first experiment involved Italian adults, we tested whether personal events and non-personal events influence MTL along the sagittal and horizontal axis. The hypothesis is that personal events should be represented along the sagittal axis, which is centered on the body – that is, the ego - (Núñez & Cooperrider, 2013; Rinaldi et al., 2016). Non-personal events, however, should be represented along the horizontal axis, as they are experienced directly, and further may be related to reading habits (Borodisky 2000; Tversky et al., 1991).

Methods and Procedure

Participants

Fifty-one university students (30 females; mean age 22.86 ± 1.95 years) took part in this first study. Participants were recruited through the School of Psychology undergraduate participants pool (SONA System) and received course credits for participation. Participants were randomly assigned to two experimental groups, depending on whether they were tested in the sagittal axis (15 females; 25 participants, mean age 22.64 ± 1.66 years) or the horizontal axis (16 females; 26 participants mean age 23.08 ± 2.21 years). Only two participants were excluded a-priori from the analyses, one of them was excluded because did not complete the experimental session, and the second was excluded as atypical outliers, reducing the sample from fifty-four to fifty-one. Participants signed a consent form before starting the experiment. All of them had normal or corrected-to-normal visual acuity. Manual laterality was assessed using the Edinburgh Inventory (Oldfield, 1971). Only three of them were classified as left-handers.

Task and Stimuli

Audio stimuli used in the task were recorded with a female voice, and employing Audacity®, the Free, Cross-Platform Sound Editor 2.2.1 (GNU General Public License). Participants performed the task blindfolded and seated in front of a personal computer. We opted for blindfolding participants to make the two conditions (e.g., horizontal and sagittal) as much comparable as possible. Indeed, the back plate in the sagittal space may be less visible as compared to the other plates (e.g., front, or left and right in the horizontal space), thus possibly interacting with the setting of any space-time association. A plywood board was connected with the Makey Makey sensors, and participants had to grasp in the non-dominant hand a sensor that turns on the device. As mentioned before, the Makey Makey device is composed of sensors connected to an electronic circuit. This circuit is connected using a USB cable to the laptop. Its sensors were connected to three metal plates (right, middle and left side for the horizontal condition; front, middle, back for the sagittal condition) on a wooden board (size 40x60 cm). The plates were squares of 8 cm per side; the distance of the central plate from the two sides was 18 cm per side. E-Prime version 2.0 was used to program the experiment and record the participants' responses. Participants were asked to indicate whether the event presented referred to the past (e.g., First Kiss/*Primo Bacio* (personal), Twin Towers/*Torri Gemelle* (non-personal)) or the future (e.g., Becoming Grandparents/*Diventare Nonni* (personal), African Pope/*Papa Africano* (non-personal)). Participants delivered their responses depending on the group to which they are randomly assigned.

The first group was instructed to move their arm horizontally in front of them to respond. The second group reacted with the board positioned alongside the sagittal space, in correspondence of their dominant arm. In both the two spatial axes, participants had to place their dominant hand on the central plate and move it to the right/left or forward/backward plate to respond, depending on the condition. Each participant had to perform four blocks of 48 trials each, two for each type of memory content (i.e., personal or non-personal). The two blocks per memory content could be congruent and incongruent. In the congruent condition, the past and the future were respectively associated with the left and right space for the horizontal mapping, whereas back and front for the sagittal mapping. In the incongruent condition, it was just reversed.

Each group performed the two conditions (i.e., congruent and incongruent) twice, with personal and non-personal events presented in separated blocks (i.e., for a total of 4 experimental blocks). In particular, in the personal event blocks, participants had to categorize only personal stimuli and refrain from answering to non-personal stimuli (i.e., distractors; N=12 per block). In the non-personal event blocks, participants had to categorize only non-personal stimuli and refrain from answering to distractors (i.e., personal stimuli). Distractors were different events than those used in the experimental conditions. Before each block participants performed a practice session, not blindfolded. The duration of each stimulus was 1300 ms, with an interstimulus interval of 500 ms, in the practice session, participants saw a point of fixation. The time limit to respond was set on 2500 ms. As in the first pilot experiment, we computed reaction times concerning time releasing the starting plate (Choice RT), and the time to press the second plate (i.e., computed from the release of the starting plate; Answer RT). We also computed accuracy, concerning whether the direction of the movement was correct about the task mapping. In the end, to explore the effects of the Time factor on the participants' RTs, we carried out another analysis.

Data Analysis

Reaction Time (RTs)

To analyze the data, we used Generalized Linear Mixed Models. In particular, the analysis was performed using the lme4 package (Bates, Mächler, Bolker, & Walker, 2015) in R environment (R Development Core Team, 2006). The within-subjects effects of Memory (Personal and Non-personal events), Congruency (Congruent and Incongruent), and the between-subjects effect of Mapping/Space (Horizontal and Sagittal) on the participants' Reaction Times (RT) were analyzed. All these independent variables were thus entered in the model as categorical predictors (i.e., fixed effects). Reactions times were normalized and converted to their logarithm-based value before entering them as the dependent variable. Further, trial, event, session (i.e., referred to whether participants performed the congruent or incongruent task as first) and subject were included in the analyses as random intercepts, as supported by a Likelihood Ratio Test for random effects variances.

We next tested the full model against a null model (i.e., only random effects) and selected the best model based on stepwise selection (backward elimination of non-significant effects). The best model was identified as the full model with all simple and interactive terms. Once the model was fitted, atypical outliers were identified and removed (employing 2.5 *SD* of the residual errors as a criterion). The models were then refitted to ensure that a few excessively influential outliers did not drive the results.

We found a significant effect of Congruency (F (1, 66) = 25.16, p < .001), with lower RTs for congruent (M = 3.12; SD = 0.01) than incongruent condition

Table 1. Summary table of significance related to main effects and interactions.

ANOVA Effects						
	Sum of Squares	**df**	**Mean Square**	**deDF**	**F**	**p**
Congruency	0.11	1	0.11	6649	25.16	0.001
Memory	0.07	1	0.07	1582	21.9	0.001
Congruency x Memory x Mapping	0.03	1	0.03	6648	7.9	0.049

(*M* =3.12, *SD* = 0.02). A significant effect was found as well for Memory (*F* (1, 22) = 15.83, *p* <.001), with lower RTs for Personal (*M* = 3.09; *SD* = 0.01) than non-personal (*M* = 3.15, *SD* = 0.01). Critically, we also found a 3-way interaction Congruency × Memory × Mapping (*F* (1, 66) = 7.93, *p* <.049) (Figure 4). Post-Hoc analysis was conducted using the phia package (De Rosario-Martinez et al, 2015) to explore whether a congruency effect was differently modulated by memory content and spatial axis. Results indicated a significant difference between the congruent (*M* = 3.09, *SD* = 0.02) and incongruent condition (*M* = 3.08, *SD* = 0.02) (p=.01) for processing non-personal events in the horizontal mapping (see Table 1 for all main effects and interaction).

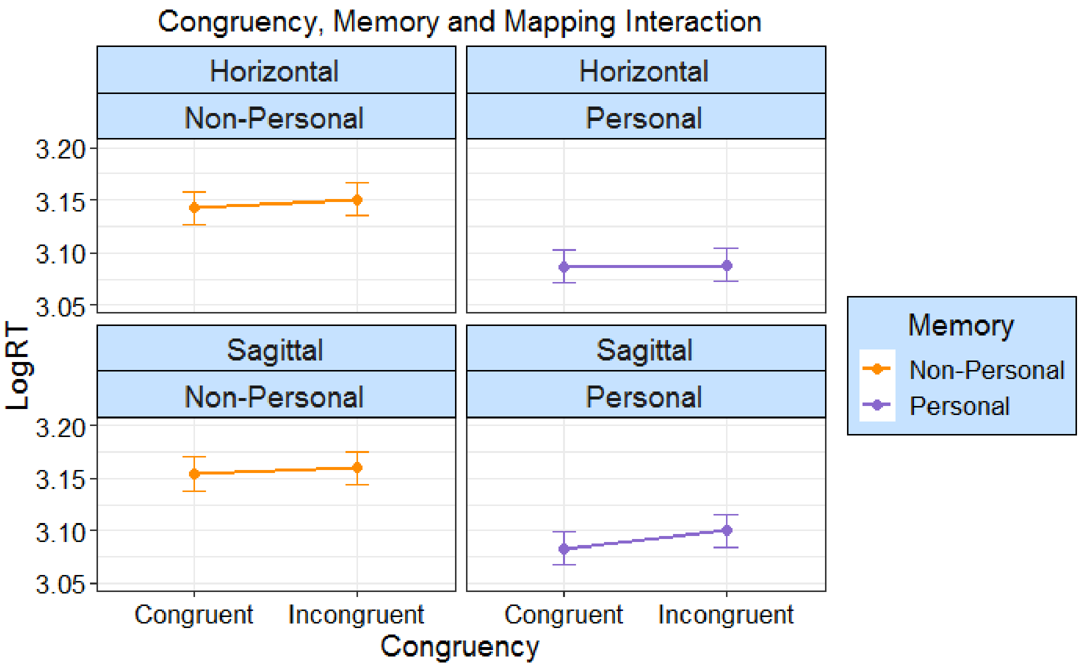

Figure 4. 3-way interaction Congruency × Memory × Mapping. Congruency effect in the horizontal mapping only for non-personal events, whereas in the sagittal mapping only for personal events.

Table 2. **Summary t*able of Fixed Effects of* Accuracy**.

	Fixed Effects			
	Estimate	**SE**	**z value**	**p**
Congruency	0.12	0.06	2.08	0.037
Memory	-0.22	0.12	-1.83	0.066

No difference was found between congruent (*M* = 3.09, *SD* = 0.02) and incongruent (*M* = 3.09, *SD* = 0.02) condition for personal events in the horizontal mapping. In other words, a congruency effect in the horizontal space was observed only for non-personal events. In turn, we found a significant difference between congruent (*M* = 3.15, *SD* = 0.02) and incongruent condition (*M* = 3.16, *SD* = 0.02) for processing personal events in the sagittal space (p=.001). No difference was found between congruent (*M* = 3.15, SD = 0.02) and incongruent (*M* = 3.16, *SD* = 0.02) condition for non-personal events in the sagittal mapping space. In the sagittal mapping, therefore, a congruency effect was found only for personal events.

Accuracy

We next analyzed the accuracy data. We used glmer function of the lme4 package to perform Mixed Effects Logistic regression to model binary outcome variables. The log odds of the outcomes are modeled as a linear combination of the predictor variables considering fixed and random effects. The variance component of each random factor reported in can be estimated. If the estimated variance components are larger than zero, than each random factor captures a significant variance component. The overall model was kept identical as for reaction times (i.e., the full model tested). The binary dependent variable was coded as 1 (correct responses) and 0 (wrong responses). Table 2 reports the Fixed effects, whereas (Figure 5) represents the data as a function of all conditions. Results of the binary logistic regression indicated that there was a significant effect of Congruency (p< .037), Congruent (*M* = 0.98, *SD* = 0.04) and Incongruent (*M* = 0.97, *SD* = 0.04). A tendency to significant effect was found in Memory factor (p>.066). Participants were correct in the congruent condition than incongruent and when they responded to personal events.

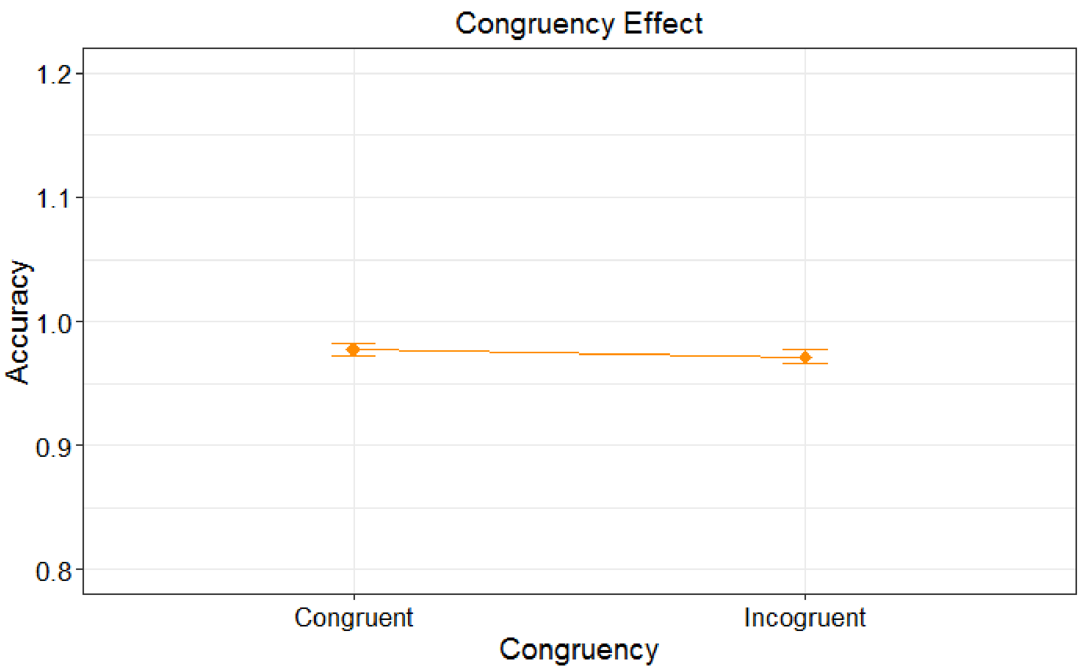

Figure 5. Accurate Answers of Congruency. Significant difference between congruent and incongruent condition.

A zoom on the congruency effect – Time Reaction Time (RTs)

To explore the effects of Time and the direction of Movement on the participants' RTs, we used Generalized Linear Mixed Models. We used the same procedure described in the previous analysis. We performed the analysis for each mapping/space condition, Horizontal, and Sagittal. The within-subjects effects of Time (past and future), Memory (personal and non-personal events), and the between-subjects effect of Movement (left/right or backward/forward) were analyzed. All these independent variables were thus entered in the model as categorical predictors (i.e., fixed effects). Reactions times were normalized and converted to their logarithm-based value before entering them as the dependent variable. Further, trial, event, session (i.e., session considers the order of personal and non-personal block in the congruent and incongruent condition in each mapping), and subject were included in the analyses as random intercepts, as supported by a Likelihood Ratio Test for random effects variances. We next tested the full model against a null model (i.e., only random effects) and selected the best model based on stepwise selection (backward elimination of non-significant effects).

The best model was identified as the full model with all simple and interactive terms. Once the model was fitted, atypical outliers were identified and removed (employing 2.5 *SD* of the residual errors as a criterion). The models were then refitted to ensure that a few excessively influential outliers did not drive the results.

In the Horizontal Mapping we found a significant effect in Memory (F (1, 21) = 15.61, p <.001), with lower RTs in personal events (M = 3.09; SD = 0.002) than non-personal (M = 3.15, SD = 0.01). Critically, we also found a 2-way interaction Time × Movement (F (1, 33) = 4.55, p=.02) (Figure 6).

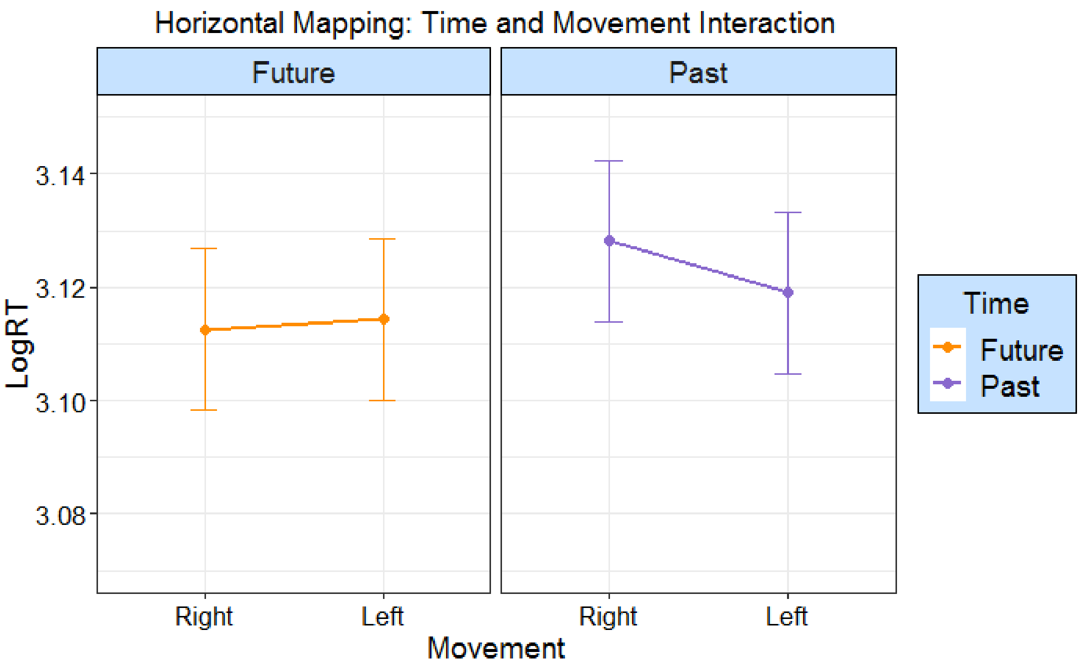

Figure 6. 2-way interaction Time × Movement. Participants recorded lower RTs to the right side for the future and left a side for the past.

Post-Hoc analysis was conducted using the phia package (De Rosario-Martinez, 2015) to explore whether a time effect was differently modulated by movement content. Results indicated a significant difference between the left movement (M= 3.13, SD 0.01) and right movement in the future condition (M = 3.12, SD = 0.01) (p=.02).

In the Sagittal Mapping we found a significant effect in Memory (F (1, 23) = 18.71, p <.001), with lower RTs for Personal (M = 3.09; SD = 0.01) than Non-Personal (M = 3.16, SD = 0.01). Critically, we also found a 2-way interaction Time × Movement (F (1, 32) = 32.62, p <.001) (Figure 7). Post-Hoc analysis was conducted to explore whether a time effect was differently modulated by movement content. Results indicated a significant difference between the forward movement (M = 3.13, SD = 0.003) and backward movement in the past condition (M = 3.12, SD = 0.01) (p=.001) and forward movement (M = 3.12, SD = 0.01) and backward movement in the future condition (M = 3.13, SD = 0.01) (p=.001).

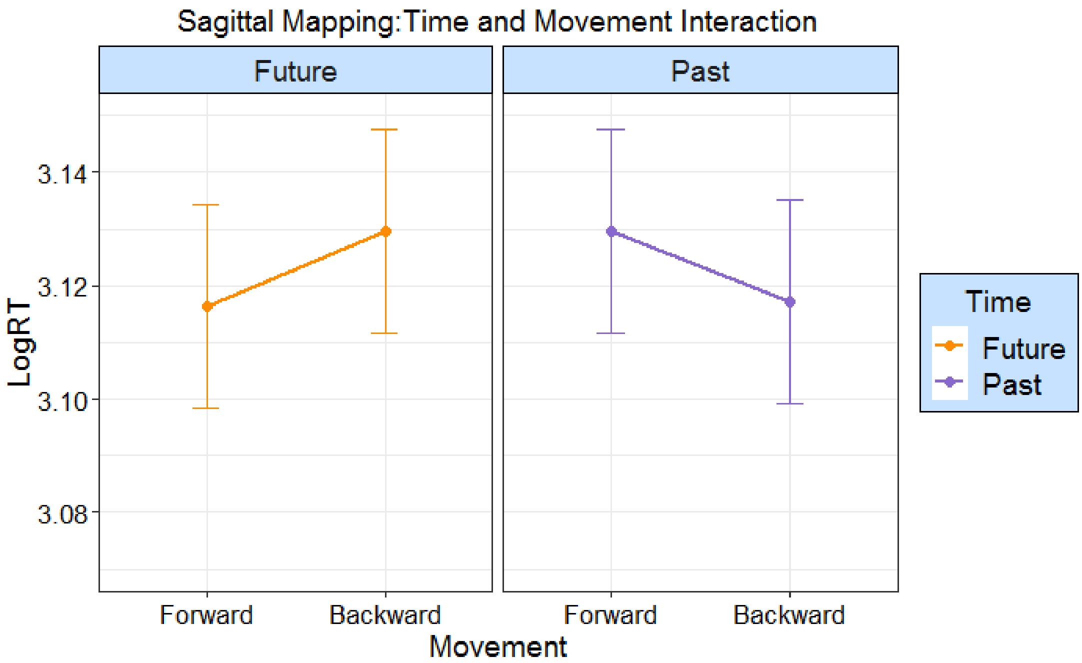

Figure 7. 2-way interaction Time × Movement. Participants recorded lower RTs forward for the future and backward for the past.

Therefore, these further analyses that consider the temporal component and the movement underline once again that the representations of events, personal and non-personal, find on the horizontal axis the past on the left and the future on the right side, while on the sagittal axis the past is backward and the future forward.

Vividness and Likelihood Survey analysis, results and discussion

At the end of the task, participants completed the ‘Events Vividness and Likelihood Survey’ presented through the Qualtrics Experience Management Software. In particular, they had to indicate using a 7-point Likert scale1 (not at all) to 7 (Extremely Well), how clearly, they could remember each personal or non-personal past event, and how likely an event will occur in the future each event (see Appendix C). This was done for each event presented during the experimental task. Descriptive Statistic Analysis of Likert points for each personal and non-personal event was calculated using SPSS Statistics 25 software. In particular, the average and the standard deviation of the past and the future Tense for each type of memory were calculated: future non-personal events (M = 5.37, SD = 1.55); past non-personal (M = 4.48, SD = 1.90); future personal (M = 5.58, SD = 1.23); past personal (M = 5.64, SD = 1.46). The purpose was to verify the reliability of the selected events regarding the vividness of the participants' memory and to verify any possible difference that may have affected the experimental task. Participants have indicated for future non-personal a Likert score of 5 (well), past non-personal of 4 (fairly), future personal of 5/6 (very well) and past personal of 5/6 (very well) (Figure 8).

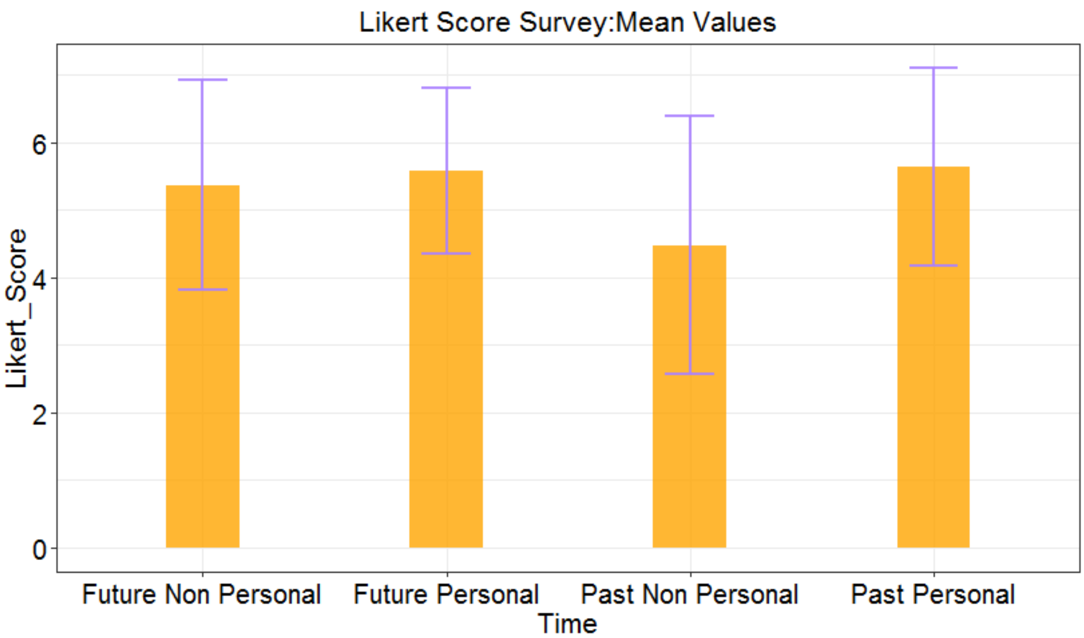

Figure 8. Mean and SD of Likert score about personal and non-personal events in ‘Vividness and Likelihood Survey’.

Afterward, we investigated whether the vividness of the memories and the ease or not to imagine a future event could influence the speed of reaction times. Therefore, a correlation analysis was performed between participants' reaction times differential score obtained in the Mental Time Travel task (i.e., the scores of the congruent condition were subtracted from the scores of the incongruent condition) and the Likert scores obtained in the survey, both the scores were converted in Z value. No correlation was found between the Likert scores and participants' reaction time.

2.3.3 Interim discussion

In this study, we explored whether the type of memory content to be processed at hand can exert an influence in the setting on the specific spatial axis onto which the Mental Time Line is mapped. Crucially, and according to our hypotheses, we found that the congruency effect was more pronounced for personal events in the sagittal axis than in the horizontal axis. In striking contrast, in the horizontal axis, we found a similar pattern of congruency effect, albeit in this case, for non-personal events representation. This speaks in favor of a dissociation between the horizontal and sagittal MTL as a function of the memory content to be contingently processed. In addition to this, we also found that personal events were responded much faster as compared to non-personal events. This pattern of results may depend on the facility (e.g., in terms for instance of familiarity and general knowledge) by which personal events are elaborated. Also, the analysis of Accuracy showed that the participants are more accurate in the congruent condition, as well as for personal events than non-personal. The analysis related to the effects of time and movement direction on the participants' RTs confirmed the differences between personal and non-personal memory on reaction times. Also, this analysis highlights that on the horizontal mapping, the participants were faster to move on the right for the future. On the sagittal axis, participants reacted faster when they moved the hand backward for the past and forward for the future. The questionnaire administered at the end of the experimental task confirmed that participants remembered and processed well the events presented in the experiment. It also indicates that participants considered possible that these events will occur in the future. Most critically, ruled out the possibility that vividness and likelihood of the events could influence the reaction time and the space-time mapping observed in the experimental task. Indeed, no correlation was found between the questionnaire and the strength of the congruency effect. This further corroborates the possibility that the observed findings are related explicitly to the space-mapping representation of memories.

To sum up, our results suggest that personal events preferentially trigger space-time mapping in the sagittal axis. This may be because participants are adopting an egocentric perspective on the temporal sequence: the ego (body) will be inherently collocated with the moment ‘now’, with the past behind and the future in front. In turn, the preferential activation of the horizontal MTL for non-personal events may be linked to reading-writing habits. Non-personal events, like the ones employed in this study, are indeed often learned by text and the ego may take an external perspective on the series.

2.4 Second experiment: spatial representation of personal and non-personal events in English adult speakers

As specified previously, empirical research has provided support to the view that this linguistic representation would be more than just a metaphorical mapping. That is, effects compatible with the direction of the MTL have been observed at the level of the motor system, utilizing response-side compatibility tasks. In many cultures, time is often conceptualized along with the sagittal space and their prototypical spatial metaphor map past events with spatial locations beyond the body and future events with locations in front of it. This is reflected in some linguistic expressions, such as when encouraging someone else to take a step (in time) to reflect about some past events. According to the so-called ‘Ego-Moving Metaphor’, time would be conceived as a stationary line extended through the sagittal space with the speaker moving forward along it.

Therefore, the second experiment involved English adult speakers; we tested whether personal events and non-personal events influence MTL along the sagittal and horizontal axis. Like in the first experiment the hypothesis is that personal events should be represented along the sagittal axis, which is centered on the body – that is, the ego - (Núñez & Cooperrider, 2013; Rinaldi et al., 2016). Non-personal events, however, should be represented along the horizontal axis, since they have not been experienced directly, and further may be related to reading habits (Borodisky 2000; Tversky et al., 1991).

2.4.1 Preliminary experiment: stimuli selection

As in the first experiment, we conducted an events survey to select the personal and non-personal events to use in the computerized task, involving English speaker participants. The survey aimed to choose the most common and realistic personal and non-personal events in English and Irish culture.

Participants

Thirty-eight university students and adults (13 females, mean age 30 ± 9.89 years) took part in the events survey.

Procedure

We created a survey Qualtrics Experience Management Software. Participants were asked to evaluate some events (personal and non-personal) using a 7-point Likert scale (0 'Not at all'; 7 'Extremely well'). The scores indicated how clear they could be remembered the past events and how likely they will be occurring in the future. Like in the first experiment, personal events were selected as commonly happening during the lifespan, and non-personal events were famous and important events read on newspapers or listened to in the tv news.

Further, in the second part of this survey, we asked to specify how long-ago these events happened in the past, or when they will occur in the future. The survey included eight questions, four regarding personal events and four regarding non-personal events (see Appendix D). The events were different than those used Italian survey; they were selected based on the sample considering cultural differences and Ethics Commitment approval.

Data analysis and stimuli selection results

We compute descriptive statistics for each personal and non-personal with SPSS Statistical software. Events that obtained a Likert value between 4 (fairly) and 6 (very well) were administered in the computerized task. Forty-eight evens, 24 personal (e.g., Last Day at School, Buy New Car) and 24 non-personal(e.g., Next Olympic Games, Brexit Referendum), half of which referred to the past (6 targets and 6 distractors) and the other half to the future (6 targets and 6 distractors) were selected (see Appendix E).

2.4.2 Main Study: Mental Time Line Task

Methods and procedure

Participants

Forty-nine native English adult speakers (21 males, mean age of 29.27 ± 8.96 years) were recruited. Participants were recruited through social media such as Facebook. The participants were counterbalanced in the two experimental groups with the two different task condition, in analogy to Experiment 1: sagittal (25 participants) and horizontal space (25 participants). Participants signed a consent form before starting the experiment. All participants had normal or corrected-to-normal visual acuity. Manual laterality was assessed using the Edinburgh Inventory (Oldfield, 1971): only three of them were classified as left-handers.

Task and stimuli

After having selected the stimuli, audio stimuli used in the task were recorded with a female voice, and employing Audacity®, the Free, Cross-Platform Sound Editor 2.2.1 (GNU General Public License) like in the first experiment. Compared to the Italian sample who performed the experiment seated, however, here participants performed the experiment standing. Also, participants were blindfolded and wore headphones. They were asked to indicate whether the event presented referred to the past (e.g., Last Day at School/Obama's Election) or the future (e.g.,

Figure 9. Arduino device and slider used to perform the experiment. Size 22x95 cm.

Retirement/Queen Elizabeth's Death). The experimental design was overall identical to the first experiment. In this case, responses were recorded using a slider instead of the keyboard (see Figure 9), developed specifically for this study at the Development Lab of Queen's University Belfast. This device is made up of a metal bar with three sensors, on the left side, on the right side, and in the middle (if considered as aligned in the horizontal space). Participants moved the lever centrally positioned on the bar, to touch and activate the sensors. This hardware was built and programmed with the aid of an Arduino electronic board and software and connected to the computer. Arduino is made up of a microcontroller, an analog, a digital pin signals, a flash memory, and a USB serial port. Before each stimulus, participants heard a sound ("beep") that activated this system. The slider was locked in the middle and was automatically unlocked by the Arduino system after the beep. Participants moved the slider and touched the sensors, and this allowed the system to record the answers. E-Prime software version 2.0 (Psychology Software Tools, Pittsburgh, PA, USA) was used to record the participants' responses. The group performing the task in the horizontal axis moved the lever along a metal groove positioned horizontally in front of them to respond. The group performing the task in the sagittal axis task responded with the metal groove positioned alongside them (i.e., sagittal axis).

Participants' reaction times were measured by considering) the time to move the lever away from the starting position (Choice RT) and the time taken to complete the movement and to reach the lateral sensor (Answer RT). As in Experiment 1, we also recorded accuracy. The overall design was the same adopted for the first experiment. The duration of the stimuli was set to 1300 ms, with an interstimulus interval of 5100 ms. Time to answer was set to 2500 ms. We computed reaction times concerning time releasing the starting plate (Choice RT), and the time to press the second plate (i.e., computed from the release of the starting plate; Answer RT). We also computed accuracy, concerning whether the direction of the movement was correct about the task mapping. We finally performed analysis with age as a covariate to evaluate the trend of RT as a function of age. At the end, to explore the effects of the Time factor on the participants' RTs, we carried out another analysis.

Data analysis

Reaction Time (RTs)

In analogy to Experiment 1, to analyze the data, we used Generalized Linear Mixed Models. In particular, the analysis was performed using the lme4 package (Bates et.al, 2006) in an R environment (R Development Core Team, 2006). The within-subjects effects of Memory (personal and non-personal events), Congruency (congruent and incongruent), and the between-subjects effect of Mapping/Space (horizontal and sagittal) on the participants' Reaction Times (RTs) were analyzed. All these independent variables were thus entered in the model as categorical predictors (i.e., fixed effects). Reactions times were normalized and converted to their logarithm-based value before entering them as the dependent variable. Further, trial, event, session (i.e., session considers the order of personal and non-personal block in the congruent and incongruent condition in each mapping) and subject were included in the analyses as random intercepts, as supported by a Likelihood Ratio Test for random effects variances. We next tested the full model against a null model (i.e., only random effects) and selected the best model based on stepwise selection (backward elimination of non-significant effects). The best model was identified as the model with simple effects (i.e., Congruency, Memory, Space) and the interactive term Congruency x Space. Once the model was fitted, atypical outliers were identified and removed (employing 2.5 *SD* of the residual errors as a criterion). The models were then refitted to ensure that a few excessively influential outliers did not drive the results.

We found a significant effect of Congruency (F (1, 58) = 18.69, p < .001) indicating that participants were faster in the congruent (M = 3.15; SD = 0.01) as compared to the incongruent (M = 3.16; SD = 0.01) condition. A significant effect of Memory was also observed (F (1, 21) = 35.17, p < .001), with faster reaction times for personal (M = 3.13, SD = 0.01) than non-personal events (M = 3.19; SD = 0.01)

Table 3. **Summary table of significance related to main effects and interactions.**

ANOVA Effects						
	Sum of Squares	**df**	**Mean Square**	**deDF**	**F**	**p**
Congruency	0.11	1	0.11	5762	18.68	0.001
Memory	0.21	1	0.21	21	35.17	0.001
Congruency x Mapping	0.12	1	0.12	5761	20.13	0.001

(Figure 10). Critically, we also found a 2-way interaction Congruency × Mapping (*F* (1,58) =20.13, *p* <.001). Post-Hoc analysis using the phia R package (De Rosario-Martinez, 2015), unveiled that only in the sagittal space the Congruent condition (*M* = 3.14; *SD* = 0.01) was faster than the incongruent one (*M* = 3.16; *SD* = 0.01) (*p* < .001). On the contrary, in the horizontal space the congruent condition (*M* = 3.17; *SD* = 0.003) did not differ from the incongruent one (*M* =3.17; *SD* = 0.01) (p=0.9). That is, a congruency effect was only observed in the sagittal space (Figure 11) (see Table 3 for all main effects and interaction).

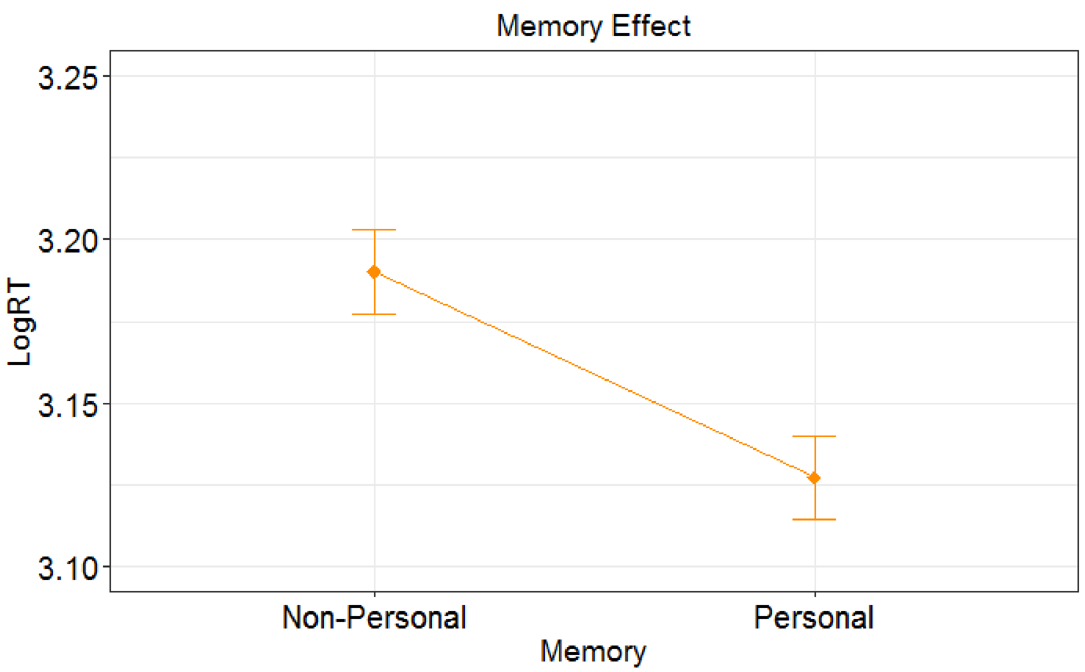

Figure 10. **Memory Effect.** Participants reacted faster to Personal Memory than Non-Personal Memory. Personal (M = 3.13, SD = 0.01) and Non-Personal events (M =3.19; SD =0.01).

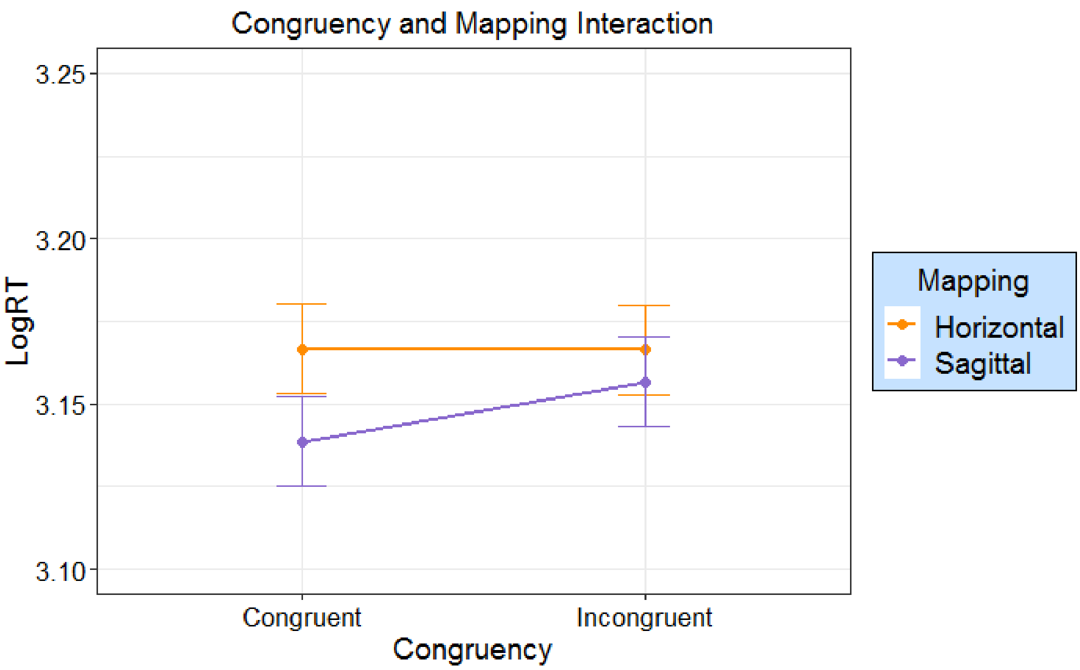

Figure 11. Congruency × Mapping Interaction. Results showed a congruency effect only in the sagittal mapping, but not in the horizontal one.

We finally performed a Linear Mixed Model with age as a covariate, whereas Subject, Trial, Item, Session as random intercepts. Participants in this experiment, indeed, had an average age of 29.27, but the range was wide, spanning from 19 to 48. Results showed that there was a tendency toward significance for the effect of age (t = -1.84, p = .07) (see Table 6). That is, older adult participants responded and classified faster the events compared to younger. Figure 12 shows the decreasing trend of RT as a function of age.

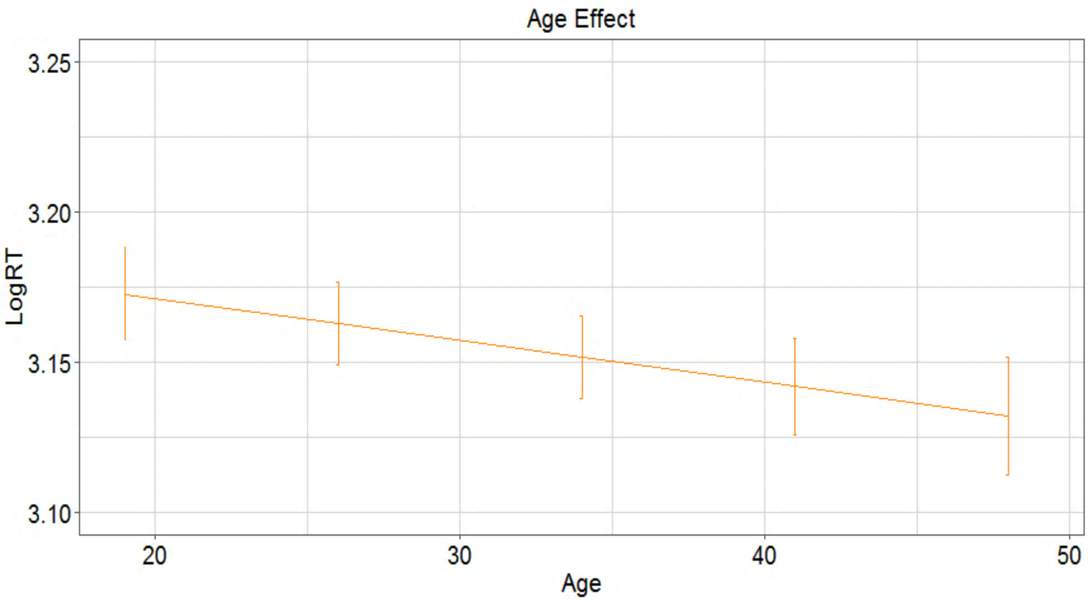

Figure 12. Reaction Times as a function of Age. Adult participants responded faster than younger participants to the temporal events.

Table 4. Accuracy data. Significant fixed effects table.

	Fixed Effects			
	Estimate	SE	z value	p
(Intercept)	3.84	0.3	13.16	0.001
Memory	-0.92	0.23	- 4.04	0.001

Accuracy

To analyze the accuracy of the participants' responses, as for the Italian sample, we used a generalized linear mixed model. We used glmer function of the lme4 package to perform Mixed Effects Logistic regression to model binary outcome variables. The log odds of the outcomes are modeled as a linear combination of the predictor variables considering fixed and random effects. We found only a main effect of Memory ($p< .001$), personal ($M = 0.99$, $SD = 0.03$) and non-personal ($M = 0.95$, $SD = 0.02$). Participants were more accurate when they had to respond to personal events (Figure 13), as compared to non-personal events. Values of significant fixed effects are shown in Table 4.

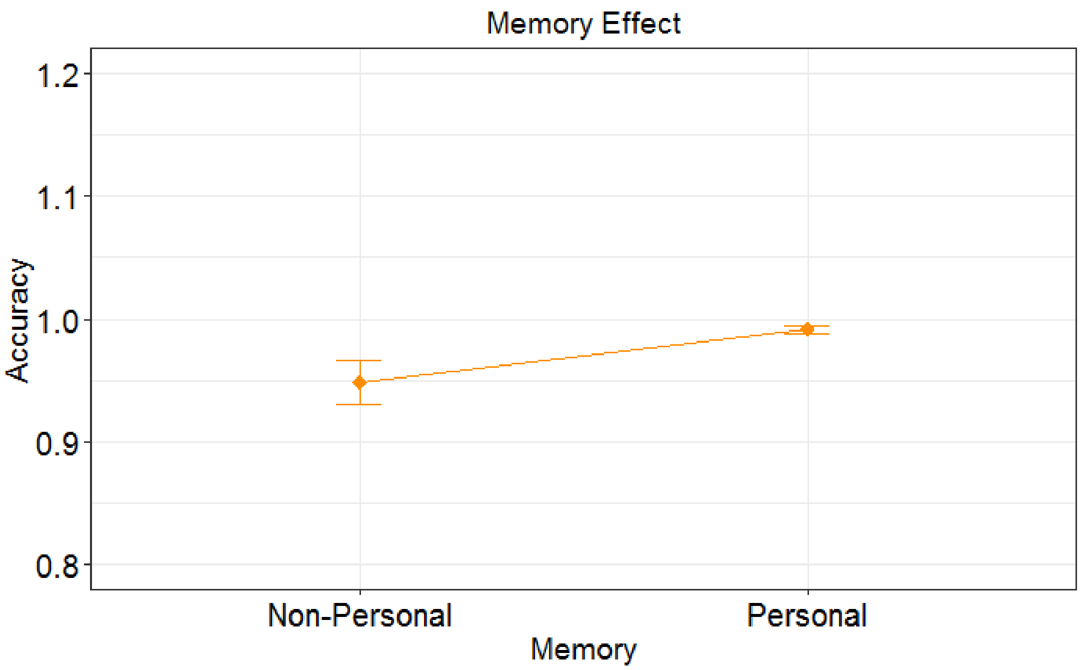

Figure 13. Accuracy of Answers. Memory. A significant difference between the processing personal and non-personal memory. Participants are more accurate in personal memory.

A zoom on the congruency effect – Time Reaction Time (RTs)

To explore the effects of Time and the direction of Movement on the participants' RTs, we used Generalized Linear Mixed Models. We used the same procedure described in the previous analysis. We performed the analysis for each mapping/space condition, Horizontal, and Sagittal. The within-subjects effects of Time (past and future), Memory (personal and non-personal events), and the between-subjects effect of Movement (left/right or backward/forward) were analyzed. All these independent variables were thus entered in the model as categorical predictors (i.e., fixed effects). Reactions times were normalized and converted to their logarithm-based value before entering them as the dependent variable. Further, trial, event, session(i.e., session consider the order of personal and non-personal block in the congruent and incongruent condition in each mapping) were considered random effects, and subject were included in the analyses as random intercepts, as supported by a Likelihood Ratio Test for random effects variances.

We next tested the full model against a null model (i.e., only random effects) and selected the best model based on stepwise selection (backward elimination of non-significant effects). The best model was identified as the full model with all simple and interactive terms. Once the model was fitted, atypical outliers were identified and removed (employing 2.5 *SD* of the residual errors as a criterion). In the Horizontal Mapping we found a significant effect for Memory (F (1, 21) = 36.71, p <.001), with lower RTs for personal (M = 3.13; SD = 0.01) than non-personal (M = 3.20, SD = 0.01) and a 2-way interaction Movement × Memory (F (1, 21) = 6.30, p =.01) (Figure 14).

Post-Hoc analysis was conducted using the phia package (De Rosario-Martinez et al.,2015) to explore whether a time effect was differently modulated by movement content. Results indicated a significant difference between the left movement (M = 3.14, SD = 0.01) and right movement in the personal memory (M = 3.13, SD =0.01) (p=.01).

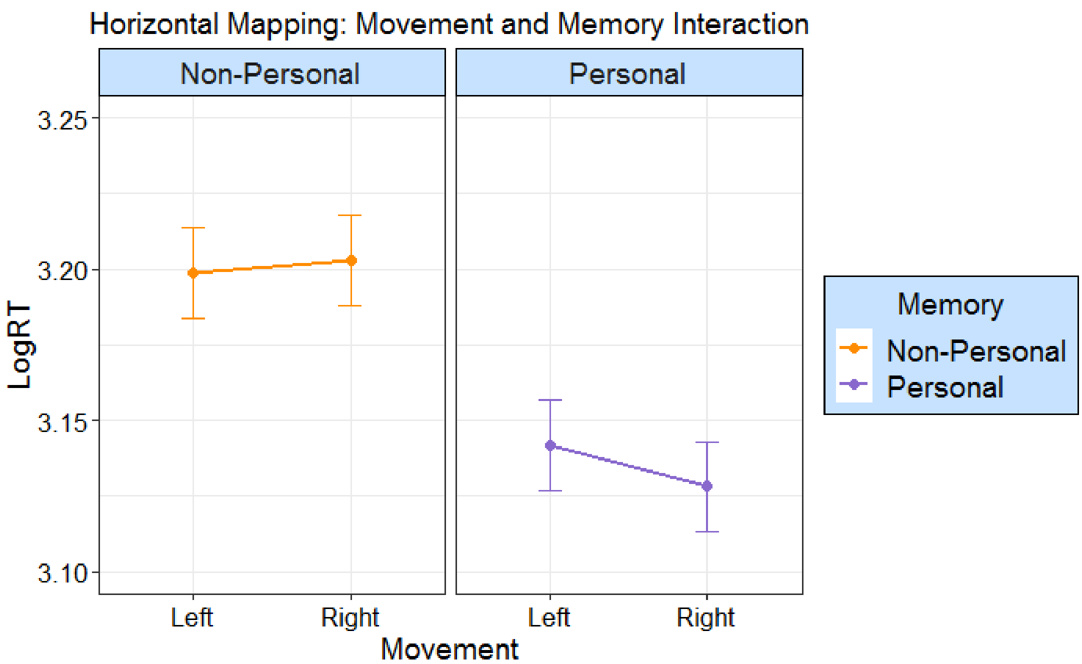

Figure 14. 2-way interaction Time × Movement in Horizontal Mapping.

In the Sagittal Mapping we found a significant effect for Memory (F (1, 19) = 44.67, p <.001), with lower RTs for personal (M = 3.12; SD = 0.01) than non-personal (M = 3.18, SD = 0.01). Critically, we also found a 2-way interaction Time × Movement (F

(1, 29) = 40.43, *p* <.001) (Figure 16). Post-Hoc analysis was conducted to explore whether a time effect was differently modulated by movement content. Results indicated a significant difference between future backward (*M* = 3.16, *SD* = 0.01) and past backward (*M* = 3.14, *SD* =.01) (p=.008) (Figure15).

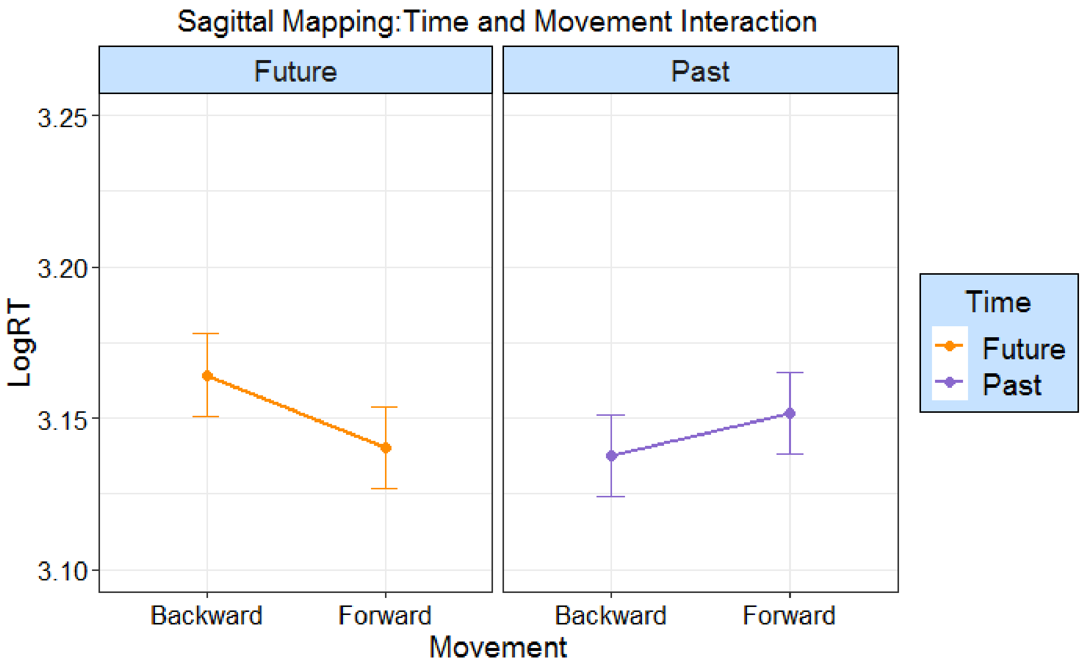

Figure 15. **2-way interaction Time × Movement** in the Sagittal Mapping.

The two last analysis showed how time modules differently the movement in the horizontal and in sagittal space. The movement underline once again that the representations of events, personal and non-personal, find on the horizontal axis the past on the left and the future on the right side, while on the sagittal axis the past is backward and the future forward.

Vividness and Likelihood Survey

As for the Italian sample, English participants at the end of the experiment completed the 'Events Vividness and Likelihood Survey' for each event presented using Qualtrics Experience Management Software (please see Appendix F). In particular, they indicated using a 7-point Likert scale (Not at all) to 7 (Extremely well), how clearly, they could remember each personal or non-personal past event, and how likely they could imagine each future event. A Descriptive Statistic Analysis of Likert points for each personal and non-personal event using SPSS Statistics 25 software was carried out (Figure 16).

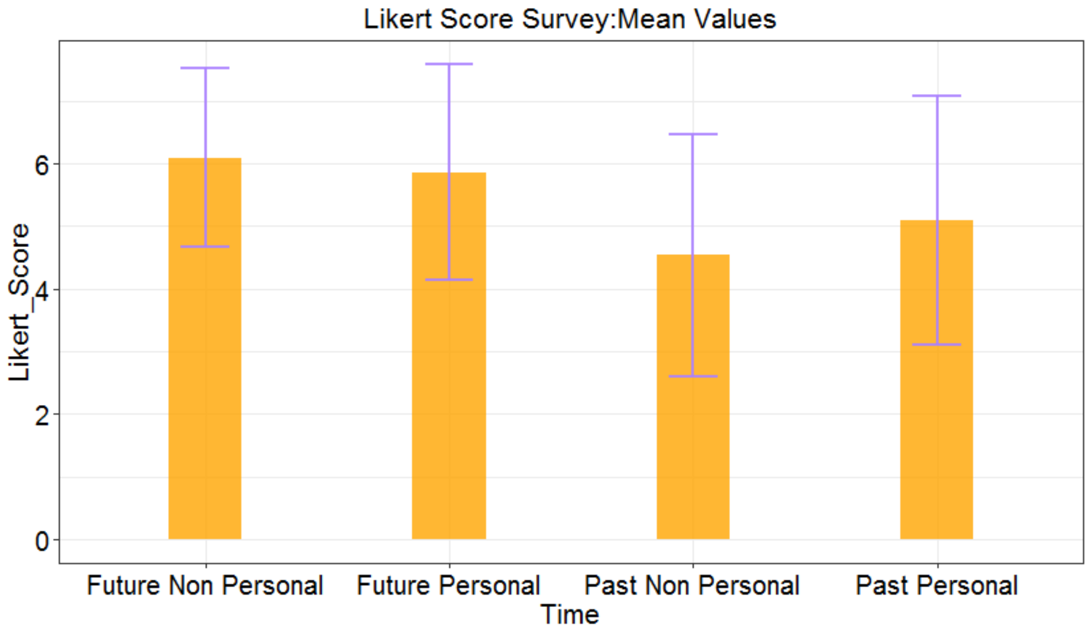

Figure 16. Mean and Standard Deviation of Likert score about personal and non-personal events in "Vividness and Likelihood Survey."

The mean values for each condition were: future non-personal events (M = 6.08, SD = 1.43); past non-personal (M = 4.53, SD = 1.94); future personal (M = 5.86, SD = 1.72); past personal (M = 5.09, SD = 1.98). Participants remember very well future non-personal events, fairly/well past non-personal events, very well/extremely well future personal events and well past personal events. The aim was to verify the reliability of the selected events regarding the vividness of the participants' memory and their likelihood to happen in the future. Afterward, like in the first experiment, we investigated whether the vividness of the memories and the ease or not to imagine a future event could influence the speed of reaction times. Therefore, a correlation analysis was performed between participants' reaction times differential score obtained in the Mental Time Travel task (i.e., the scores of the congruent condition were subtracted from the scores of the incongruent condition) and the Likert scores obtained in the survey, both the scores were converted in Z value. No correlation was found between the Likert scores and participants' reaction time.

2.4.3 Interim discussion

Native English speakers performed the experiment standing and blindfolded. We found a congruency effect only for the sagittal space, but not for the horizontal one. Memory did not modulate such a congruency effect, thus in contrast to what has been observed in Experiment 1. Further, participants were faster to respond to personal events than non-personal events, in analogy to what found in the Italian group. Finally, Also, the analysis of Accuracy showed that the participants are more accurate in the congruent condition, as well as for personal events than non-personal. The analysis related to the effects of time and movement direction on the participants' RTs confirmed the differences between personal and non-personal memory on reaction times in particular on the sagittal axis. Also, this analysis highlights that on the horizontal mapping, the participants were faster to move on the right for personal event. On the sagittal axis, participants reacted faster when they moved the hand backward for the past and forward for the future. The questionnaire administered at the end of the experimental task confirmed the Experimental 1 result and that participants remembered and processed well the events presented in the experiment. It also indicates that participants considered possible that these events will occur in the future. Most critically, ruled out the possibility that vividness and likelihood of the events could influence the reaction time and the space-time mapping observed in the experimental task. Indeed, no correlation was found between the questionnaire and the strength of the congruency effect. This further corroborates the possibility that the observed findings are related explicitly to the space-mapping representation of memories. In conclusion, this experiment only partially replicates the previous one. These differences may depend on some variations in the experimental paradigm used (i.e., device and body posture), as discussed in the next section.

2.5 General Discussion

In this chapter, we explored whether the specific memory content processed during the task at hand may affect the particular spatial frame of reference onto which time is represented. In particular, we reasoned that the processing of personal and non-personal information might elicit a preferential activation of the sagittal and horizontal MTL, respectively. Indeed, the processing of personal events may facilitate the setting of the horizontal MTL, as the ego primarily takes an external perspective when representing time along this spatial axis. In turn, the processing of personal information may preferentially activate the sagittal space, as the ego here takes an internal perspective on the timeline obligatorily. In the first and second studies presented here, we thus considered two different types of memory events, personal life events, which happen commonly in people's life and non-personal events, such as popular public events. Results of the first study corroborated our hypothesis, with a space-time mapping for non-personal/public events observed only along the horizontal axis, whereas a space-time mapping for personal events was found only along the sagittal axis. The former MTL, spanning along the horizontal plane, may be well interpreted as originating from textual knowledge and from the reading and writing system direction (i.e., that follows a left-to-right orientation in Western languages). Our findings thus point to a role of memory content, in that non personal events may be primarily conceived from an external perspective, thus leading to the activation of the horizontal MTL (Boroditsky, 2007); (Tversky et al., Winter, 1991; Nunez & Cooperride,2013; Fuhrman & Boroditsky,2010) On the other hand, we observed that only personal elicited an MTL along the sagittal axis. This may be related to the fact that in the sagittal space we obligatory take an egocentric perspective on the time series. Such an egocentric perspective may, therefore, be reinforced when the memory content to be processed itself personal (i.e., or egocentric) rather than non-personal. Accordingly, the ego-moving metaphor of time maintains that time may be conceived as a stationary line, with the ego-moving forward (i.e., in time, but implicitly also in space, given the spatial nature of this construal) along with it. Together, therefore, findings from the first study converge with prior evidence (e.g., Walker et al., 2017), highlighting the possible role of the particular perspective from which a person interprets an event in the construal of the

MTL. They further indicate that the memory content processed at hand may influence the activation of different spatially organized MTLs.

In a second study, we then aimed to replicate such a pattern of results, by an English-language group in a similar paradigm. In this study, however, we only found evidence for a space-time association o along the sagittal axis for personal events. In striking contrast, no congruency effect was observed in the horizontal space. Further, no modulation of the type of memory content was found, thus different from the first study.

This may be related to the fact that, in line with previous studies, we found longer reaction times in non-personal events than personal events (Anelli et al., 2016). Such facilitation in processing personal events may have also affected the preferential setting of the sagittal MTL. However, similar facilitation was also observed for the first study, thus making this interpretation unrealistic.

To account for the different pattern of results across studies, we rather pinpoint that such differences may depend on some variations in the experimental paradigm used: the device used, and the body posture adopted First, the device used across studies were different. Indeed, the device used in the first study (i.e., Makey Makey) required participants to perform discrete movements. That is, they had to release the central plate and then making free movements toward the lateralized (i.e., left and right, back, and front) plates for classifying the events. Hence, the response setting was dichotomous, and this may have promoted the setting up of space-time association. On the contrary, in the second study, the device required participants to move the lever from a central position to the extreme ends of the bar. Such a device (see for a similar device Ulrich & Maienborn, 2010), forcing participants to make continuous movements, may have negatively affected the setting up of dichotomous space-time associations. This is particularly relevant in the case of the horizontal space, where the adoption of an external perspective on the sequence may be more related to a dichotomous response setting. Accordingly, a congruency effect was observed in the sagittal space in both studies: in this case, thus, continuous movements may be easily integrated with the egocentric perspective. As an additional difference between devices, we also note that the distances from the central position to the lateral ones were not equal in the two studies (i.e., the size of the slider used in Experiment 1 was 22x95 cm. Instead, the Makey Makey was connected to the wooden board (size 40x60 cm, the plates were squares of 8 cm per side; the distance of the central plate from the two sides was 18 cm per side).

The more considerable distance in the second study and the relative enhanced biomechanical efforts in responding through arm movement may have as well affected the observed dissociation.

Second, whereas participants performed the study seated in the first study, they were standing in the second study. The standing body posture in the second study may have enhanced the adoption of an egocentric perspective and, thus, the activation of the sagittal MTL. Indeed, the ego-moving metaphor of time implies a standing speaker moving (i.e., or rather walking) along a stationary line.

Also, in Experiment 1 and Experiment 2, the analysis of Accuracy showed that the participants are more accurate in the congruent condition, as well as for personal events than non-personal. Also, Experiment 2 shows that older participants were overall faster than younger participants, likely because they have more experience (e.g., textual) and thus better representation of the presented events. The analysis related to the effects of time and movement direction on the participants' RTs confirmed the differences between personal and non-personal memory on reaction times in both the experiments. Also, this analysis highlights that on the horizontal mapping, the participants were faster to move on the right for the future. On the sagittal axis, participants reacted faster when they moved the hand backward for the past and forward for the future. No differences between past and future reaction time were found, as highlights in Anelli at all, 2016. The questionnaire administered at the end of the experimental task confirmed that participants remembered and processed well the events presented in the experiment. It also indicates that participants considered possible that these events will occur in the future. Most critically, ruled out the possibility that vividness and likelihood of the events could influence the reaction time and the space-time mapping observed in the experimental task. Indeed, no correlation was found between the questionnaire and the strength of the congruency effect. This further corroborates the possibility that the observed findings are specifically related to the space-mapping representation of memories.

Taken together, these studies offer partial evidence for a modulation of the memory content to be processed on the specific activation of horizontal and sagittal MTL. The former MTL would be mainly triggered by personal events, while the latter by non-personal events. This points to a possible role of the frames of reference (i.e., egocentric vs. allocentric) in the setting of the spatial representation of time along these two axes.

Chapter 3

Personal and non-personal events representation on the Mental Time Line in a pencil-paper task.

3.1 Introduction

People seem to have multiple representations of ordinal information, such as number and time, which undergo profound changes in lifespan in relation to their experience. As mentioned in Chapter 1, the association between temporal information and imaginative space led to the hypothesized the existence of a Mental Time Line (MTL) (Di Bono et al., 2012; Bonato et al., 2012; Magnani et al., 2011). A similar construal is the so-called Mental Number Line (MNL), which is meant to be a representation of numerical information and which would take the form of a left-right or right-left continuum, dependent on reading-writing habits. The spatial-numerical association of response is described as an index of automatic access to the spatial representation of the numerical quantity (Dehaene,1992; Chinello, de Hevia, Geraci, & Girelli, 2012; Vicario, et al.,2008). As described above, this effect relies on cultural practices. For instance, Zebian (2005) suggested that the MNL is reversed in cultures where reading and writing proceeds from right-to-left.

Evidence about the association between numbers and space can be observed in patients with parietal lesions. In a task requiring participants to bisect numeric intervals, Zorzi et al. (2002) have found that the patients with neglect tend to provide larger answers as compared to the objective midpoint, which is thus analogous to a rightward bias in the hypothetical numerical mental line. This, therefore, resembles the pattern of visuospatial asymmetries in physical space. Interestingly, Malgrati, et al. (2008) studied temporal processing deficits in patients with right lesions and visuospatial deficit, as well as patients without a visuospatial deficit in a sound duration discrimination task. Results have shown that patients with hemispatial neglect spatial showed a deficit in temporal discrimination. Thus, both MNL and MTL seems to rely on mechanisms that also drive the allocation of visuospatial resources.

In the Linguistic Hypothesis, Mental Time Line is a representation modulated by cultural factors, such as the direction of the reading-writing system (Tversky et al. 1991) along the horizontal axis (e.g. Italian, English, Arabic) (Torralbo et al.2006; Santiago et al. 2007; Santiago et al. 2010), thus in strict analogy to the MNL. Maass and Russo (2003) compared Italian and Arab people who were asked to draw up some sentences that were presented (e.g., the girl pushes the boy). The Italian participants positioned the girl to the left of the boy while the Arab participants positioned the girl to the right of the boy. This last figure was in line with another study showing that Jewish participants made a directional error from right to left while performing sentence-reading and space exploration tasks (Tversky, Kugelmass, & Winter, 1991). As mentioned before, adults in Western societies tend to map future and past events either on a lateral (left/past, right/future) spatial axis, or on a sagittal (backward/past, forward/future) axis (Nunez & Cooperrider, 2013). Embodied approaches to cognition believe that concepts are understood through sensorimotor simulations in which neural systems are involved in understanding the actions of objects and events in the real world, it depends on whether in our mind actions and movements are simulated. Another way to possibly dissociate the horizontal and sagittal MTL, therefore, may rely on paradigms widely used in the numerical cognition literature.

Siegler and Opfer (2003), for instance, asked to schoolchildren in second, fourth, and sixth grades, as well as adults, to perform two estimation tasks. In a so call ‘Number-Position Task’ (NP) the participants were shown numbers and asked to estimate their position on a numerical line. In the second so call ‘Position-Number Task’ (PN), participants were shown a position on a numerical line and asked to estimate the number corresponding to that position. Some numerical lines had 0 at one end and 100 at the other; others had 0 at one end and 1,000 at the other. The results of this study have shown that participants have multiple representations of some numbers and generate more models of estimation. Schooling and experience lead to consider the transition from a logarithmic to a linear representation as a function of age. Further, participants showed a bigger linear estimation pattern in the 0-100 scale than in the 0-1000 scale, which supports a logarithmic also as a function of the numerical interval considered. These results, thus, would demonstrate the use of multiple representations of numeric quantity in childhood. Schoolchildren of second and fourth class use a logarithmic model, while sixth-class children rely on a linear representation.

In another previous study, Anelli, et al. (2016) investigated Mental Time Travel through the lifespan using personal and non-personal events, with participants imaging themselves as moving into the future or the past (i.e.;10 years ago and in 10 years). Results showed that older participants had greater difficulty in judging the future rather than past events, relative to their self-location. Participants showed greater emotional involvement for personal than non-personal events; further, older participants were less able to pinpoint events in time, a difficulty likely related to recall abilities and in accessing contextual details of autobiographical memory.

Critically, adults seem to have different representations for the day, week, and year. The separate representation of time on different scales plays an essential role in humans' memory for times of past events. Friedman (1987) asked university students to recall an event, an earthquake that occurred nine months earlier, by also requiring them to indicate the day of the week, number of the day of the month, month and year. The results of this survey have shown that the students made a mistake about the estimate of the month, of about two months, while the judgment of the day was accurate, and the exact time was also indicated. Friedman (1987) concluded that this type of information could be constrained by a time scale (e-g.; the day of the year), so that the existence of processes related to the location of an event can be demonstrated by a phenomenon called 'Scale Effects'.

In the experiments described in chapter 2, we explored whether the type of memory content to be processed at hand can exert an influence in the setting on the specific spatial axis onto which the Mental Time Line is mapped. According to our hypotheses, we found that the congruency effect was more pronounced for personal events in the sagittal axis than in the horizontal axis. In striking contrast, in the horizontal axis, we found a similar pattern of congruency effect, albeit in this case for non-personal events representation, in the Italian group. Results are in favor of a dissociation between the horizontal and sagittal MTL as a function of the memory content to be contingently processed. The English-speakers group's results corroborate our results, suggesting that personal events preferentially trigger space-time mapping in the sagittal axis.

Based on the evidence reviewed above, the aim of this third experiment is to investigate whether in a paper and pencil task, similar to the number-to-position task described before, we can observe a similar dissociation between personal and non-personal events as a function of spatial axis. We developed a new bisection task, in which the stimulus to be positioned on a line was either a past or a future temporal event.

In particular, we asked whether the linear representation of events on space may be influenced by these two variables. That is, we hypothesized a stronger linear representation of personal events on the sagittal space, rather than on the horizontal axis. On the contrary, we hypothesized a stronger linear representation of non-personal events on the horizontal space.

3.2 Representation of the Mental Time Line in a pencil-paper task

Methods and Procedure

Participants

Forty-eight university students (30 females; mean age 22.90 ± 2.01 years), all right-handed and neurologically healthy were recruited. We involved the same participants who were recruited in the computerized task reported in Chapter 2. All participants had normal or corrected-to-normal visual acuity. Manual laterality was assessed using the Edinburgh Inventory (Oldfield, 1971).

Task and Stimuli

Before and after the computerized task, the participants performed a Time Estimation Task. The lines represented the Mental Time Line (a black line, 2 mm thick and with a length of 16 cm) and were drawn on a paper. Line were presented on both the horizontal axis and the sagittal axis, and all the participants us performed both tasks. The group that performed the computerized horizontal condition performed the sagittal bisection task first, whereas the group that performed the sagittal computer task first performed the horizontal bisection task first. Participants were seated and aligned with the center of the paper, and the experimenter read a brief description of a personal or non-personal event referring to the past or the future. Precisely, the experimenter asked the participants to "Imagine being on the timeline at the present moment and to place past and future events". Participants were asked to place the events by marking the line with a pen. The stimuli for the personal memory condition were 6 events chosen among the stimuli used for the computerized experiment (each event with its line to be marked),3 for the past and 3 for the future. Similarly, 6 events were chosen for the non-personal memory. Also, the experimenter asked the participants to "Imagine being on the timeline at the present moment and placing past and future events," and they had to mark the line with a pen. Also, four other options were added: "Marking the midpoint of the line" (at the beginning and end of the block), to mark on the line "Yourself 10 years ago" and "Yourself in 10 years", as well as "Imagine that the line represents your life, where would you place yourself?". Therefore, the stimuli were in total 17, At the end of the line estimation task, the participants also completed a survey in which they had to indicate how many years ago the events occurred in the past and when, hypothetically, the future events will occur (please see the Appendix G).

Data Analysis

Participants marked the points on the line with a pen to indicate the events. We measured with a ruler the point on the line corresponding to each event (Subjective Point on the line). The distance in centimeters from the left end of the line to the event point on the horizontal lines, and from the bottom to the event point on the sagittal lines was measured. This measure was used to calculate where the events were positioned on the line. Further, in this way past events should be associated with lower values and, thus, with locations on the lines on the left/bottom.

We also computed the Objective order, that is, the verbal estimation of past and future events made by participants. In particular, we ordered the events from 0 to 9, so that also in this case past events should be associated with lower values, whereas future events with higher values. To analyze the data, we used Generalized Linear

Mixed Models. In particular, the analysis was performed using the lme4 package (Bates et al.,2015) in an R environment (R Development Core Team, 2006). We performed two different analysis of Personal and Non-Personal events. In both analyses, Subjective order was entered as dependent variables, while Mapping (Horizontal and Sagittal) and Objective Order as independent variables. Further, the Subject was included in the analyses as random intercepts, as supported by a Likelihood Ratio Test for random effects variances.

In the Non-Personal memory condition, we found a significant effect of Mapping (F (1, 864) = 24.76, p <.001), as well as we found a significant effect of Objective Order (F (1, 864) = 559.55, p <.001). Critically, we also found a 2-way interaction Objective Order × Mapping (F (1, 864) = 18.95, p <.001) (Figure 17). This interaction was due to the fact that the linear fitting of the Horizontal Mapping (F (1, 384) = 491.28, p <.001) was better than the Sagittal Mapping (F (1, 432) = 155.88, p <.001).

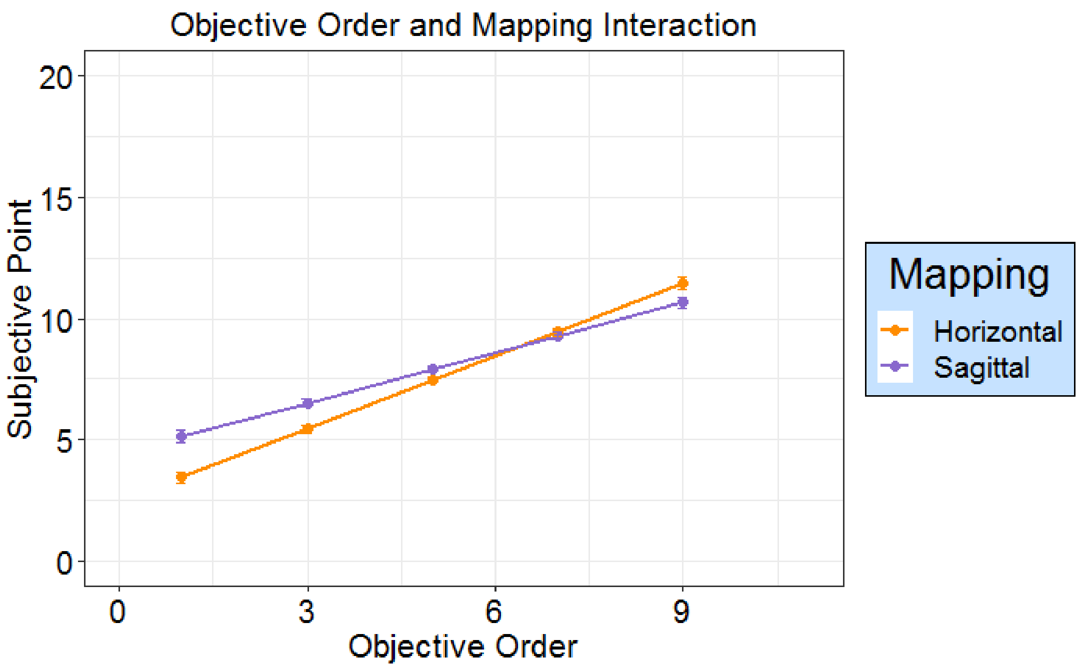

Figure 17. Non-Personal Memory. Subjective Points based on Objective Order in the Sagittal Mapping (F (1, 432) = 155.88, p <.001) and the Horizontal Mapping (F (1, 384) = 491.28, p <.001).

In the Personal memory condition, we found a significant effect of Mapping (F (1, 876) = 33.87, p <.001), as well as we found a significant effect of Objective Order (F (1, 876) = 663.15, p <.001). Critically, we also found a 2-way interaction Objective Order × Mapping (F (1, 876) = 29.49, p <.001) (Figure 18). As for non-personal memory, this interaction was due to the fact that the linear fitting of the Horizontal Mapping (F (1, 441) = 766.64, p <.001) was better than the Sagittal Mapping (F (1, 435) = 149.84, p <.001).

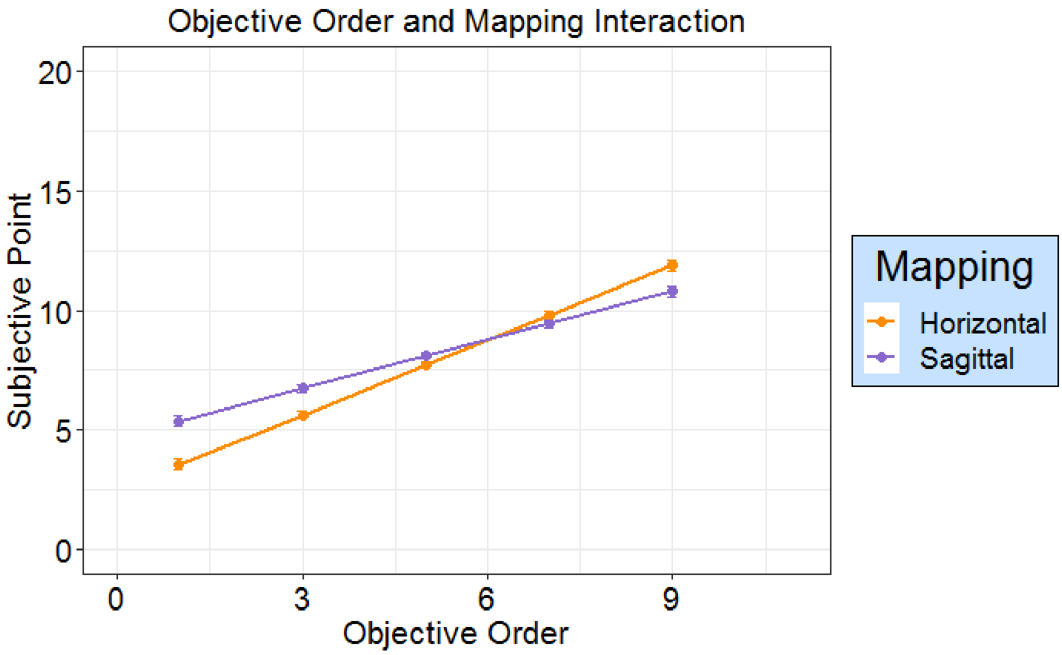

Figure 18. Personal Memory. Single line coefficient to predict Subjective Points based on Objective Order: Sagittal Mapping (F (1, 435) = 149.84, p <.001); Horizontal Mapping (F (1, 441) = 766.64, p <.001).

3.3 General Discussion

In our study, we explored the spatial representation of personal and non-personal events in a paper-and-pencil task in which participants had to map temporal information on a line. In particular, the aim of the third experiment was to study whether in a paper and pencil task we could obtain the same time-space representation of the personal and non-personal event obtained in the computerized tasks. We, therefore, manipulated also the spatial frame of reference, presenting lines in the horizontal and the sagittal axis.

First, the results showed that in the horizontal axis, most participants tended to map events from left-to-right. This pattern resembles the canonical MTL, also observed in typical computerization tasks, and can be inferred from the positive slopes of the lines. Similarly, in the sagittal axis, we found that most participants mapped events from back to front, again resembling the canonical sagittal MTL.

However, and critically, we also found that regardless of the memory content, all participants mapped better events along the horizontal axis, as compared to the sagittal one. The preferential activation of the horizontal MTL may be explained by specific task requirements. In this task, indeed, participants placed the events using a pen. Such a requirement may have emphasized reading-writing strategies, resulting therefore in the observed pattern of results. In addition to this, the dissociation observed in the second chapter may be found only when participants are under speed-constraints instructions.

Chapter 4

The development of space-time representation in native English and Italian primary schoolchildren

4.1 Introduction

A consistent body of research has demonstrated that the specific direction of the Mental Time Line (MTL) representation depends on cultural factors, such as reading habits. For instance, in the Western populations with a left-to-right reading and writing system, past and future events or short and long duration are preferentially mapped on the left/right sides of space (Vallesi et al., 2008; Vicario et al., 2008, Santiago et al, 2007),whereas the direction is reversed (Fuhrman & Boroditsky, 2010; Ouellet et al., 2010) or even rotated in the vertical axis (Boroditsky et al., 2011) in other populations (i.e., Hebrew speakers), depending on reading habits. Hence, the MTL is extensively shaped through experience and, more specifically, through the learning of the reading-writing system, (Bonato et al., 2012; Casasanto & Bottini, 2014; Magnani & Musetti, 2017).

Even though most of the literature has been focused on the horizontal MTL, time can also be represented on the sagittal space. Western adults typically map past and future events with back and front locations, concerning their body (Torralbo et al., 2006; Ulrich et al., 2012; Eikmeier et al., 2013; de la Fuente et al., 2014). A similar representation has also been documented for short and long duration, starting from an early age (Charras et al., 2017) although the origins of the MTL (notably, concerning the representation of past and future events) remains largely unknown.

As suggested by Bottini and Casasanto (2010), the language system has a role in the spatial mapping of time, possibly at the semantic (i.e., or metaphoric) level. Indeed, we often talk about time using words with primary spatial meaning, such as those referring to spatial distance (e.g., short/long) and spatial locations (e.g., backward/forward or up/down) (Clark, 1973; Bottini & Casasanto, 2010). The exposure to such language statistics, would, therefore, reinforce the spatial representation of time, alongside specific sensorimotor directional experience (i.e., reading and writing in the horizontal space).

Several studies published in the last few years concur with the idea that the acquisition of (mature) time representation follows a protracted development trajectory. This is likely because the ability to reason about time is strictly related to working memory, attention, and the capacity to recall events accurately. For instance, Busby-Grant and Suddendorf (2005) conducted a study involving children from three to five years of age, who were asked temporal questions such as “What did you do yesterday? What will you do tomorrow?”. The authors reported that the ability to respond to the questions about the past and the future are related, but only four- and five-year-old children reacted correctly. Some works carried out in the early 1990s (Friedman, 1991,1992) converge on this idea and that children aged four to nine can recall memories from the past accurately, (e.g., yesterday, last weekend, last summer, holidays). However, three years old children are unable to order chronologically past event in the specific time point in which happened. Therefore, Friedman (1992) suggested that there are multiple levels and steps to develop the order and position of autobiographical events in memory during childhood. An interesting aspect is that children seem able to use names, an activity, or something done in a specific period during the year as a cue to recall their memories.

Further, it is essential to highlight that distance and location judgments develop separately (Friedman, 1991) and children show this ability at about nine age (Friedman, Gardner & Zubin, 1995). Regarding the ability to judge the distance between future events, Friedman (2000) has demonstrated that children aged four are unable to distinguish future distances compared to five-year-old children, who can identify events that would occur in the coming weeks and months, as well as events that would not happen for many months. Despite this, the ability to judge and order the near future appears from eight to ten years of age.

Interestingly, despite the role of experience in setting the MTL, thus suggestive of a protracted development, some studies have observed an early association between space and time that resembles the adult MTL. To date, associations between other ordinal dimensions, such as number, and space have been repeatedly documented in preschoolers and school-aged children (McCrink, Shaki, & Berkowitz, 2014; Opfer, Thompson, & Furlong, 2010; Patro & Haman, 2012; Rinaldi, Gallucci, & Girelli, 2016). Notably, similar findings also have reported for the spatial representation of time. First, it has been shown that of preschool and children's natural graphic productions (arrangement of transparencies: Tversky, Kugelmass, & Winter, 1991; drawing sequences of events: Dobel et. al, 2007) of temporal order are spatially organized. Second, and critically, two recent studies reported a congruency effect in space-time mapping along the horizontal axis in five-six and ten-year-old children (Nava, Rinaldi, Bulf & Macchi Cassia, 2017; Nava, Rinaldi, Bulf & Macchi Cassia, 2018). Together, this evidence suggests that children possess an MTL that resembles the adult one. However, it is worth noting that previous studies have focused primarily on the horizontal axis.

To sum up, the association between time and space has been shown to rely to certain extents on language (i.e., metaphorical mapping), but mainly to sensorimotor routines, such as reading-writing s habits and, walking (i.e., depending on the specific spatial axis considered). On the one hand, therefore, the origin of time representation would depend on the use of spatial metaphors to talk about time in everyday language (e.g., such as in the expression, "Look ahead to what may happen in your future"). Such linguistic mapping has been shown to emerge spontaneously already in school-age children (Tillman et al.,2015) Further, and according to the Construal Level Theory, there is a strong link between temporal and spatial constructs to express psychological distance (Trope & Liberman, 2010). On the other hand, the sensorimotor experience would play a crucial role in the construction of the MTL. For instance, the direction of reading and writing habits strongly shapes the direction of the horizontal (or vertical) MTL. Similarly, the direction of walking would possibly determine the sagittal MTL. Accordingly, Rinaldi et al. (2016) have shown that an MTL at the level of whole-body movements: that is, processing past and future related words are facilitated by making backward and forward movements as compared to the reverse response mapping.

To the best of our knowledge, no research study has so far explored the development of the sagittal MTL, being most of the literature focused on horizontal representations. On these grounds, the present study aims to investigate the development of the sagittal MTL on a group of primary school children. In addition to this, and based on the effects reported in Chapter 2, we also aim to explore whether the sagittal MTL is preferentially activated for a specific memory content, thus asking children to map personal and non-personal memory. Children can indeed represent the ideal population to compare sensorimotor and linguistic hypotheses and study the processes that underlie the spatial representation of time. Indeed, their amount of linguistic experience is certainly limited if compared to adulthood. We thus investigated whether the space-time association is already present in primary school-age children, eventually grasping the changes that may occur in this period of development as a function of age.

Based on these purposes, we explored whether there is a differential mapping in childhood for personal events and non-personal events on the sagittal axis. As shown in the first experiment reported in the previous chapter, personal events are preferentially represented along the sagittal axis, while non-personal along the horizontal axis. Further, this pattern is likely affected by the participant's body posture while performing the task (i.e., please see the second experiment on English native speakers). We thus aim at exploring whether such pattern (sagittal mapping) can be observed in children as well.

In the first experiment, we directly tested the Linguistic hypothesis and Sensorimotor hypothesis in a sample of Italian children. To do so, we asked children to perform a typical motor compatibility task (i.e., as those used in the other experiments reported in this thesis), with responses provided along the sagittal axis. To directly investigate the linguistic association along, however, we ideated a purely linguistic task, by adopting a paper and pencil version of the Implicit Association Test (IAT, Greenwald, et al., 1998). In this task, children were indeed shown with a target word (i.e., referring either to space or time domains) and asked, in a congruent condition, to indicate whether the word referred to a first category matching back locations and paste events, or to a second category matching front locations and future events. Children were also asked to perform a similar version of the task, in which the category match was revered (i.e., a first category matching back locations and future events, a second category matching front locations and past events). In this way, we had both congruent and incongruent measures of the linguistic association between space and time. We reasoned that, if there is an implicit linguistic association between temporal categories and spatial categories, then the answers will be more numerous and accurate in the congruent trials (‘Past-Backward’ and ‘Future-Forward’) rather than the incongruent trials (‘Past-Forward’ and "’Future-Backward’). Further, evaluating children at different ages (from 3rd to 5th grade), we were interested in exploring whether one type of space-time mapping (i.e., motor or linguistic) emerges before the other or not. We further recruited a control group of adults to validate the experiment and compare children’s results to this standard.

In the second experiment, we, therefore, investigated the ontogeny of the spatial representation of personal and non-personal events in native English-speaking schoolchildren using a similar task performed by Italian and English adults. Children often are not aware of public events that happen around the world as adults are. Therefore, we opted for replacing public events with an imaginary person named Alex, aged like the participants. Children’s understanding of time may not reflect the same distinctions between past, present, and future like adults (McCormack & Hoerl, 2011). Therefore, we may expect relative assessments of past and future events and factors that affect them differently than adults. Further, we may expect differences as a function of age. For instance, the sensorimotor and linguistic components may be more pronounced in older children, both due to the consolidation of such experiences and to the maturity of cognitive processes, like working memory. We must emphasize that prospective memory involves the mechanisms of working memory, such as planning action schemes, semantic, and episodic knowledge (Baddeley, 1990, Kvavilashvili, 1987). Keeping this in mind, we also decided to test Children's WM ability, administering the Digit-Span task (backward and forward form), to get a measure of verbal working memory storage capacity. Moreover, and for the same reasons, we used the Corsi block-tapping test to assesses visuospatial and short-term working memory. In particular, we focused on how this ability can influence space-time mapping and children's performance because it is related to the recall of information and prospective memory mechanisms.

4.2 First Experiment: development of time representation

According to the linguistic hypothesis, the way in which we metaphorically map temporal concepts on space in language would be a determinant key factor of the congruency effect observed in adults, and, consequently of the construction of MTL. This hypothesis, relying on a crucial role of language statistics, would emphasize less the possible influence of low level sensory and motor activities, linked for instance to the reading-writing systems or locomotion behaviour, as in the case of the sagittal MTL. This second experiment aimed to investigate the linguistic and motor hypothesis on the sagittal axis involving three groups of children of primary school (i.e., first, second and third classes) and one group of adults as a standard reference. In particular, we explored in all groups the presence of a space-time mapping in a linguistic task (i.e., IAT) and a canonical motor compatibility task. We thus examined whether children showed a congruency effect in both tasks and which compatibility effect (i.e., linguistic or motor) possibly precedes the other.

4.2.1 Adults experiment

Methods and procedure

Participants

Thirty-three young adults 18 to 29 aged (mean age 22.04 ± 2.77 years) took part to the experiment. Participants were recruited through the SONA System of the University of Milano-Bicocca and received course credit for participation.

Materials

A computerized task and a paper-and-pencil task were administered. First participants took part in the paper-and-pencil task in which they performed the IAT (Greenwald et al., 1998). Then, they completed the computerized task, and in between the computerized task bocks, they were administered Coding subtest of the WAIS-IV Battery (Orsini, Pezzuti, & Picone, 2012).

Implicit Association Test (IAT): task and stimuli

The first task was presented in a paper-and-pencil form. An Implicit Association Test (IAT) measured the relation between a concept defined as the target and an implicit attribute. Three different IATs were used, and each had to be completed in 90 seconds. Each different version had a congruent and incongruent condition, for a total of 6 conditions. The first IAT served as a baseline and was similar to Greenwald et al.'s (1998) task, in which a table with a central column, composed by names of flowers (e.g., rose, sunflower), insect names (e.g., fly, mosquito), positive words (e.g., love, joy) and negative words (e.g., hate, bad), was presented. In the congruent condition, participants had to write an X on the answer box drawn with a circle on the left side of the word whether they read a flower name or a positive word, while they have to write an X on the right side of the word whether they read an insect name or a negative word. In the incongruent condition, they had to write an X on the answer box when they read a flower name or a negative word, while they had to write an X on the right side of the word when they read an insect name or a positive word (i.e., mapping reversed). In the second IAT, words referred to the 'Past' (e.g., yesterday, before), 'Future' (e.g., tomorrow, after), 'Behind' (e.g., shoulders, back), 'Front' (e.g., front, face) categories were used: the congruent condition matched 'Past-Behind' and 'Future-Front', while the incongruent condition matched 'Past-Front' and 'Future-Behind'. We also assessed the possible association between spatial and temporal distance in a third IAT. In particular, participants were presented with words referred to the categories 'Short' (e.g., second, minute), 'Long' (e.g., month, year), 'Near' (e.g., on, Milan) and 'Far' (e.g., distant, Paris). The congruent condition matched the associations 'Short-Near' and 'Long-Far' and the incongruent 'Short-Far' and 'Long-Near'. To balance the experimental design, half of the participants first performed congruent tests and then the incongruent ones, whereas the other half of the participants performed the incongruent conditions first and then the congruent ones. For all the task the number of total responses was calculated participants' accurate answers (please see Appendix H).

Computerized task

The E-Prime2 software version 2.0 (Psychology Software Tools, Pittsburgh, PA, USA) was used to program the experiment and record the participants' responses. To collect participants' responses, we used a QWERTY keyboard, connected to the laptop. The keyboard was rotated 90 degrees, thus creating a sagittal response mapping space. The keys not used for response were removed from the keyboard to facilitate finger movements. Each trial started with participants pressing a central key with the index finger of their dominant hand. When the word was presented, participants had to release their hand from the central key as fast as possible and move it backward or forward to press the corresponding response key. Response keys were equidistant from the central key. After moving their hand to one of the response keys, participants had to return to the starting position and wait for the next trial. Stimuli were presented auditorily (i.e., through headphones) and visually at the centre of the screen in a white font on a black background. All auditory items were recorded from the same female voice, had equal auditory properties, and were played at a constant intensity level.

Participants performed two main tasks, each of which included a congruent and an incongruent condition, for a total of four blocks, presented in a counterbalanced order. In the first task participants were presented words and asked to classify them as ‘Past’ (e.g., yesterday, before, previous) or ‘Future’ (e.g., tomorrow, after, next). In a first block, each participant had to make a backward movement in response to past-related words, and a forward movement in response to future-related words (congruent condition). In the second, the response assignment was inverted (incongruent condition). In the second task participants had to classify temporal words as ‘Short’ (e.g., minute, second, early) or ‘Long’ (e.g., month, year, late). In a first block, the participant had to make a backward movement in response to short time-related words, and a forward movement in response to long time-related words (congruent condition). In the second, the response assignment was inverted (incongruent condition). Participants received feedback only in the practice session. Six stimuli were presented in the practice session, while in the experimental session

24 stimuli were presented in a random order for each block. Response times were calculated from the moment participants left the start key.

Coding

The Coding subtest of WAIS-IV Battery (Orsini & Pezzuti, 2013) was used to assess the participants' cognitive abilities, especially Working Memory and processing speed. The Coding subtest was chosen as a control task to gather information about the participants' processing speed, sustained attention, short-term memory, and visual-motor coordination. This was done, because differences in these abilities may explain individual differences in our experimental task, especially in the IAT tasks. The battery includes 100 numeric stimuli, with digits going from one to nine paired with nine different symbols. Participants had 120 seconds to copy in the box below each number the appropriate and correspondent symbol. The raw score obtained was calculated by counting the correct number of couplings; then, this score was converted into a weighted score that took into account the participants' age.

Data analysis

Adults experiment

Adults' paper-and-pencil IAT scores were analysed using paired sample t-test to compare performance in the congruent and incongruent conditions in the three versions of the task (i.e., baseline, space-time, spatiotemporal distance). Data were analysed through IBM SPSS Statistic 25. To analyse the computerized task results, we calculated the Inverse Efficiency Score (IES) and compared the congruent and incongruent conditions using paired sample t-tests. Participants who got a score lower than 10 in the Coding subtest and less than 50% accuracy in the computerized task were discarded. The remaining participants were 24 right-handed adults (19 females), aged between 18 and 29 years old (average age 22.04 ± 2.77 years). In the computerised task, we considered only trials with responses given within the 250 - 2000 ms interval.

IAT Baseline, Time and Distance Task

A paired sample t-test on the "IAT Baseline" task revealed a significant congruency t (23) = 8.056; $p < .001$, with participants showing more accurate answers in the congruent condition (M = 44.67, SD = 5.56) compared to the incongruent condition (M = 35.29, SD = 7.45). Similarly, a congruency effect was found in the "IAT Time" task: answers were more accurate in the congruent condition (M = 39.29, SD = 6.91) than in the incongruent condition (M = 23.63, SD = 5.23), t (23) = 10.567; $p < .001$. In the "IAT Distance" task, the congruency factor resulted significant as well, t (23) = 22.547; $p < .001$: with participants being more accurate in the congruent condition (M = 40.79, SD = 6.35) than in the incongruent condition (M = 18.42, SD = 4.50). Therefore, these results show that in all IAT tasks participants were more accurate in the congruent condition than in the incongruent one.

Time and Distance Reaction Time (RTs)

In the ‘Time’ task we found a significant effect of congruency t (23) =-3.005; p = .001, with faster responses in the congruent (M = 663, SD = 115.2) than in the incongruent condition (M = 739.1, SD = 134). In the ‘Distance’ task, we only found a trend towards significance for the congruency effect, t (23) = -1.796; p = .086, with faster responses in the congruent condition (M = 635.9; SD = 100.7) than in the incongruent one (M = 673.1, SD = 108.3).

4.2.2 Children experiment

Methods and procedure

Participants

One hundred children (Female= 44; mean age 8.93 ± 0.95 years) of the primary school of “Comprensivo di Cantù” took part to the experiment. The sample included 31 children (mean age 8.64 ± 0.36 years) attending the third grade, 33 attending the fourth grade (mean age 9.60 ± 0.34 years) and 34 the fifth grade (mean age 10.64 ±

0.32). Children's parents provided consent before participation and children were informed at the start of the study that they could stop at any point.

Procedure and materials

The same paper-and-pencil and computerized tasks administered to adults were used. The only difference is that children were presented with the Coding subtest of the WISC-IV Battery (Orsini, Pezzuti, & Picone, 2012), instead of the WAIS-IV Battery. In analogy to the adult sample, the Coding subtest of WISC-IV Battery was used to assesses children's cognitive abilities, especially speed of processing, but also learning, short-term memory, and Working Memory. The individual is presented with a key in which the numbers 1 to 9 are each paired with a different symbol; his/her task is then to use this key to put in the appropriate symbols for a list of numbers between 1 and 9. The battery consists of 126 numeric trials to complete in 120 seconds, children had to copy the appropriate and correspondent symbols in each box below each number. We calculated the raw score, corresponding to the correct number of couplings, and the weighted score, based on the children's age. Children who obtained a score less than eight scores in the Coding subtest and less than 50% accurate answers on the single association test in the computerized task were excluded. The IAT tasks were administered in group to the whole class, whereas the computerized tasks and the Coding subtest were administered individually (Figure 19).

Figure 19. Experimental Setting at School 'Comprensivo di Cantù'.

Data analysis

A 2×3 repeated measures ANOVA was carried out for each paper-and-pencil IAT task (i.e., Baseline, Time and Distance tasks), with the condition (congruent, incongruent) as within-subjects factor, and class (III, IV, V) as between-subjects factor. For the computerized task, IES (Inverse Efficiency Score) effects were analysed using a 2×3 repeated measures ANOVA, with condition (congruent, incongruent) as within-subjects factor, and class (III, IV, V) as between-subjects factor. In both analyses, Post-hoc comparisons with Bonferroni correction were used to further investigate the significant interaction effects. In the computerised task, only the answers recorded in a range between 300 and 3000 ms, and only those movements that were completed in the interval 100-2000 ms we considered.

IAT Baseline, Time and Distance Task

In the "IAT Baseline" task we found a main effect of Congruency, F (1.94) = 158.56, p < .001, η^2 p = .628, with children being more accurate in the congruent (M = 42.26, SD = 0.785) than in the incongruent condition (M = 29.59, SD = 0.919). We also found a significant effect of Group, F (2.94) = 15.18, p < .001, $\eta^2 p$= .244. Post-hoc comparisons showed that the fifth-grade children provided more correct answers (M = 40.51, SD = 1.18) compared to the fourth-grade children (M = 36.136, SD = 1.1849; p = .010) and the third-grade children (M = 31.14, SD = 1.22; p = .004); in addition, fourth grade children provided more correct answers than third-grade children (p < .001) (Figure 20).

In the 'IAT Time' task we found a main significant effect of Congruency, F (1.94) = 76.27, p < .001, $\eta^2 p$ = .448, with children being more accurate in the congruent condition (M = 24.19, SD = 0.87) than in the incongruent condition (M = 17.39, SD = 0.50). We also found a significant main effect of Group, F (2.94) = 18.61, p < .001, $\eta^2 p$ = 284). In particular, fifth-grade children provided more accurate answers (M = 25.16, SD = 1.02; p = .005) compared to the fourth grade (M = 21.01, SD = 1.02) and third-grade children (M = 16.19, SD = 1.05, p <.001).

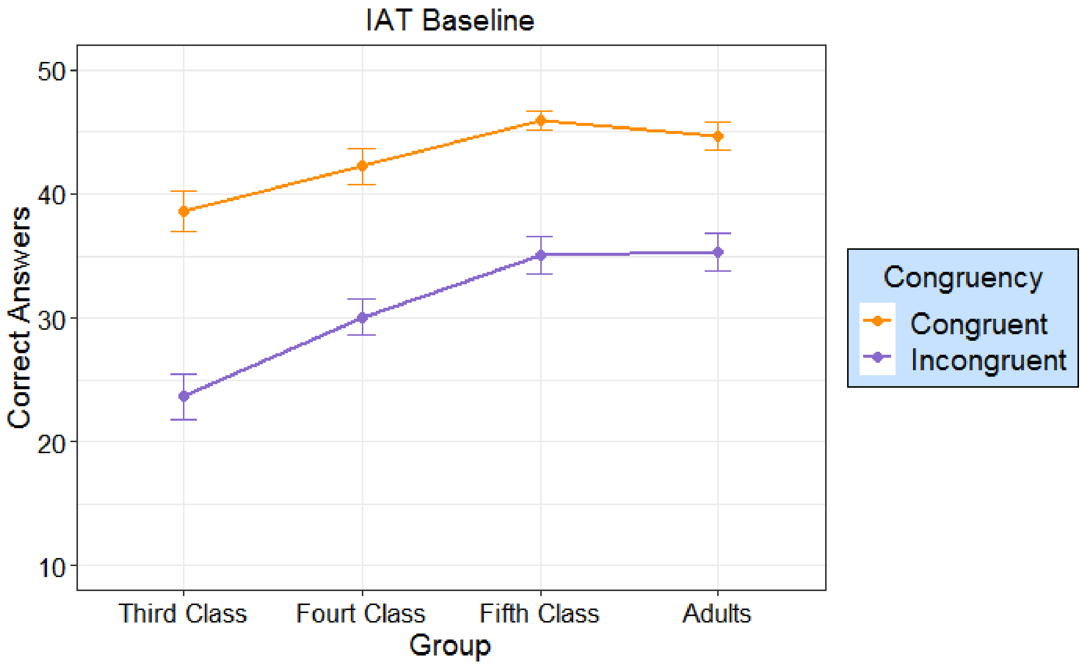

Figure 20. IAT Baseline. Correct answers. Experiment 1 and 2. Participants provide more answers in the congruent condition than the incongruent. Fifth-grade children provided more accurate answers.

Further, the fourth-grade children provided more accurate answers than the third-grade children (p = .001). The interaction between Group × Congruency (F (2.94) = 7.32, p = .001, η^2p = .136) was also significant. Post-hoc analysis carried out with Bonferroni correction indicated that only in the fourth class (congruent: M = 24.93, SD = 1.50; incongruent: M = 17.09, SD = .85; p = 0.001) and in the fifth class (congruent: M = 30.09, SD = 1.50; incongruent: M = 20.24, SD = .85; p <.001) the accurate answers differed between the congruent and incongruent conditions. On the contrary, no significant difference was found in third-grade children (congruent: M = 17.54, SD =1.54; incongruent: M = 14.83, SD = .88; p = 0.781) (Figure 21).

In the “IAT Distance” task, we found a significant effect of Congruency, F (1.94) = 168.90; p < .001; η^2p = .642. Children provided much more accurate answers in the congruent (M = 26.86, SD = 0.87) compared to the incongruent condition (M = 15.58, SD = 0.53). We also found a significant effect of Group, F (2.94) = 11.62; p < .001; η^2p = 0.198. The fifth-grade children (M = 24.92; SD = 0.99) provided more accurate answers than fourth-grade children (M = 20.56; SD = 0.99; p = .004) and third-grade children (M = 18.19; SD = 1.02; p < .001). A significant interaction between Congruency × Class was also found, F (2.94) = 4.88;

p = .010; η^2p = .094.

Post-hoc comparisons (Bonferroni) showed a Congruency effect in all groups of children: third-graders (congruent: M = 22.35, SD = 1.53; incongruent: M = 14.03, SD = 0.94; p <.001), fourth-graders (congruent: M = 25.87, SD = 1.49, incongruent: M = 15.24, SD = .91; p <.001) and fifth-graders (congruent: M = 32.36, SD = 1.49; incongruent: M = 17.48, SD = 0.91; p <.001) (Figure 22).

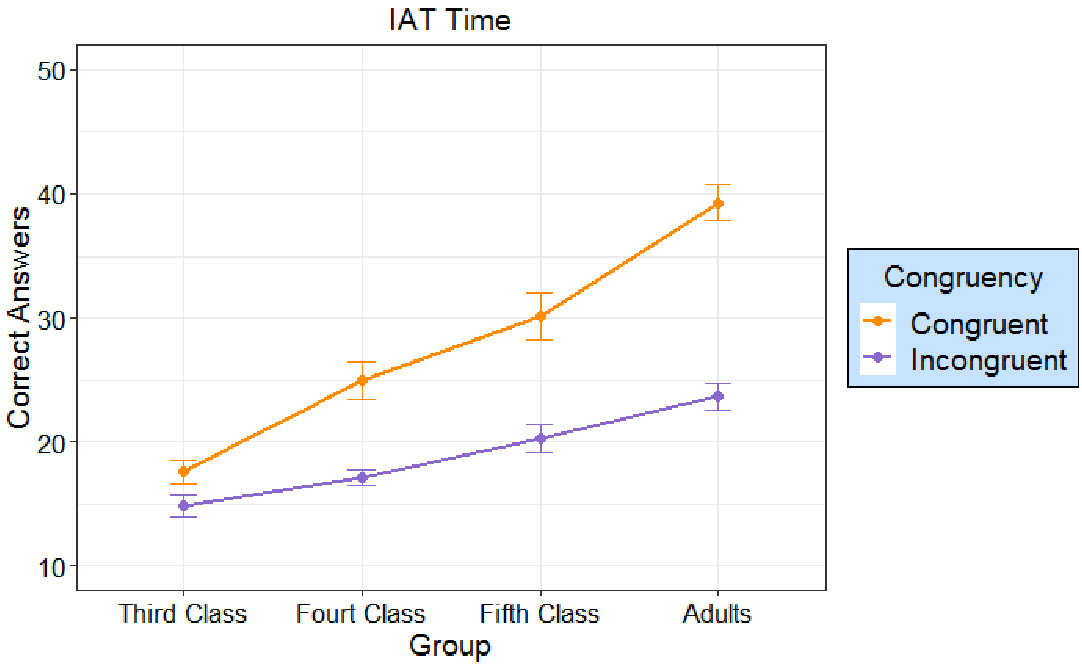

Figure 21. IAT Time. Correct answers. Experiment 1 and 2. Participants provided more correct answers in the congruent condition than in the incongruent one. The fourth-grade children provided more accurate answers than the third- and fourth-grade children.

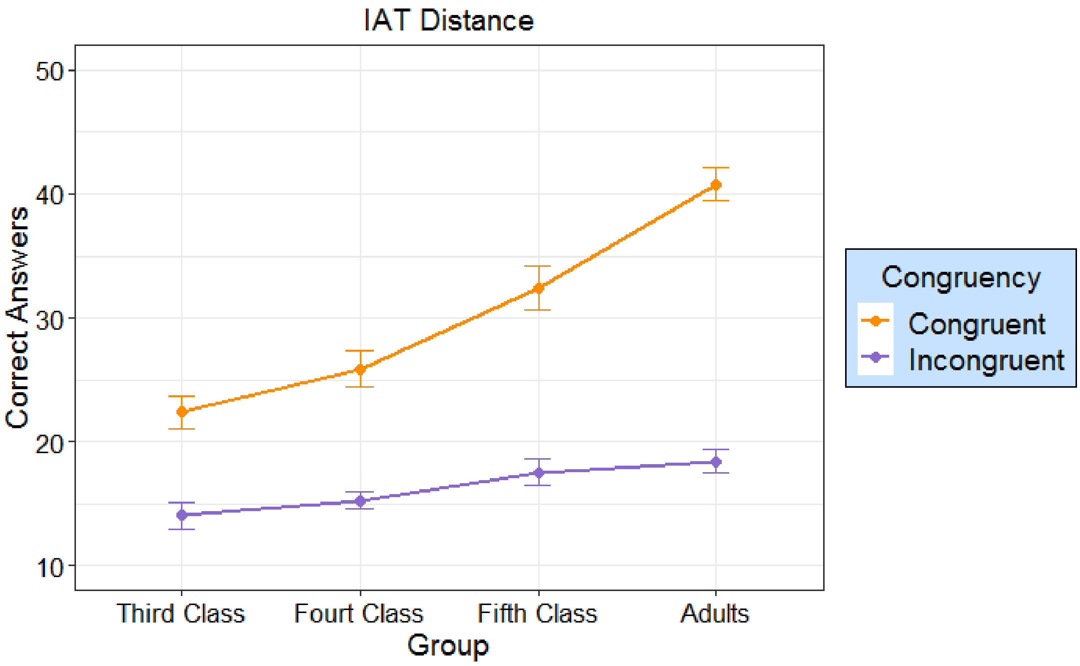

Figure 22. IAT Distance. Correct answers. Experiment 1 and 2. Participants provided more correct answers in the congruent condition than in the incongruent one. The fourth-grade children provided more accurate answers than the third- and fourth-grade children.

Time and Distance Reaction Time (RTs)

The analysis of the "IES Time" computerized task indicated a significant effect of Congruency F (1.94) = 24.95; p <.001; $\eta^2 p$ = .210; with children being more accurate (shorter IES) in congruent (M = 1237.0, SD = 38.2) compared to the incongruent condition (M = 1394.4, SD = 43.8). We also found a significant effect of Group F (2.94) = 4,20; p = .018; $\eta^2 p$ = .082. In particular, fifth-grade children (M = 1228.8, SD = 65.0) were more accurate than third-grade children (M = 1472.59; SD = 67.10; p = .011); further, fourth-grade children (M = 1245.7, SD = 65.0; p = .017) were more accurate than third-grade children (Figure 23). No significant interaction was found.

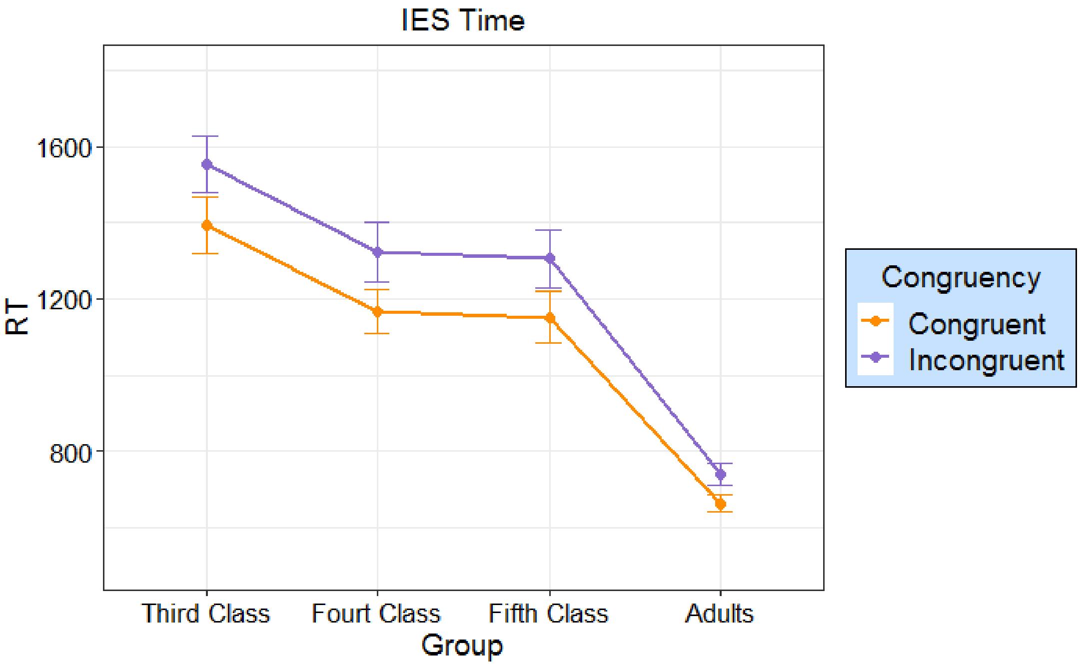

Figure 23. IES Time. Experiment 1 and 2. Inverse Efficiency Score as a function of group and congruency.

In the "IES Distance" computerized task, we found a main effect of Congruency *F* (1.94) = 7.06; *p* = .009; $\eta^2 p$= .070. Children performed better in the congruent condition (*M* = 1116.3; *SD* = 25.2) than incongruent condition (*M* = 1181.3, *SD* = 35.3). The main effect of Group was also significant, *F* (2.94) = 12.25; *p* <.001; $\eta^2 p$ = .207. Third grades performed with a lower accuracy the task (*M* = 1347.7, SD = 49.8) as compared to fourth grades (*M* = 1038.8, *SD* = 48.2; *p* <.001) and fifth grades (*M* = 1060.0; *SD* = 48.3; *p* <.001). The interaction was not significant, *F* (2.94) = 1.397; *p* = .253, (Figure 24).

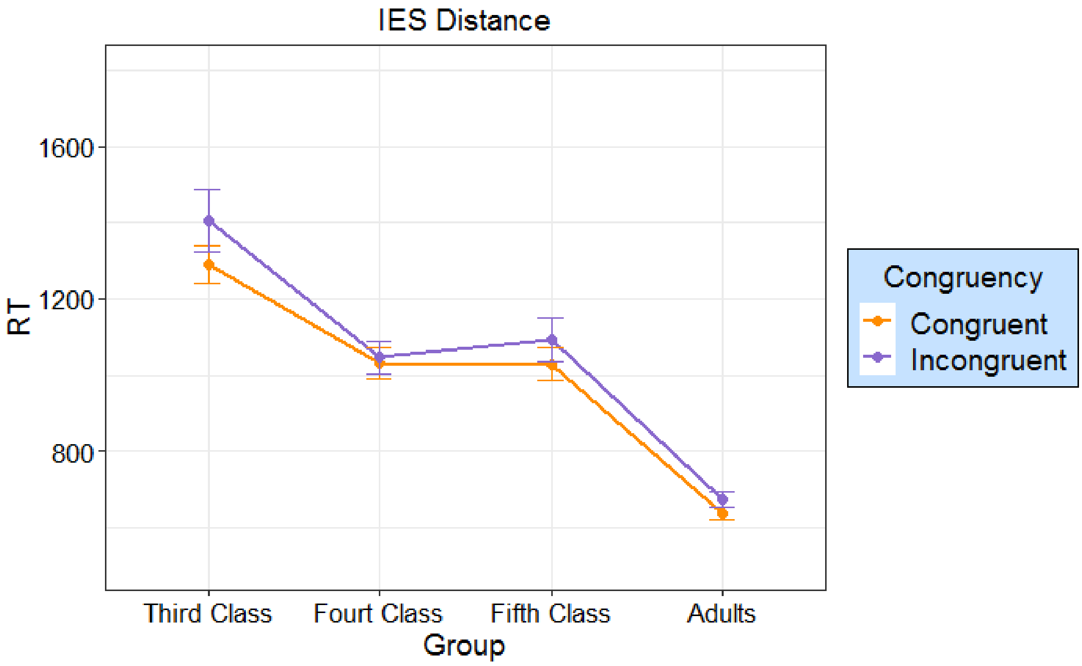

Figure 24. IES Distance. Inverse Efficiency Score. Experiment 1 and 2. Participants provide more accurate answers (shorter IES times) in the congruent condition than the incongruent.

4.3 Interim Discussion

Results supported the presence of space-time associations in both tasks and, thus, at both linguistic and motor levels. A similar association was reported at the linguistic level for terms referring to spatial and temporal distance. This pattern almost reached significance in the motor task. Results indicated that the tendency to map past events with locations behind the body and future events with locations in front of it was already present at a young age in the motor task. Most notably, the size of the congruency effect did not differ as a function of age.

The linguistic association as tested by the IAT was modulated by age. Indeed, only 4th and 5th grades children showed a congruency effect, meaning that they performed more accurately the congruent than the incongruent condition. The younger group of children (i.e., 3rd grades) in turn did not show any congruency effect. The specificity of these results was supported by the distance task. In this case, indeed, we found a congruency effect at the motor level, not modulated by age.

Thus, the association between space (back, front) and time (past, future) is present at the motor level starting from a young age, but not at the linguistic level.

4.4 Second Experiment: Mental Time Line in personal and non-personal memory

In the second experiment, we investigated the ontogeny of personal and non-personal events representation on the sagittal axis in native English-speaking school-aged children. In particular, we asked whether personal events induce a stronger congruency effect between time and space along the sagittal axis, with the future preferentially mapped in front and the past mapped in backspace (i.e., a congruent condition in the experiment), as compared to non-personal events. In the light of the previous studies in literature, about children's space-time representation skills, as well as the age in which it appears, and the task that involving complex mnestic abilities (i.e., focused on personal and non-personal events) we involved children from six to nine years of age. We considered adults' results in the Italian and English sample, as well as children's results in Italians, study, in the light of the association between space (back, front) and time (past, future), at the motor level present from a young age, but not at the linguistic level. Therefore, we tested only the sagittal axis.

Methods and procedure

Participants

Seventy native English-speaking schoolchildren from Belfast were recruited. Among this initial sample of children, 22 were excluded. We considered participants that completed at last one block with 40 % accuracy. Also, we exclude participants with technical problems in recording their answers, and incomplete performance (i.e., those children who could not complete all the experimental blocks) and participants with reaction time outliers (i.e., they have short or long reaction times). The remaining 48 children (24 females; mean age 7.44 ± 1.05 years) were analysed and divided into two groups depending on their age, 25 children aged six-seven (12 females; mean age 6.56 ± 0.51 years; named as the younger group in the reaming of the chapter), and 23 children aged eight-nine (12 females; mean age 8.39 ± 0.50 years; called as the older group). Manual laterality was assessed by asking directly participants their preferred hand in writing (participants were all classified as right-handed). Children were recruited through flyers, posters, and social media posts and by directly asking some local schools to distribute flyers with the study details. Children's parents signed a consent form and read an information sheet with all the relevant information concerning the tasks, and at the end of the experiment, they received a debriefing. Children signed with a cross a content form as well, and they were informed at the start of the study that they could stop participating at any point. At the end of the experiment, parents received a refund of £7, and children received a goody bag (i.e., a bag of small gifts to thank them) and a thanking certificate. All participants had normal or corrected-to-normal visual acuity.

Materials

The overall experimental session was divided into three parts. Before the main experimental task, participants were invited to complete a brief working memory assessment using a standard measure of verbal working memory (Forward and Backward Digit Span) and visuospatial working memory (Corsi Block-Tapping Test). Then, participants took part in the computerized task, and finally, they were asked to complete the events Vividness and Likelihood Survey about personal events.

Working Memory Assessment

Forward and Backward Digit Span are subtests of WISC-IV(Wechsler,2003). This battery was used to assesses participants' verbal working memory. Visuospatial working memory was evaluated using the Corsi Block-Tapping Test (Corsi, 1972). Both tests were administered following the standard protocol and were scored according to standard procedures. s. The child required to repeat 3 - 9 digits forward and 2 -9 digits backward. Measures short-term memory, attention, and concentration. In particular, in the Digit Span Forward, the experimenter read aloud the instructions to the child: "I am going to say some numbers. Listen carefully, and when I through say them right after me. For example, if I say 7-1-9, what would you say?" If the participant failed the example, the experimenter said: "No, you would say 7-1-9. I say 7-1-9, so all you have to do is repeat what I said. You would say 7-1-9. Now try these numbers. Remember, you have to repeat them back to me. 3-4-8." If the participant responded correctly (7-1-9), the experimenter said: "That's right," and proceed to Item 1. The child was presented with two trials for each of the memory storage items (i.e., starting from 2 elements to be remembered). The test was interrupted after failure on both trials of any item. In the Digit Span Backward and Forward Test the task was identical, except for the fact that the child had to repeat the elements in the opposite order concerning their original presentation. In the Corsi Block-Tapping Test, we said: "Now I am going to show a board on which there are nine blocks. Now, I will touch some of these blocks, and you will have to copy what I will do. Let's try". If the participant failed the example, the experimenter had to state: "No, you would touch these blocks like this … Now try…." Whether the participant responded correctly, the experimenter proceeded to the testing items.

Main Experiment: Mental Time Line Task

The first task administered after the working memory assessment phase was the Mental Time Line task. Audio stimuli were recorded using Audacity software (GNU General Public License). A picture showing a personal or non-personal event referring to the past or the future was presented to the children; upon the presentation of the pictures, participants listened to a brief description of those events. Personal events described frequent events happening in a children's life (e.g., Your fifth birthday) or that would likely occur in their future (e.g., You will learn to drive). Non-personal events were referred to another imaginary child called Alex. Children were told that Alex was a child just like them, with the same age and enrolled in the same class in primary school. In each block, they had to indicate for each event whether the event referred to the past (e.g., Alex's last school trip) or the future (e.g., Alex's next sleepover). Each block also contained some 'no-go' distractor items, related to non-temporal categories, such as fruits (e.g., the banana is yellow) or animals (e.g., the dog is brown) (please see Appendix I and Appendix J). Participants were invited to complete four blocks: two involving personal events (i.e., in the congruent and incongruent settings), and two involving responses to non-personal events (i.e., again in congruent and incongruent settings). Participants sat in front of a personal computer aligned with the center of the screen and wore headphones. A plywood board was connected to Makey Makey sensors, and they grasped in the non-dominant hand a sensor that turned on the device. Makey Makey was the same device used in Italian adults' experiment reported in the previous Chapter. E-Prime 2.0 (Psychology Software Tools, Pittsburgh, PA, USA) was used to administer the task and record responses. Participants made their responses in the sagittal axis. A wooden board with three metal plates was positioned alongside them and was connected to Makey Makey and E-Prime. Participant's hand rested on the middle plate at the start of each trial, and they moved their hand either forward or backward to touch one of the other two plates on each of the experimental trials. Congruency was manipulated in separate blocks. In the congruent conditions, participants moved their hand backward for past events and forwarded for future events, with the reversed mapping for the incongruent conditions. Each of these four blocks comprised 48 trials (36 test trials and 12 distractor trials). They also completed six practice trials before each block, and they had a short break between each block. Stimuli duration was 1300 ms and time to respond was 1500 ms, with an interstimulus interval of 1000 ms.

Events Vividness and Likelihood Survey

At the end of the experimental session, participants completed a short 'Events Vividness and Likelihood Survey' regarding personal events listened in the computerized task. Children were shown with five pictures that represented the same landscape gradually becoming blurred to indicate the vividness levels of their memories and future events. Each picture corresponded to a score of a 5-point Likert scale that specified how clearly they could remember each personal or non-personal past event, and how likely each event could occur in the future. To record the participants' responses, we used an ad-hoc questionnaire (please see Appendix K).

Data Analysis

Reaction Time (RTs)

We opted to analyze our data using two statistical approaches. In a first approach, we included all children (i.e., thus for a total of 49) and their performance was analyzed through classical analyses of variance. 48 children (24 females; mean age 7.44 ± 1.05 years) were analyzed and divided into two groups depending on their age, 25 children aged six-seven (12 females; mean age 6.56 ± 0.51 years; named as the younger group in the reaming of the chapter), and 23 children aged eight-nine (12 females; mean age 8.39 ± 0.50 years; named as the older group). In this case, we specifically analyzed the accuracy, reaction times, and a combined score of these two variables. Reaction times above 100 ms and below 3500 ms were considered for the Choice and for the Answer the reaction times suppress the 100 ms (i.e., the time to release the starting sensor/button (Choice RT), and the time to press the second response sensor button, computed from the release of the starting sensor/button; Answer RT). Obviously, by also considering the children with a high error rate, accuracy is deemed to be the most informative variable with this first statistical approach. However, we could also explore whether any observed pattern for accuracy is then replicated for RTs and the combined score, thus informing more generally about the participants' performance.

Next, in a second approach, we focused more specifically on RTs and 31 children (15 females; mean age 7.54 ± 1.04 years) were analysed and divided into two groups depending on their age: 15 children aged six-seven (7 females; mean age 6.58 ± 0.50 years; named as the younger group in the reaming of the chapter), and 16 children aged eight-nine (9 females; mean age 8.39 ± 0.49 years; named as the older group). In this case we used a linear mixed model (LMM) approach and selected only those children who had at least 60 % of accurate responses in each experimental block. In this way, we could thus explore whether these two approaches converge on the same pattern of results, thus being indicative of the same behavioural performance.

First statistical approach (all children considered and focus on accuracy scores)

We examined participants' reaction times and accuracy along the sagittal axis as a function of nature (personal or non-personal) of the events and space-time congruency (congruent or incongruent). Participants' latency reaction times (i.e., latency from the start of the experimental stimulus, named choice RT) were measured. Only responses more significant than 100 ms and less than 3500 ms were considered. In particular, we tested the within-subjects effects of Memory (personal and non-personal events) and Congruency (congruent and incongruent), as well as the between-subjects effect of Age-Group (younger: 6-7 y.o.; older:8-9 y.o.) on the participants' Reaction Times (RT) and accuracy level. To do so, we, therefore, performed three separated Repeated Measures ANOVA using Jamovi 0.9.1.0. The first two mixed ANOVA was performed on the proportion of correct responses and on Reaction time. Reaction times were normalized and converted to their logarithm before entering them as the dependent variable in the ANOVA. We further computed the Inverse Efficiency Score (IES), as a composite score for both RT and accuracy (i.e., mean correct RT divided by the percentage of correct responses in a given condition). All effects were statistically significant at the .05 significance level, and effect sizes were calculated used partial η^2. Post-hoc analyses were carried out to improve understanding of the interaction effects with Bonferroni correction.

Proportion of Correct Responses

A first mixed ANOVA on the proportion of correct responses was performed. We found a Significant within-subjects effect was found for Congruency (F (1, 46) = 6.44, p = .015 $\eta^2 p$ =.12), indicating a significant difference between the congruent condition (M = 0.65, SD = 0.22) and the incongruent condition (M = 0.61, SD = 0.23), with children being more accurate in the former condition (Figure 25). We found a significant effect of Age-Group (F (1, 46) =5.62, p = .022, η^2 p = .11), with more correct responses for older (M = 0.69, SD = 0.19) than younger children (M = 0.57, SD = 0.23).We also found a significant effect of Memory (F (1, 46) = 15.04, p < .001, η^2 p= .22), with more accurate responses to personal events (M = .64, SD = .24) than non-personal events (M = 0.62; SD = 0.22). Further, we found a significant interaction between Memory × Age-Group (F (1, 46) = 6.97, p = .011 $\eta^2 p$ =.10) showed a significant effect (Figure 26).

Post-Hoc analyses with Bonferroni correction were conducted on all possible pairwise contrasts and showed a significant difference between non-personal (*M* = 0.61, *SD* = 0.18) and personal memory in older children (*M* = 0.77, *SD* = 0.18) (*p* = .001), as well as a significant difference between older children (*M* = 0.77, *SD* = 0.18) and younger children for personal memory (*M* = 0.59, *SD* = 0.25) (*p* =.01). Finally, all the other effects were not significant (see Table 5 for all main effects and interaction).

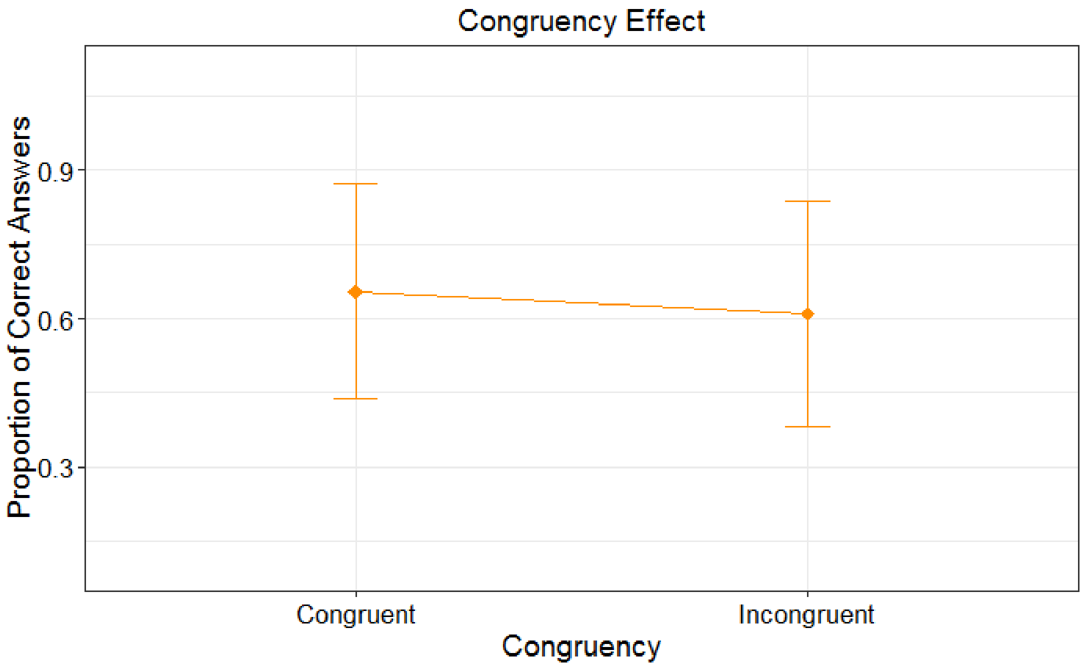

Figure 25. Congruency Effect. A significant difference between congruent (M =.65, SD = .22) and incongruent (M =.61, SD = .23), condition, with children being more accurate in the former condition.

Table 5. Table of proportion of correct responses, main effect, and interaction (between and within).

ANOVA Effects						
	Sum of Squares	**df**	**Mean Square**	**F**	**p**	**partial η^2**
Congruency	0.10	1	0.10089	6.44	0.015	0.12
Memory	0.44	1	0.44016	15.04	0 .001	0.22
Memory x Group	0.20	1	0.20397	6.97	0.011	0.10
Group	0.68	1	0.68	5.62	0.022	0.11

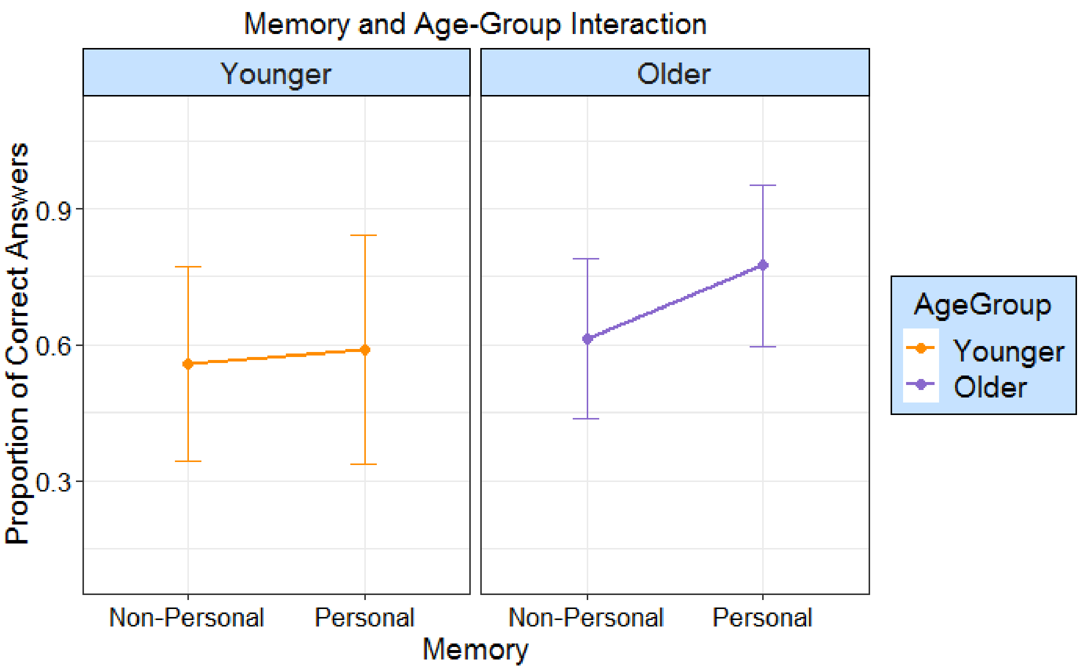

Figure 26. 2-way interaction Memory × Age-Group. A higher number of correct responses for personal memory (M = .64, SD = .24) as compared to non-personal memory (*M* = 0.62; *SD* = 0.22). Also, it was found significant difference between non-personal (*M* = 0.61, *SD* = 0.18) and personal memory (*M* = 0.77, *SD* = 0.18) in older children. A significant difference between older children (*M* = 0.77, *SD* = 0.18) and younger children for personal memory (*M* = 0.59, *SD* = 0.25) was found.

Reaction Time (RTs)

Next, we performed a mixed ANOVA on correct Reaction Times. We found a significant effect of Congruency (F (1, 46) =7.29, p = .010, $\eta^2 p$ = .13), with faster reaction times in the congruent (M = 1995, SD = 270.8) than in the incongruent condition (M = 2065, SD = 289.9) (Figure 27).

Table 6. Table of RT(s), main effects.

ANOVA Effects						
	Sum of Squares	**df**	**Mean Square**	**F**	**p**	**partial η^2**
Congruency	242957	1	242957	7.29	0.010	0.13
Memory	892158	1	892158	25.93	0.001	0.35

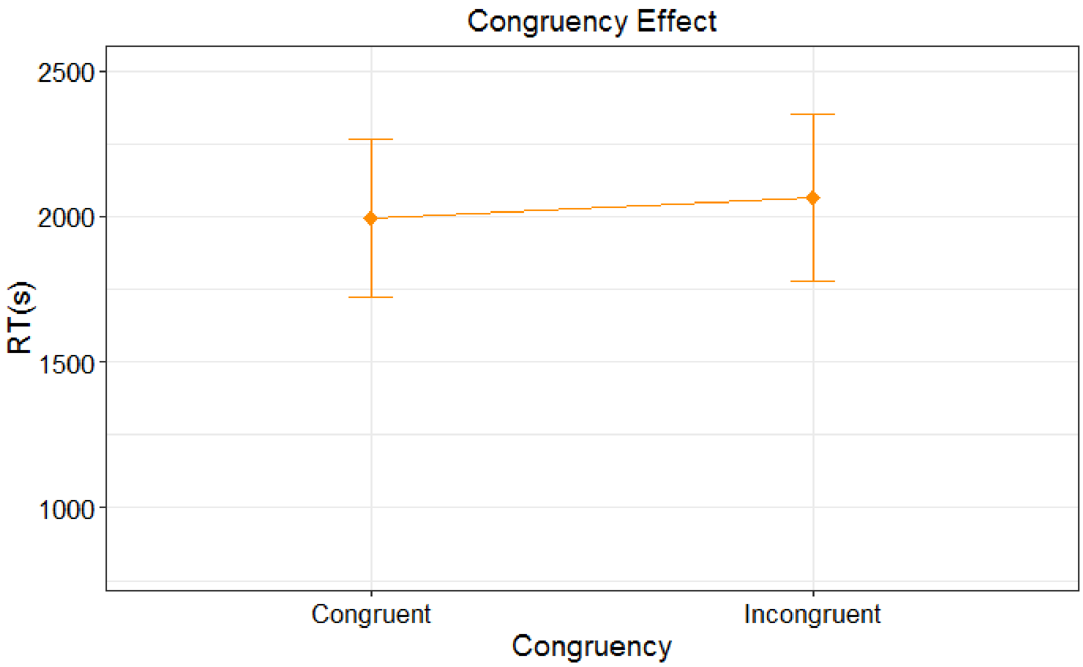

Figure 27. Congruency Effect. A significant difference between the congruent (M = 1995, SD = 270.8) and in the incongruent (M = 2065, SD = 289.9) condition was found.

The analysis showed also a significant effect of Memory (F (1, 46) = 25.93, $p < .001$, $\eta^2 p = .35$), with faster RTs for personal memory (M = 1963, SD = 284,39) than non-personal Memory (M = 2097; SD = 264,29)(see Figure 28 and Table 6 for all main effects).

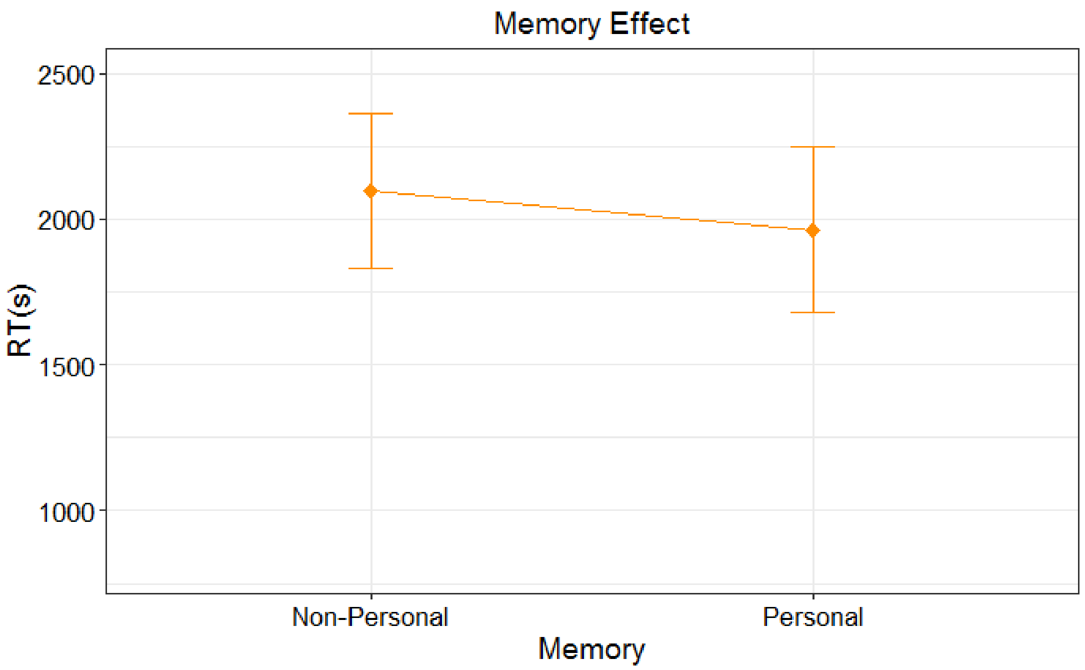

Figure 28. Memory Effect. A significant difference between personal (M = 1963, SD = 284,39) and non-personal (M = 2097; SD = 264,29) memory was found. Faster RTs was recorded in personal memory condition.

Inverse Efficiency Score (IES)

A mixed ANOVA on Inverse Efficiency Score (IES) were performed, IES were normalized and converted to their logarithm-based value before. We found a Significant within-subjects effect was found for Congruency (F (1, 46) = 6.60, p = .013 $\eta^2 p$ =.12), indicating a significant difference between the congruent condition (M =3.51, SD = 0.21) and the incongruent condition (M = 3.56, SD = 0.26), with children being more accurate in the former condition.

We found a significant effect of Age-Group (F (1, 46) =6.92, p = .012, $\eta^2 p$ =.13), with more correct responses for older (M = 3.48, SD = 0.17) than younger children (M =3.60, SD = 0.25).We also found a significant effect of Memory (F (1, 46) = 10.35, p = .002, $\eta^2 p$ = .17), with more accurate responses to personal events (M = 3.58, SD = 0.21) than non-personal events (M = 3.50; SD = 0.23). Further, we found a significant interaction between Memory × Age-Group (F (1, 46) = 4.24, p = .045 $\eta^2 p$ =.07) (Figure 29).

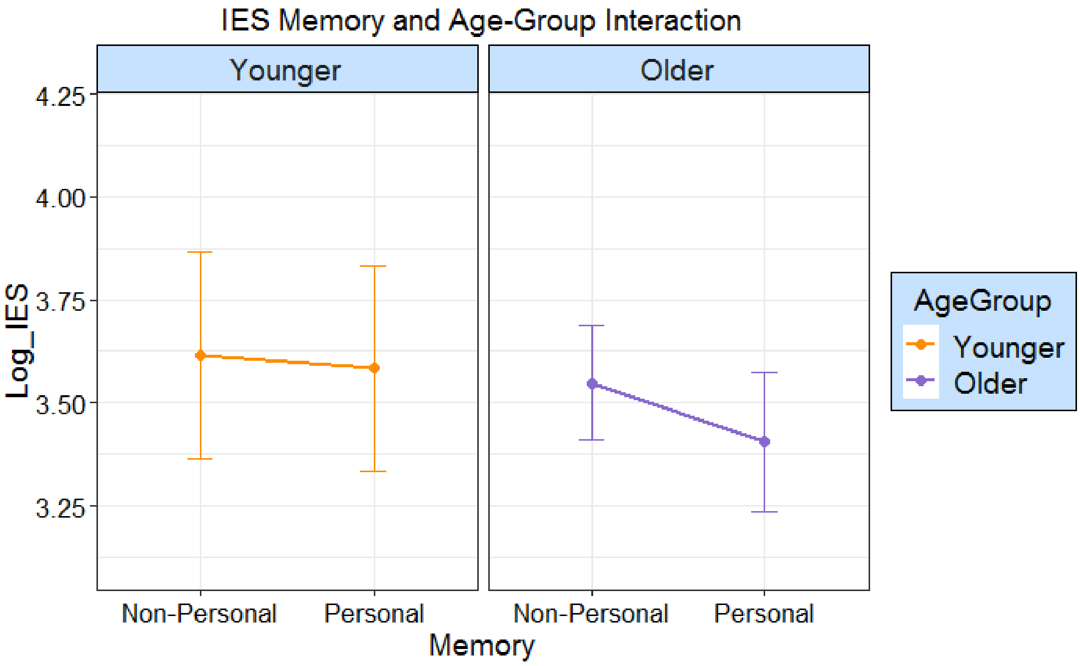

Figure 29. 2-way interaction Memory × Age-Group. A significant difference was found between a significant difference between non-personal (*M* = 3.55, *SD* = 0.14) and personal memory in older children (*M* =3 .40, *SD* = 0.17), as well as a significant difference between older children (*M* = 3.40, *SD* = 0.17) and younger children for personal memory (*M* = 3.58, *SD* = 0.25).

Also, we found a significant interaction effect Congruency × Memory (F (1, 46) = 4.53, p = .039 $\eta^2 p$ =.09) (Figure 30).

Post-Hoc analyses with Bonferroni correction were conducted on all possible pairwise contrasts and showed a significant difference between non-personal (*M* = 3.55, *SD* = 0.14) and personal memory in older children (*M* = 3 .40, *SD* = 0.17) (*p* = .004), as well as a significant difference between older children (*M* = 3.40, *SD* = 0.17) and younger children for personal memory (*M* = 3.58, *SD* = 0.25) (*p* =.009). Finally, all the other effects were not significant. Also, post-hoc showed a significant difference between congruent non-personal (*M* = 3.53, *SD* = 0.15) and incongruent non-personal memory (*M* = 3.63, *SD* = 0.24) (*p* = .007), as well as a significant difference between incongruent non-personal (*M* = 3.63, *SD* = 0.24) and incongruent personal memory (*M* = 3.51, SD = 0.21) (p = .001), (see Table 7 for all main effects and interaction).

Table 7. **IES, main effects, and interaction.**

ANOVA Effects						
	Sum of Squares	**df**	**Mean Square**	**F**	**p**	**partial η^2**
Congruency	0.14	1	0.14	6.60	0.013	0.12
Memory	0.36	1	0.36	10.35	0.002	0.17
Memory x Age-Group	0.15	1	0.15	4.24	0.045	0.07
Congruency x Memory	0.06	1	0.06	4.53	0.039	0.09
Group	0.74	1	0.74	6.92	0.012	0.13

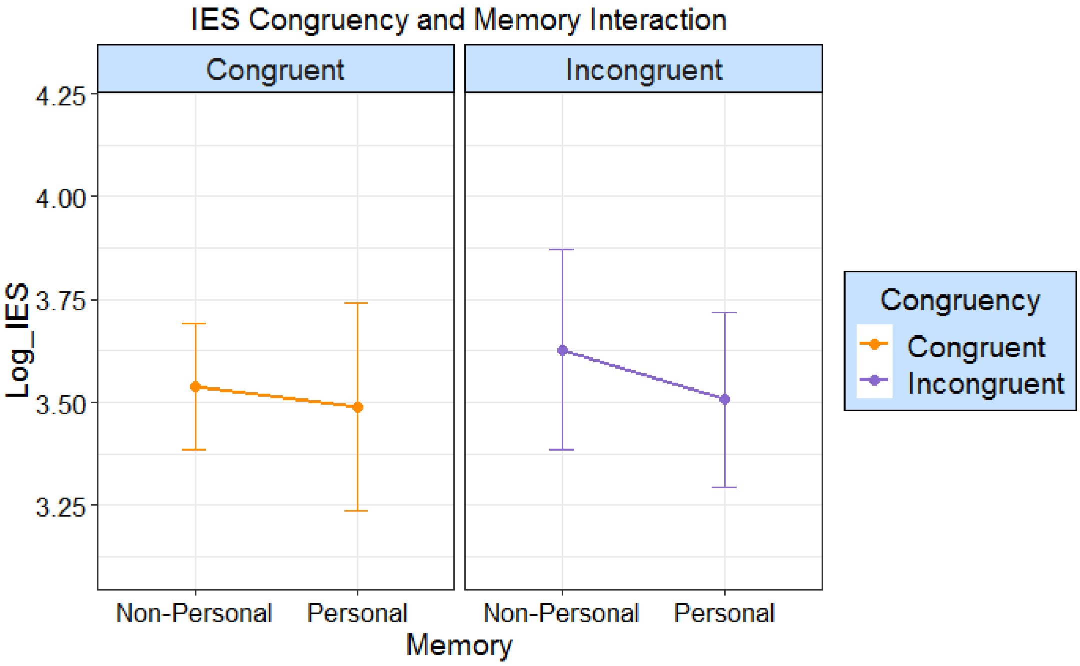

Figure 30: **2-way interaction Congruency × Memory.** A significant difference was found between difference between congruent non-personal (M = 3.53, SD = 0.15) and incongruent non-personal memory (M = 3.63, SD = 0.24), as well as a significant difference between incongruent non-personal (M = 3.63, SD = 0.24) and Incongruent personal memory (M = 3.51, SD = 0.21).

Second statistical approach (only children performing the task correctly)

Reaction Time (RTs)

In this second statistical approach, we used Generalized Linear Mixed Models to test whether the effects found in the proportion of correct responses, Efficiency Score (IES) and Reaction time analysis could be confirmed. The analysis was performed using the lme4 package (Bates et al, 2015) of the R environment (R Development

Core Team, 2006). Thirty-one children (15 females; mean age 7.54 ± 1.04 years) were analysed and divided into two groups depending on their age: 15 children aged six-seven (7 females; mean age 6.58 ± 0.50 years; named as the younger group in the reaming of the chapter), and 16 children aged eight-nine (9 females; mean age 8.39 ± 0.49 years; named as the older group).

Congruency, Memory and Age-Group factor were entered in the model as categorical predictors (i.e., fixed effects); while the Subject, Item, Trial, and Session (i.e., session considers the order of personal and non-personal block in the congruent and incongruent condition in each mapping) were entered as random effects. Reaction times were normalized and converted to their logarithm before entering them as the dependent variable. The analysis started with a full factorial model, which was progressively simplified by removing the variables that did not significantly contribute to the goodness of fit of the model (i.e., the result of the likelihood ratio test comparing the goodness-of-fit of the model before and after removing the effect of each non-significant parameter). All the parameters were significant and, therefore, no one of them was excluded. Restricted Maximum Likelihood (REML) gives estimates for the variance components, and it produces less biased estimates than the maximum likelihood (ML) of the variance component, and the estimates can be improved. We compared the full model (with random and fixed effects) vs. null model (only random effects) to choose the best model that can represent the effect on the reaction times using ANOVA. AIC lower values confirmed a better fit for the full (-5784.4) than the null model (-5743.2). Once the model was fitted, atypical outliers were identified and removed (employing 2.5 *SD* of the residual errors as a criterion). All effects were statistically significant at the .05 significance level. Post-hoc analyses were carried out using the phia R package (De Rosario-Martinez, Fox & Core Team, 2015). We found a significant effect of Congruency (F (1, 2534) = 8.30, p = .004) (Figure 31) indicating lower reaction times for the congruent (M = 3.29, SD = 0.01) than the incongruent condition (M = 3.30, SD = 0.01). A significant effect was found also for Memory (F (1, 21) =5.28, p = .032), with lower RTs for personal (M = 3.28, SD = 0.02) than non-personal memory (M = 3.31, SD = 0.02). Also, a tendency to a significant difference was found in Age-Group (F (1,29) = 3.01, p = .09). A significant interaction between

Table 8. **RT(s) main effects and interaction.**

ANOVA Effects						
	Sum of Squares	**df**	**Mean Square**	**F**	**p**	**partial η^2**
Congruency	0.05	1	0.05	2534.15	8.30	0.004
Memory	0.03	1	0.03	20.82	5.28	0.032
Congruency x Age-Group	0.04	1	0.04	3070.94	6.82	0.009
Memory x Age-Group	0.24	1	0.24	3102.37	36.93	0.001

Memory × Age-Group (F (1, 31) = 36.93, p < .001) was found (Figure 32), also a significant interaction between Congruency × Age-Group (F (1, 31) = 6.82, p = .009) was found (Figure 33). Post-hoc analysis showed a significant difference between congruent (M = 3.27, SD = 0.02) and incongruent condition (M = 3.29, SD = 0.02) in older children (p = 0.001), also a significant difference in non-personal memory (M = 3.30, SD = 0.02) and personal memory (M = 3.26, SD = 0.02) in older children (p=0.001), (please see Table 8 for all main effects and interaction).

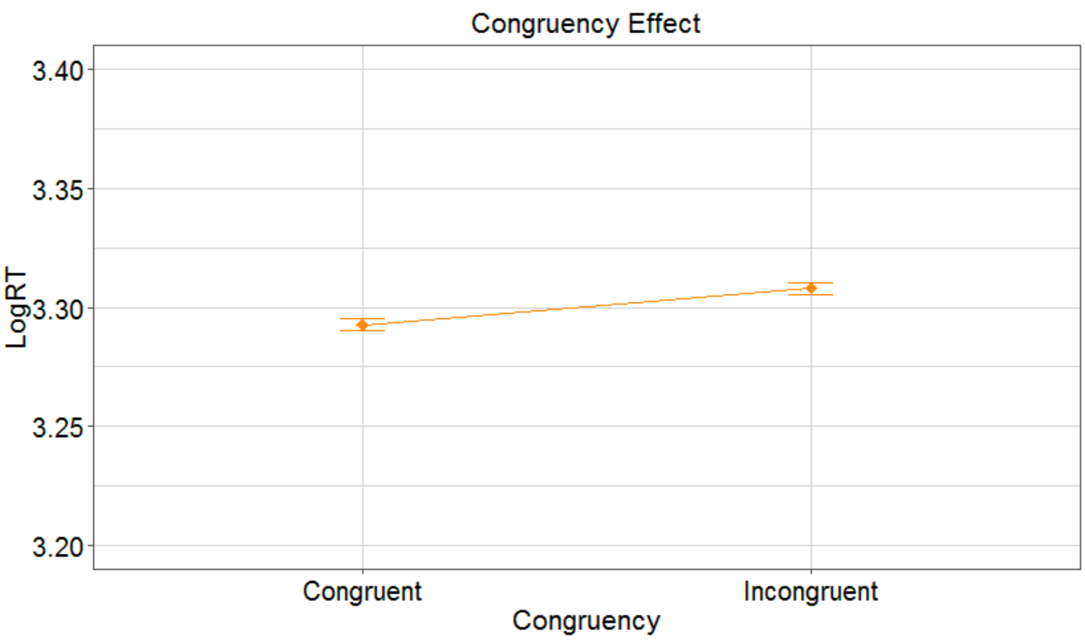

Figure 31. **Congruency Effect.** A difference between congruent (M = 3.29, SD = 0.01) and Incongruent condition (M = 3.30, SD = 0.01), lower reaction times were found in the congruent condition.

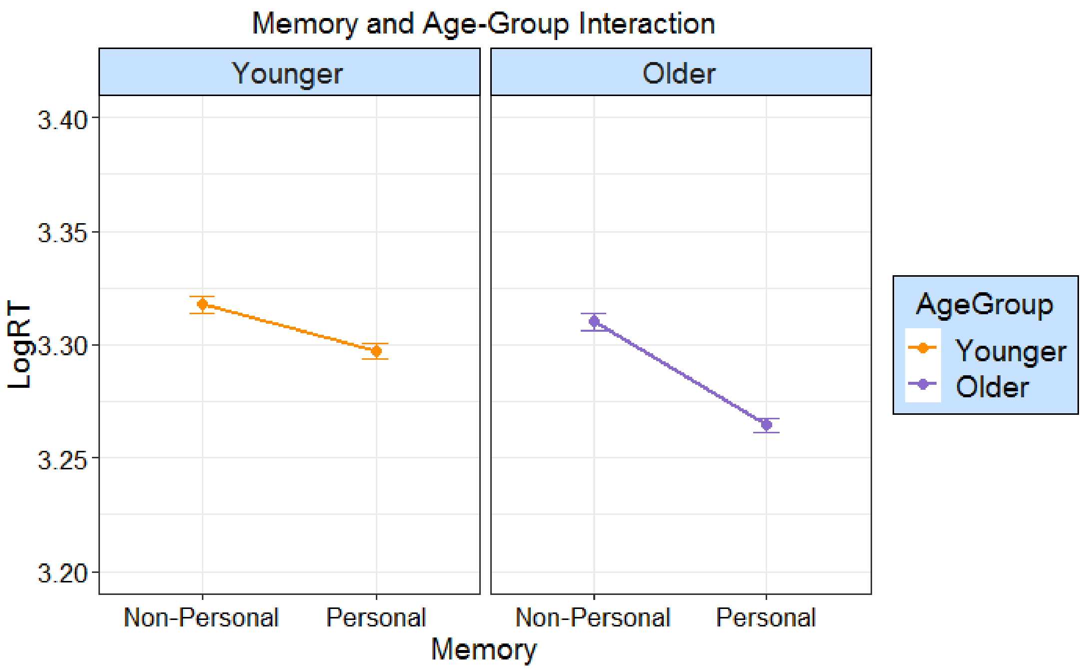

Figure 32. 2-way interaction Memory × Age-Group. Differences between non-personal (*M* = 3.30, *SD* = 0.02) and personal memory (*M* = 3.26, *SD* = 0.02) in older children. Groups recorded faster reaction times in personal memory and older children were faster than younger.

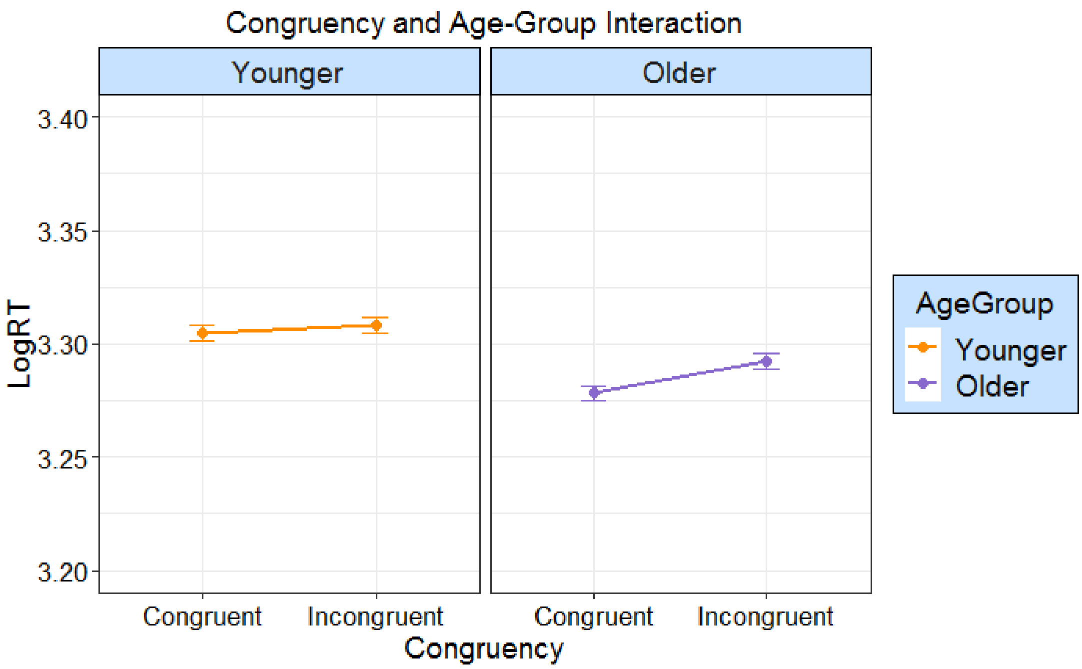

Figure 33. 2-way interaction Congruency × Age-Group. Differences between congruent (*M* = 3.27, *SD* = 0.02) and incongruent condition (*M*=3.29, *SD* = 0.02) in older children.

Table 9. Summary table of Fixed Effects of Accuracy.

	Fixed Effects			
	Estimate	**SE**	**z value**	**p**
Memory	-0.34	0.10	-3.24	0.001
Memory x Age-Group	-0.17	0.37	-4.72	0.001

Accuracy

We used the glmer function of the lme4 package to perform Mixed Effects Logistic regression to model binary outcome variables for analysing accuracy scores. The log odds of the outcomes are modelled as a linear combination of the predictor variables considering fixed and random effects. Congruency, Memory, Age Group, and Memory by Group were considered as fixed factors, whereas Subject as a random intercept, thus fully replicating the model for RTs. A significant difference was found between non-personal (*M* = 0.59, *SD* = 0.11) and personal (*M* = 0.80, *SD* = 0.08) memory in older children (*p* = 0.001) (Figure 34). Children were more accurate in personal memory task. Also, we found that older children were more accurate than younger as demonstrate by the fixed effects table (see Table 9) and RTs analysis.

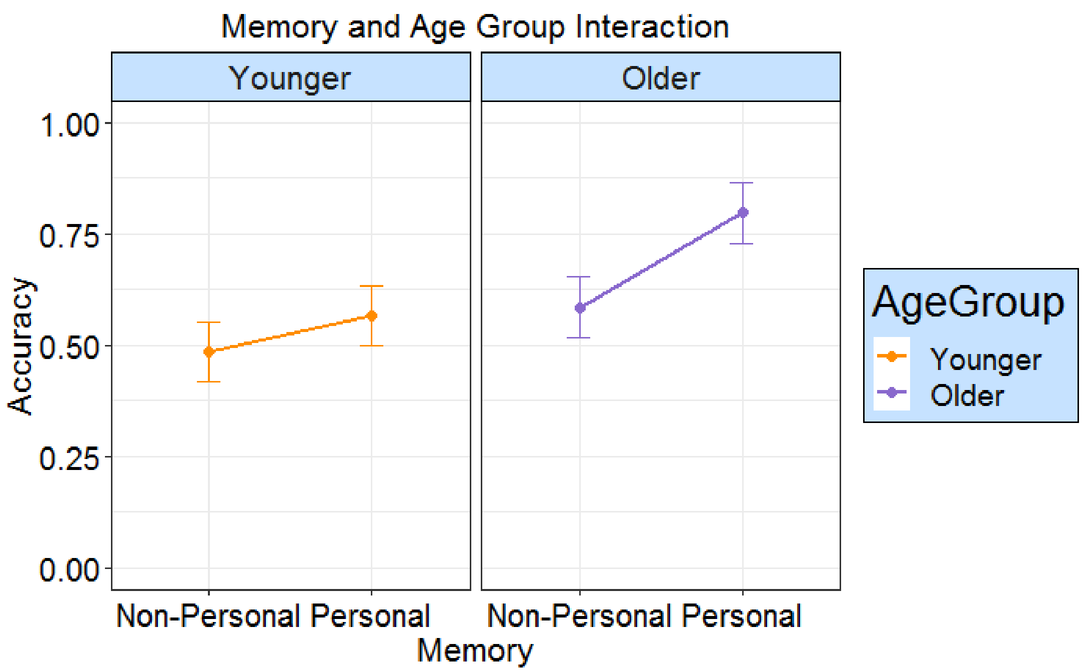

Figure 34. Accurate Answers in Memory. A significant difference between non-personal and personal memory.

Together, results from both statistical approaches concur in highlighting a significant congruency effect. Such an effect testifies a preferential association between past events and backward movements, and future events and forward movements, thus being reminiscent of the sagittal MTL observed in adults.

A zoom on the congruency effect – Time Reaction Time (RTs)

To explore the effects of Time and the direction of Movement on the participants' RTs, we used Generalized Linear Mixed Models. We used the same procedure described in the previous analysis. We performed the analysis for each Age-Group, Younger, and Older. The within-subjects effects of Time (past and future), Memory (personal and non-personal events), and the between-subjects effect of Movement (backward/forward) were analysed. All these independent variables were thus entered in the model as categorical predictors (i.e., fixed effects). Reactions times were normalized and converted to their logarithm-based value before entering them as the dependent variable. Further, Trial, Event, Session (i.e., session consider the order of personal and non-personal block in the congruent and incongruent condition in each mapping) and subject were included in the analyses as random intercepts, as supported by a Likelihood Ratio Test for random effects variances. We next tested the full model against a null model (i.e., only random effects) and selected the best model based on stepwise selection (backward elimination of non-significant effects). The best model was identified as the full model with all simple and interactive terms. Once the model was fitted, atypical outliers were identified and removed (employing 2.5 SD of the residual errors as a criterion). The models were then refitted to ensure that the results were not driven by a few excessively influential outliers.

In the younger Age-Group we found a significant effect in Time (F (1, 21) = 15.47, p <.001) (Figure 35), with lower RTs for future (M = 3.30; SD =0.02) than past (M =3.33, SD = 0.02).

In the older Age-Group we found a significant effect in Memory (F (1, 21) = 16.60, p <.001), with lower RTs for personal (M =3.26; SD =0.01) than non-personal (M =3.31, SD = 0.02); also a significant effect in Time (F (1, 23) = 9.18, p = .006), with lower RTs for future (M =3.26; SD = 0.02) than past (M = 3.30, SD = 0.02). Critically, we also found a 2-way interaction Time × Movement (F (1, 14) = 13.52, p

<.001) (Figure 36). Post-Hoc analysis was conducted to explore whether a time effect was differently modulated by movement content. A tendency to significant effect was found in Memory × Time × Movement (F (1, 16) = 3.39, p = .065). Post-Hoc performed with Bonferroni correction showed a significant difference between the Forward Movement in Future (M= 3.25, SD = 0.02) and Forward Movement in the Past condition (M = 3.30, SD = 0.02) (p =.001).

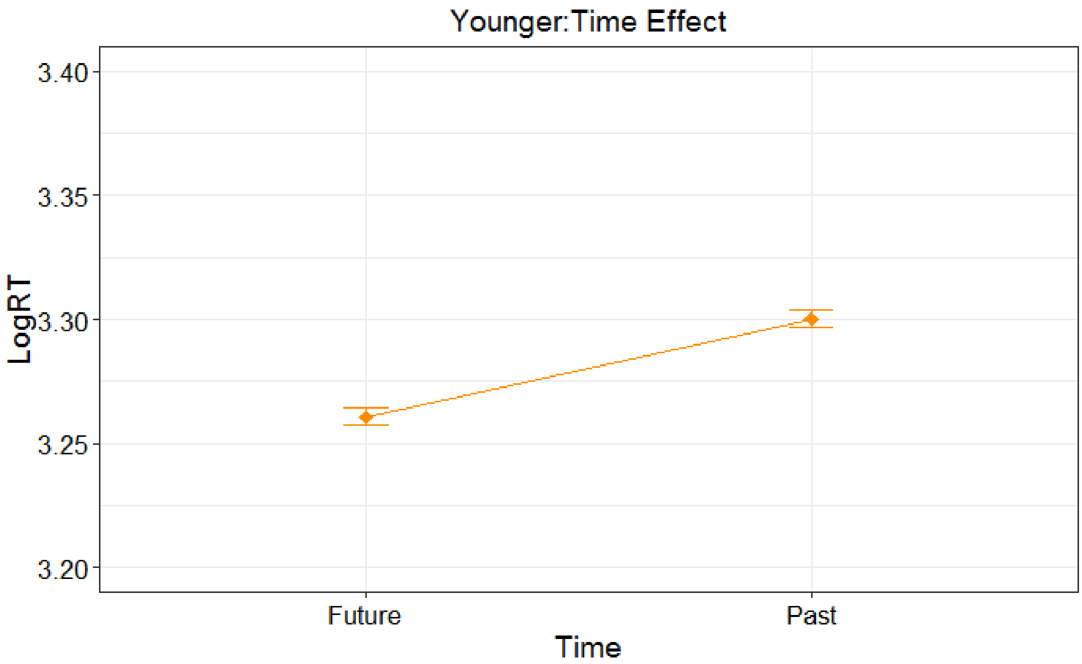

Figure 35. Time Effects Younger. Participants recorded lower RTs in for the future than for the past.

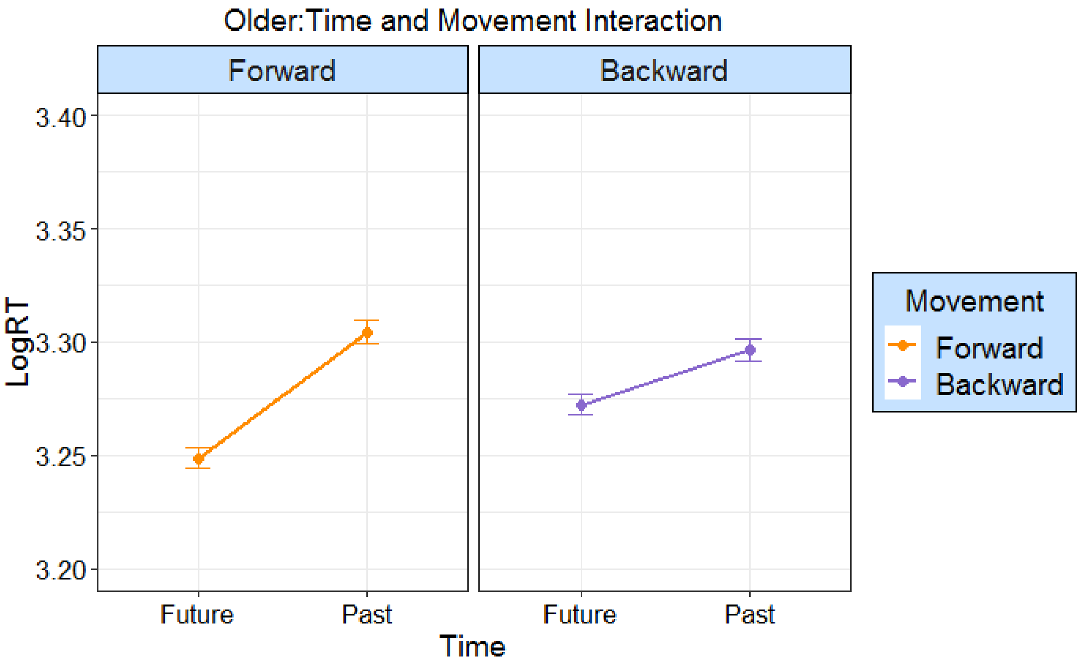

Figure 36. 2-way interaction Time × Movement Older. Participants recorded lower RTs forward for the future.

Therefore, these further analyses that consider the temporal component and the movement underline once again that the representations of events, younger participants recorded lower RTs for the future than for the past. Also, older participants recorded lower RTs forward for the future.

Vividness and Likelihood Survey analysis, results and discussion

Children participants at the end of the experiment completed the "Events Vividness and Likelihood Survey," for each event presented using five images that represents a landscape. Each Likert scale scores (i.e., pretty unclear, not so clear, somewhat clear, very clear and very very clear) corresponded to a level of image sharpness (Appendix K). The experimenter read the instructions to the child: "Often when we think about things that have happened to us or will happen to us. We have a picture of them in our heads. In this bit, I will ask you to think about different things that have happened to you or will happen to you, and I want you to use these pictures to show me how clear each of these things looks to you when you think about them. This means that it looked not at all clear (pointing left to right), pretty unclear, not so clear, somewhat clear, very clear and very, very clear.". Events regarded only personal events (e.g., "How well do you remember your "Last Halloween Fancy Dress?"; "How likely can be occur your "Next Christmas Dinner" in the future?"). A Descriptive Statistic Analysis of Likert points for each personal event using SPSS Statistics 25 software was carried out in each Age Group. Effects were plotted using the R environment and ggplot2 (R Development Core Team, 2006; Wickham, 2016). The purpose was to verify how clearly, they could remember each personal or non-personal past event, and how likely they could imagine each future event. Children six and seven aged have totalized an average and standard deviation respectively of: Past Personal: (M = 3.55, SD = 0.74); Future Personal: (M = 3.77, SD = 0.65) (Figure 37), while children eight and nine aged have totalized respectively Past Personal: (M = 2.89, SD = 0.68); Future Personal: (M = 3.15, SD = 0.95) (Figure 38).

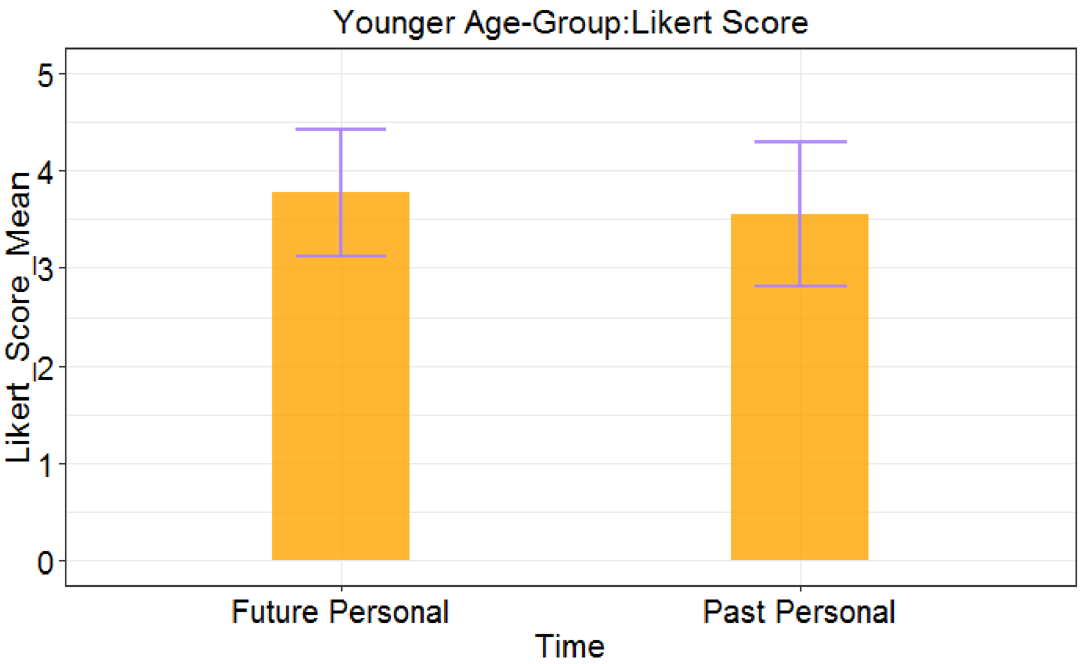

Figure 37. Mean and Standard Deviation of Likert Score. Personal and non-personal events in "Vividness and Likelihood Survey." Children 6-7 aged Likert Score.

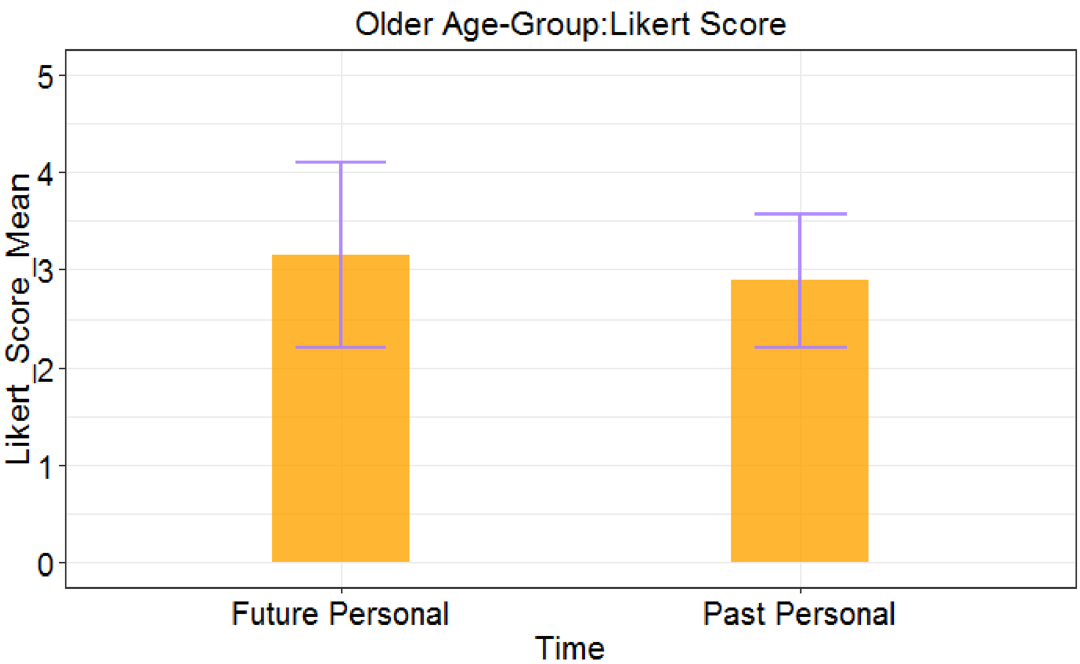

Figure 38. Mean and Standard Deviation of Likert Score. Personal and non-personal events in "Vividness and Likelihood Survey." Children 8-9 aged Likert Score.

Afterward, like in the first study, we investigated whether the vividness of the memories and the ease or not to imagine a future event could influence the speed of reaction times. Therefore, a correlation analysis was performed between participants' reaction times differential score obtained in the Mental Time Travel task (i.e., the scores of the congruent condition were subtracted from the scores of the incongruent condition) and the Likert scores obtained in the survey, both the scores were converted in Z value. A Pearson correlation coefficient was computed to assess the relationship between Likert scores and IES, RT, Proportion of correct answers A correlation between the Likert scores and younger participants' IES in particular between Future Survey and Future IES (r=.455, n 25=, p = .022) was found. The participants obtained higher Likert scores in future events, considering them likely than the vividness scores of past events. Therefore, they were faster in classifying future events.

Working Memory Assessment

To correct and standardize Digit Span Backward and Forward Test (REF) and Corsi Block-Tapping Test (Corsi, 1972), we used Linear Models. The analysis was performed using the lme4 package (Bates & Sarkar, 2006) of the R environment (R Development Core Team, 2006). Digit Span Backward and Forward scores were calculated separately. Three different analyses were performed and Corsi Span, Digit Span Backward and Forward factor were entered in the model as a dependent variable; while Age as fixed effects. After we carry out regression also, we calculated residuals scores for each span and each participant. Younger children obtained lower scores than older children: Corsi Span Younger (M = -0.06, SD = 1,07) and Corsi Span Older (M = 0.07 , SD = 0.88); Digit Span Backward Younger (M = -0.13, SD = 0.09) and Digit Span Backward Older (M = 0.15, SD = 1.44); Digit Span Forward Younger (M = 0.06 , SD =1.73) and Digit Span Forward Older (M = 0.07 , SD = 2.02). Therefore, a correlation analysis was performed between participants' reaction times differential score obtained in the Mental Time Travel task (i.e., the scores of the congruent condition were subtracted from the scores of the incongruent condition) and tests scores. Afterward, using SPSS Statistics 25 software, Pearson correlation coefficient was computed to assess the relationship between residuals scores of Corsi Span, Digit Span (i.e. Backward and Forward) and IES, RT, Proportion of correct answers, all scores were converted in Z value. A correlation was found between Corsi Span and Proportion of correct answers of Personal events (r = .475, n =23, p = .022), also a correlation was found between Corsi Span and IES of Personal events (r = -.415, n =23, p = .049). It appears that the higher the differential score of Proportion of correct answers (i.e., more corrected answers), the higher the score of the Corsi Block-Tapping Test. Also, it appears that the lower the differential score of IES (i.e., more corrected answers), the higher the score of the Corsi Block-Tapping Test. So, it is likely that this ability correlates with the spatial representation of personal events skill.

4.5 Interim Discussion

Native English schoolchildren performed the experiment seated and blindfolded. We found a congruency effect on the sagittal space: participants were faster and more accurate to respond to personal events than non-personal events . The questionnaire administered at the end of the experimental task confirmed that participants remembered and processed well the events presented in the experiment. It also indicates that participants considered possible that these events will occur in the future. The participants obtained higher Likert scores in future events, considering them likely than the vividness scores of past events. Therefore, they were faster in classifying future events. We also notice that the lower the differential score of IES (i.e., more corrected answers in personal memory), the higher the score of the Corsi Block-Tapping Test. So, it is likely that this ability correlates with the spatial representation of personal events. All these results, however, corroborate the possibility that the observed findings are specifically related to the space-mapping representation of memories. Children's understanding of time reflects the same distinctions between past, present, and future like adults, in particular in older children.

4.6 General Discussion

The two studies described in this chapter aimed at shedding further light on the origins of space-time mapping in school-aged children. Indeed, to the best of our knowledge, no study had so far investigated whether children show a sagittal MNL and whether this construal is mainly determined by sensorimotor or linguistic experience.

In the first study, we explored more deeply the possible origins of the sagittal MTL in Italian school-age children, by comparing directly the sensorimotor hypothesis and the linguistic hypothesis. To do so, participants were asked to perform both a motor classification task, like the one used in the previous Chapter, as well as a purely linguistic task, readapted from the IAT. We first validated the paradigm to verify its sensitivity to the evaluation of our hypothesis on a sample of adults. Results supported the presence of space-time associations in both tasks and, thus, at both linguistic and motor levels. A similar association was reported at the linguistic level for terms referring to spatial and temporal distance. This pattern almost reached significance in the motor task. Next, we involved 3rd, 4t, and 5th-grade children and explored the presence of space-time associations as a function of age. Results indicated that the tendency to map past events with locations behind the body and future events with locations in front of it was already present at a young age in the motor task. Most notably, the size of the congruency effect did not differ as a function of age.

On the contrary, and critically concerning our purposes, the linguistic association as tested by the IAT was modulated by age. Indeed, only 4th and 5th grades children showed a congruency effect, meaning that they performed more accurately the congruent than the incongruent condition. The younger group of children (i.e., 3rd grades) in turn did not show any congruency effect. The specificity of these results was supported by the distance task. In this case, indeed, we found a congruency effect at the motor level, not modulated by age. Critically, however, all children showed a linguistic congruency effect. That is, all children irrespective by age, performed more accurately the congruent than the incongruent condition, matching temporal and spatial terms together. Thus, the association between space (back, front) and time (past, future) is present at the motor level starting from a young age, but not at the linguistic level. Despite existing literature (e.g., Eikmer et al., 2015), has suggested that the compatibility effect observed at the motor level emerges at higher levels of cognition, possibly reflecting a conceptual overlap due to language statistics between terms referring to space and time, our results do not support this view. Instead, our results suggest that sensorimotor experience may be more critical in setting the sagittal MTL.

The second experiment, conducted on English schoolchildren aged six-seven and eight-nine years old, aimed to study the ontogeny of personal and non-personal events representation on the sagittal axis, thus in analogy to the studies reported in Chapter 2. However, in contrast with the methods employed in Chapter 2, we replaced public events (as this type of non-personal memory may be not sufficiently developed in children), with events referred to an imaginary third person, named Alex. Only a few studies in the literature have investigated the mapping of personal and non-personal events and how this emerges in development, but not using a computerized task like in this experiment. The results showed that the MNL on the sagittal axis is more evident at eight-nine years of age than at six-seven when considering RTs, as results showed the congruency effect is affected by the age of children. In general, inded, we observed that older children (eight-nine aged) showed a better performance than younger children (six-seven aged). Further, older children were particularly better in performing the task with personal memory events than non-personal events. Yet, when considering accuracy (i.e., probably the most reliable dependent variable when considering young children), a congruency effect was found in both groups. This pattern of results was found irrespective of the dependent variable considered (i.e., accuracy, reaction times, and IES). Similarly, the pattern was consistent regardless of whether all the children were included or rather a subsample of those performing the tasks accurately.

This means that the tendency to associated past events with locations behind the body and future events with the space in front of it is already present, starting from a very young age. The findings were replicated in a sample of adults and replicate previous studies using motor tasks, such as the studies of Ulrich et al. (2012), Rinaldi et al. (2016) and Sell and Kaschak (2010). The type of memory content interacted with the congruency effect, meaning that personal events result in stronger response-side compatibility. The existence of such a modulation as a function of memory content may be explained by the fact that specific activation of the sagittal MNL triggered by personal events emerges early.

Moreover, the participants obtained higher Likert scores in future events, considering them likely than the vividness scores of past events. Therefore, they were faster in classifying future events. We also commented that the lower the differential score of IES (i.e., more corrected answers), the higher the score of the Corsi Block-Tapping Test. So, it is likely that Working Memory ability correlates with the spatial representation of personal events. Future studies may further explore this pattern of results, by exploring for instance whether the Corsi task taps more on an egocentric, personal perspective.

In summary, the comparison between Experiment 1 and 2 revealed some significant differences between adults and children. Regarding the time/space association, we found that in adult participants the representation of past-backward and future-forward is present both at the motor and the linguistic levels, giving rise to a congruency effect in all the tasks. In striking contrast, we observed that only the fourth- and fifth- grade children showed an association between space and time similar to adults' in the linguistic and motor task. The younger children instead showed a congruent effect only in the motor task but not in the linguistic ones. This pattern supports the motor hypothesis, according to which the association space-time would be determined by locomotion behaviour linking together space and time information (Clark, 1973; Sell and Kaschak, 2010).

The results obtained on the temporal distance are in line with Construal Level Theory (Trope & Lieberman, 2010): the stimuli that denote certain temporal proximity evoke the representations about the proximity in space, while the stimuli that indicate a temporal distance activate representations about distance in space. Thus, representations, of the high level of human cognition, can influence children's response to language tasks and may be involved in the development of spatial-distance temporal associations. This provides complementary evidence to the view that the representations of space and time are tightly interrelated.

Chapter 5

Final Discussion

The association between temporal information and space has led linguists, philosophers and cognitive neuroscientists to hypothesize the existence of a 'Mental Time Line' (MTL) (Bonato et al., 2012; Borodisky, 2000, 2001, 2007; Clark, 1973; Santiago et al., 2007). As thoroughly discussed in the previous chapters of this thesis, the origin of this mental construal has been traced back to two seemingly opposing hypotheses: Linguistic Hypothesis, and the Sensorimotor Hypothesis. The ability to mentally move from one event to another, from the past to the future, and to consciously think about the passing of time has been referred to as Mental Time Travel (MTT). A journey through time allows us to imagine new situations, what could happen in the future, relive or pre-create times and places, projecting the self over time (Tulving 1985, 2002; Atance & O'Neill, 2001). Mental Time Travel is related to Chronesthesia process (Tulving, 2002), and it is a detached mental construct that can be represented in sensorimotor systems that regulate movement.

Despite the great interest in the way humans represent temporal information, in literature, there was still a huge gap in the possible factors that may influence such a representation. Insofar, there was scarce evidence about the type of memory content that may shape the MTL. In this thesis, we particularly focused on the role of personal and non-personal events along the timeline (for example, horizontal or sagittal), filling a gap from previous research. Specifically, we asked: How does our mind represent and process domains such as time and space? What are the factors that may influence such a spatial-time representation? What is the age at which the space-time representation appears? What are the differences between adults and children representation of time? Personal or non-personal memories, sentences with temporal references can be represented along with the timeline differently? The present doctoral thesis has focused on these aspects and tried to provide some answers to such broad questions.

We investigated the mechanisms and nature of such representation, and we verified whether the ability to travel through time representation changes in lifespan. For this very reason, this thesis involved children from six to ten years of age, as well as adults from 18 to 47 years of age. A new methodology was introduced, concerning stimuli selection (i.e., a survey administered to choose events) and devices employed in computerized task.

The first and second experiments presented in the second chapter involved Italian and English adult speakers. We explored the space-time representation of two different types of memory events, personal life events, which happen commonly in people's life, and non-personal events, such as popular public events. Results of the first experiment corroborated our hypothesis, with a space-time mapping for non-personal/public events observed only along the horizontal axis, and a space-time mapping for personal events observed only along the sagittal axis. The former MTL, spanning along the horizontal plane, may be well interpreted as originating from textual knowledge and from the reading and writing system direction (i.e., that follows a left-to-right orientation in Western languages). Our findings, thus, point to a role of memory content, in that non-personal events may be primarily conceived from an external perspective, leading to the activation of the horizontal MTL (Boroditsky, 2007; Tversky et al., Winter, 1991; Nunez & Cooperride,2013; Fuhrman & Boroditsky, 2010) On the other hand, we observed that only personal events elicited a MTL along the sagittal axis. This finding may be related to the fact that in the sagittal space we obligatory take an egocentric perspective on the time series. Such an egocentric perspective may, therefore, be reinforced when the memory content to be processed itself personal (i.e., or egocentric) rather than non-personal. Accordingly, the ego-moving metaphor of time maintains that time may be conceived as a stationary line, with the ego-moving forward (i.e., in time, but implicitly also in space, given the spatial nature of this construal) along with it. Together, therefore, findings from the first experiment converge with prior evidence (e.g., Walker et al., 2017), highlighting the possible role of the particular perspective from which a person interprets an event in the construal of the MTL. They further indicate that the memory content processed at hand may influence the activation of different spatially organized MTLs.

In the second experiment, we then aimed to replicate such a pattern of results, in an English-language sample and by employing a similar paradigm. In this study, however, we only found evidence for a space-time association along the sagittal axis.

In striking contrast, no congruency effect was observed in the horizontal space. Further, no modulation of the type of memory content was found, thus different from the first study. This may be related to the fact that, in line with previous studies, we found longer reaction times in non-personal events than personal events (Anelli et al., 2016). Such facilitation in personal events processing may have also affected the preferential setting of the sagittal MTL. However, similar facilitation was also observed for the first study, thus making this interpretation not fully convincing.

To account for the different pattern of results across studies, we rather pinpoint that such differences may depend on some variations in the experimental paradigm used: the device used and the body posture adopted (i.e., seating in the first experiment vs. standing in the second experiment). First, the device used across studies were different. Indeed, the device used in the first study (i.e., Makey Makey) required participants to perform discrete movements. That is, they had to release the central plate and then making free movements toward the lateralized (i.e., left and right, back, and front) plates for classifying the events. Hence, the response setting was dichotomous, and this may have promoted the setting up of space-time association.

On the contrary, in the second study, the device required participants to move the lever from a central position to the extreme ends of the bar. Such a device (see for a similar device Ulrich & Maienborn, 2010), forcing participants to make continuous movements, may have negatively affected the setting up of dichotomous space-time associations. This is particularly relevant in the case of the horizontal space, where the adoption of an external perspective on the sequence may be more related to a dichotomous response setting. Accordingly, a congruency effect was observed in the sagittal space in both studies: in this case, thus, continuous movements may be easily integrated with the egocentric perspective. The standing body posture in the second study may have further enhanced the adoption of an egocentric perspective and, thus, the activation of the sagittal MTL. Indeed, the ego-moving metaphor of time implies a standing speaker moving (i.e., or rather walking) along a stationary line.

In addition to this, results from the second experiment showed that older participants were overall faster than younger participants, likely because they have more experience (e.g., textual) and thus better representation of the presented events.

Also, participants on the horizontal mapping were faster to move on the right for the future. On the sagittal axis, participants reacted faster when they moved the hand backward for the past and forward for the future. Finally, the questionnaire administered ruled out the possibility that vividness and likelihood of the events could influence the reaction time and the space-time mapping observed in the experimental task. This further corroborates the possibility that the observed findings are specifically related to the space-mapping representation of memories.

The third experiment aimed to study, whether, in a paper and pencil task, we could observe the same time-space representation of personal and non-personal events obtained in the computerized tasks. We studied whether the spatial representations of time on a physical line is affected by the axis adopted (i.e., horizontal or sagittal) and by the memory content.

Results showed that participants were able to represent time along the physical line, thus resembling the form of the MTL. Indeed, almost all participants were consistent in placing events in an ordered fashion from left-to-right and, albeit less consistently, from back to front. Indeed, the representation of events along the line was more linear in the horizontal than in the sagittal space. This may be because the type of task (i.e., through a pencil) may have facilitated the horizontal MTL, which is known to rely on reading and writing habits. The Mental Time Line is a representation modulated by cultural factors, such as the direction of the reading-writing system (Tversky et al. 1991) on the horizontal axis (e.g. Italian, English, Arabic) and vertical axis (e.g. Mandarin), (Torralbo et al.2006; Santiago et al. 2007; Santiago et al. 2010), and our participants followed the left-right direction in a paper and pencil task.

Yet, this experiment did not show any dissociation between non-personal and personal events across the axis. Only a few studies in the literature have investigated the mapping of personal and non-personal events and how the MTL emerges in development, especially using a computerized task like in this experiment. Further, no study to our knowledge has investigated yet the development of the sagittal MTL, and whether this construal is mainly determined by sensorimotor or linguistic experience.

In the first study, we explored more deeply the possible origins of the sagittal MTL in Italian school-age children, by comparing the sensorimotor hypothesis and the linguistic hypothesis directly. Participants were asked to perform both a motor classification task, as well as a purely linguistic task, readapted from the IAT. We involved 3rd, 4th, and 5th-grade children and explored the presence of space-time associations as a function of age. Results supported the presence of space-time associations at motor level. That is, results indicated that the tendency to map past events with locations behind the body and future events with locations in front of it was already present at a young age in the motor task. Most notably, the size of the congruency effect did not differ as a function of age. A similar association was reported for terms referring to spatial and temporal distance.

On the light of the first and the second experiment results, described in chapter 2, the first experiment in Chapter 4 was conducted on English schoolchildren aged six-seven and eight and nine years old. In contrast, with the methods employed in Chapter 2, we replaced public events with events referred to an imaginary third person, named Alex (as this type of non-personal memory may be not sufficiently developed in children). The results showed that the MTL on the sagittal is already present from six-seven years of age, with the congruency effect not being affected by the age of children. In general, however, we observed that older children (eight-nine aged) showed a better performance than younger children (six-seven aged). Further, older children were particularly better in performing the task with personal memory events than non-personal events. This means that the tendency to associate past events with locations behind the body and future events with the space in front of it is already present, starting from a very young age. The findings were replicated in a sample of adults. The type of memory content interacted with the congruency effect, meaning that personal events result in stronger response-side compatibility. The existence of such a modulation as a function of memory content may be explained by the fact that specific activation of the sagittal MNL triggered by personal events emerges early.

Interestingly, we found that the lower the differential score of IES (i.e., more correct and faster responses, indexing a stronger congruency effect), the higher the score of the Corsi Block-Tapping Test. This means that visuospatial working memory abilities are associated with the spatial representation of personal events. Such a relationship deserves further target investigation, especially because personal events are better mapped taking an egocentric perspective. However, whether the Corsi Test requires more allocentric or egocentric perspective taking is a matter of debate.

On the contrary, and critically, the linguistic association as tested by the IAT was modulated by age. Indeed, only 4th and 5th grades children showed a congruency effect, meaning that they performed more accurately the congruent than the incongruent condition. No such a linguistic congruency effect was found in 3rd-grade children. This means that the association between space (back, front) and time (past, future) is present at the motor level starting from a young age, but not at the linguistic level. Despite existing literature (e.g., Eikmer et al., 2015), has suggested that the compatibility effect observed at the motor level emerges at higher levels of cognition, possibly reflecting a conceptual overlap due to language statistics between terms referring to space and time, our results do not support this view. Instead, our results suggest that sensorimotor experience may be more critical in setting the sagittal MTL. The younger children instead showed a congruent effect only in the motor task but not in the linguistic ones. Further, these results cannot be attributed to the specific linguistic task used, as a congruency effect was reported in all children with the IAT employing terms referring to spatial and temporal distance. These last results are in line with Construal Level Theory (Trope & Lieberman, 2010): the stimuli that denote certain temporal proximity evoke the representations about the proximity in space, while the stimuli that indicate a temporal distance activate representations about distance in space.

In summary, the comparison between the five experiments revealed some differences between adults and children. Regarding the time/space association, we found that in adult participants the representation of past-backward and future-forward is present both at the motor and the linguistic levels, giving rise to a congruency effect in all the tasks. Crucially, our findings suggest that the association between space and time would be determined by locomotion behavior linking together space and time information in the sagittal space (Clark, 1973; Sell and Kaschak, 2010). This points to a possible role of the frames of reference (i.e., egocentric vs. allocentric) in the setting of the spatial representation of time along these two axes.

Our studies suggest that children possess an MTL that resembles the adult one. This provides complementary evidence to the view that the representations of space and time are tightly interrelated.

Our findings further point to the role of memory content, in that non personal events may be primarily conceived from an external perspective, thus leading to the activation of the horizontal MTL (Boroditsky, 2007; Nunez & Cooperrider, 2013; Fuhrman & Boroditsky,2010; Tversky et al., Winter, 1991).

Future studies should involve middle-aged and older participants to study the mechanisms responsible for Mental Time Travel and space-time representation in aging. The tasks could also be adapted in the assessment of retrograde and anterograde memory representation. Furthermore, the same tasks could be used with neuroimaging and electrophysiological methods, to disclose the neural networks associated with the spatial representation of time.

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APPENDIX A

A.1 Qualtrics survey used to choose the stimuli of the Italian adults computerized task.

Il presente questionario verrà utilizzato a fini di ricerca. Ti chiediamo di compilarlo in ogni sua parte. Il questionario è strutturato in 3 Sezioni: Sezione 1, Memoria Personale (eventi che sono accaduti in passato o che probabilmente accadranno in futuro); Sezione 2, Memoria Non Personale (eventi accaduti o che probabilmente accadranno in Italia o nel mondo); Sezione 3, Stima Temporale (stimare quanti anni fa sono accaduti questi eventi o tra quanto tempo potrebbero accadere). Per rispondere alle domande dovrai barrare una delle caselle della scala di valori riportata sotto ogni evento o inserire l'anno in una delle caselle. La compilazione richiederà circa 15 minuti.

[1]Valori scala Likert: Per niente; Pochissimo; Poco; In parte; Abbastanza; In gran parte; Del tutto.

Sezione 1: Memoria Personale

1.a) Passato

Di seguito sono elencati degli eventi personali accaduti nel tuo **PASSATO**. Sulla base delle tue esperienze di vita dovrai indicare **CON QUANTA CHIAREZZA/VIVIDEZZA** riesci a ricordare questi eventi. Barra una delle caselle della scala di valori riportata sotto ogni evento: da 1 (per niente) a 7 (del tutto).

1) Primo Esame
2) Esame di Maturità
5) Inizio Università
4) Diciottesimo Compleanno
5) Primo Bacio
6) Ultimo Viaggio
7) Primo Giorno di Scuola
8) Primo Compleanno
9) Primo Cellulare
10) Esame Patente
11) Primo Volo Aereo
12) Ultimo Capodanno

[1]Accanto ad ogni evento, nella sezione rievocazione il partecipante indicava la casella corrispondente al valore della scala Likert.

1.b) Futuro

Di seguito sono elencati degli eventi personali probabili. Sulla base delle tue prospettive di vita e dei tuoi obiettivi, dovrai indicare **QUANTO è PROBABILE CHE** questi eventi **ACCADANO** nella tua vita in **FUTURO**. Barra una delle caselle della scala di valori riportata sotto ogni evento: da 1 (per niente) a 7 (del tutto).

1) Primo Matrimonio
2) Laurea Magistrale
3) Diventare Nonni
4) Quarantesimo Compleanno
5) Primo Figlio
6) Prossima Vacanza
7) Matrimonio Figlio
8) Primo Mutuo
9) Pensionamento
10) Ottantesimo Compleanno
11) Nozze d'Argento
12) Prossimo Ferragosto

Sezione 2: Memoria Non Personale

2.a) Passato

Di seguito sono elencati degli eventi accaduti in **PASSATO** in Italia o nel mondo. Sulla base delle tue conoscenze dovrai indicare **CON QUANTA CHIAREZZA** riesci a ricordare questi eventi. Barra una delle caselle della scala di valori riportata sotto ogni evento: 1 (per niente) a 7 (del tutto).

1) Elezione Obama
2) Naufragio Concordia
3) Morte George Michael
4) Attentati Parigi
5) Torri Gemelle
6) Ultimo Sanremo
7) Incidente Schumacher
8) Mondiali Materazzi
9) Morte David Bowie
10) Attentati Nizza
11) Oscar DiCaprio
12) Referendum Brexit

2.b) Futuro

Di seguito sono elencati degli eventi che potrebbero accadere in Italia o nel mondo. Ti chiediamo di indicare, **QUANTO**, secondo te, è **PROBABILE CHE** questi eventi ACCADANO in **FUTURO**. Barra una delle caselle della scala di valori riportata sotto ogni evento: da 1 (per niente) a 7 (molto).

1) Omicidio Trump
2) Ponte sullo Stretto
3) Morte Berlusconi
4) Papa di Colore
5) Ritiro Buffon
6) Prossimo Giro d'Italia
7) Fine Unione Europea
8) Fine Guerra in Siria
9) Scoperta Alieni
10) Morte Merkel
11) Prossime Olimpiadi
12) Pace Medio Oriente
13) Terza Guerra Mondiale
14) Nobel Bergoglio
15) Teletrasporto
16) Viaggio su Marte
17) Dimissioni Merkel

Sezione 3: Stima Temporale[2]

3.a) Memoria Personale Passato

Di seguito sono elencati degli eventi personali accaduti nel tuo PASSATO. Sulla base delle tue esperienze di vita ti chiediamo di indicare **QUANTI ANNI FA** si sono verificati questi eventi.

1) Primo Esame
2) Esame di Maturità
5) Inizio Università
4) Diciottesimo Compleanno
5) Primo Bacio
6) Ultimo Viaggio
7) Primo Giorno di Scuola
8) Primo Compleanno
9) Primo Cellulare
10) Esame Patente
11) Primo Volo Aereo
12) Ultimo Capodanno

[2] Nella sezione stima, invece, accanto ad ogni evento il partecipante aveva un riquadro nel quale poteva riportare gli anni.

3.b) Memoria Personale Futuro

Di seguito sono elencati degli eventi che potrebbero accadere nella tua vita in **FUTURO**. Ti chiediamo di indicare, **TRA QUANTI ANNI POTREBBERO** verificarsi questi eventi.

1) Primo Matrimonio
2) Laurea Magistrale
3) Diventare Nonni
4) Quarantesimo Compleanno
5) Primo Figlio
6) Prossima Vacanza
7) Matrimonio Figlio
8) Primo Mutuo
9) Pensionamento
10) Ottantesimo Compleanno
11) Nozze d'Argento
12) Prossimo Ferragosto

3.c) Memoria Non Personale Passato

Di seguito sono elencati degli eventi accaduti in **PASSATO** in Italia o nel mondo. Sulla base delle tue conoscenze ti chiediamo di indicare **QUANTI ANNI FA** si sono verificati.

1) Elezione Obama
2) Naufragio Concordia
3) Morte George Michael
4) Attentati Parigi
5) Torri Gemelle
6) Ultimo Sanremo
7) Incidente Schumacher
8) Mondiali Materazzi
9) Morte David Bowie
10) Attentati Nizza
11) Oscar DiCaprio
12) Referendum Brexit

3.d) Memoria Non Personale Futuro

Di seguito sono elencati degli eventi che potrebbero accadere in **FUTURO** in Italia o nel mondo già elencati in precedenza. Ti chiediamo di indicare, **TRA QUANTI ANNI POTREBBERO** verificarsi questi eventi.

1) Omicidio Trump
2) Ponte sullo Stretto
3) Morte Berlusconi
4) Papa di Colore
5) Ritiro Buffon
6) Prossimo Giro d'Italia
7) Fine Unione Europea
8) Fine Guerra in Siria
9) Scoperta Alieni
10) Morte Merkel
11) Prossime Olimpiadi
12) Pace Medio Oriente
13) Terza Guerra Mondiale
14) Nobel Bergoglio
15) Teletrasporto
16) Viaggio su Marte
17) Dimissioni Merkel

A.2 English Version: Qualtrics survey used to choose the stimuli of the Italian adults experiments.

This survey will be used for research purposes. We ask you to complete every section in full. The survey is divided in 3 Section: Section 1: Personal Memory: (you have to indicate how clearly you can remember some past events of your life, and how probable some future events); Section 2: Non-Personal Memory: you have to indicate how clearly you can remember some past events, and how probable some future events are to occur in Italy or in the world; Section 3:Time Estimation (You will also be asked to specify how long-ago events happened in the past, or to estimate when events will occur in the future).
Please indicate on a scale from 1 (not at all) to 7 (completely). The survey will take about 15 minutes to complete.

[3]Likert scale values: Not at all; Very poorly; Poorly; Fairly Well; Well; Very Well; Extremely Well

Section 1: Personal Events

1.a) Past

Based on your life experience, please indicate on a scale from 1 (not at all) to 7 (Extremely Well) **HOW CLEARLY** you remember each of the following events from your **PAST**.

1) First Exam
2) Graduation Exam
3) Start University
4) Eighteenth Birthday
5) First Kiss
6) Last Holiday
7) First Day of School
8) First Birthday
9) First Mobile Phone
10) Driving Test
11) First Flight
12) Last New Year Eve's

[3] Close to each event, in Section 1 and 2, the participant indicated the corresponding Likert scale value.

1.b) Future

Based on your life experience, please indicate on a scale from 1 (not at all) to 7 (Extremely Well) **HOW LIKELY** it is that each of the following events will occur in your **FUTURE**.

1) First Marriage
2) Master's Degree
3 Become Grandparents
4 40th Birthday
5 First Child
6 Next Holiday
7) First Child's Wedding
8) First Mortgage
9) Retirement
10) 80th Birthday
11) Silver Wedding
12) Next Ferragosto

Section 2: Non-Personal Memory

2.a) Past

Based on your knowledge, please indicate on a scale from 1 (not at all) to 7 (Extremely Well) **HOW CLEARLY** you remember each of this following **HISTORICAL** events **OCCURRED** in Italy or in the world.

1) Obama's Election
2) Concordia Disaster
3) George Michael's Death
4) Paris Attacks
5) Twin Towers
6) Last Sanremo
7) Schumacher Accident
8) World Cup Materazzi
9) David Bowie's Death
10) Nice Attacks
11) DiCaprio's Oscar
12) Brexit Referendum

2.b) Future

Based on your knowledge, please indicate on a scale from 1 (not at all) to 7 (Extremely Well) **HOW CLEARLY** it is that each of these following events **WILL OCCUR** in the **FUTURE** in Italy or in the world.

1) Murder of Trump
2) Bridge on the Strait
3) Berlusconi's Death
4) African Pope
5) Buffon's Retreat
6) Next Giro d'Italia
7) The End European Union
8) The End of the Syria War
9) Discovery Alien
10) Merkel's Death
11) Next Olympics Game
12) Peace in Middle East
13) Third World War
14) Bergoglio's Nobel
15) Teleportation
16) Land on Mars
17) Merkel's resignation

Section 3: Non-Personal Memory: Time Estimation[4]

3.a) Personal Memory Past

Based on your life experience, please **ESTIMATE** the year in which the following events **HAPPENED** in your **PAST**.

1) First Exam
2) Graduation Exam
3) Start University
4) Eighteenth Birthday
5) First Kiss
6) Last Holiday
7) First Day of School
8) First Birthday
9) First Mobile Phone
10) Driving Test
11) First Flight
12) Last New Year Eve's

[4] In the estimation section, the participant wrote the year in a box close to each event.

3.b) Personal Memory Future

Based on your life experience, please indicate **HOW LIKELY** it is that each of the following events **WILL OCCUR** in your **FUTURE**.

1) First Marriage
2) Master's Degree
3 Become Grandparents
4 40th Birthday
5 First Child
6 Next Holiday
7) First Child's Wedding
8) First Mortgage
9) Retirement
10) 80th Birthday
11) Silver Wedding
12) Next Ferragosto

3.c) Non-Personal Memory Past

Based on your knowledge, please **ESTIMATE** the year in which the following events **HAPPENED** in the **PAST** in Italy or in the world.

1) Obama's Election
2) Concordia Disaster
3) George Michael's Death
4) Paris Attacks
5) Twin Towers
6) Last Sanremo
7) Schumacher Accident
8) World Cup Materazzi
9) David Bowie's Death
10) Nice Attacks
11) DiCaprio's Oscar
12) Brexit Referendum

3.d) Non-Personal Memory Future

Based on your knowledge and your point of view, please **ESTIMATE** in which year you expect each of the following events **TO OCCUR** in the **FUTURE** in Italy or in the world.

1) Murder of Trump
2) Bridge on the Strait
3) Berlusconi's Death
4) Black Pope
5) Buffon's Retreat
6) Next Giro d'Italia
7) The End European Union
8) The End of the Syria War
9) Discovery Alien
10) Merkel's Death
11) Next Olympics Game
12) Peace in Middle East
13) Third World War
14) Bergoglio's Nobel
15) Teleportation
16) Land on Mars
17) Merkel's resignation

APPENDIX B

B.1 Table of personal and non-personal events (targets and distractors) chosen and used in the Mental Time Travel task in the Italian experiments.

Eventi Personali
Target
Passato

1 Primo Esame
2 Esame di Maturità
5 Inizio Università
4 Diciottesimo Compleanno
5 Primo Bacio
6 Ultimo Viaggio

Target
Futuro

1 Primo Matrimonio
2 Laurea Magistrale
3 Diventare Nonni
4 Quarantesimo Compleanno
5 Primo Figlio
6 Prossima Vacanza

Eventi Personali
Distrattori
Passato

1 Primo Giorno di Scuola
2 Primo Compleanno
3 Primo Cellulare
4 Esame Patente
3 Primo Volo Aereo
6 Ultimo Capodanno

Distrattori
Futuro

1 Matrimonio Figlio
2 Primo Mutuo
3 Pensionamento
4 Ottantesimo Compleanno
5 Nozze d'Argento
6 Prossimo Ferragosto

Eventi Non-Personali
Target
Passato

1 Elezione Obama
2 Naufragio Concordia
5 Morte George Michael
4 Attentati Parigi
5 Torri Gemelle
6 Ultimo Sanremo

Target
Futuro

1 Omicidio Trump
2 Fine Unione Europea
3 Morte Berlusconi
4 Papa di Colore
5 Ritiro Buffon
6 Prossimo Giro d'Italia

Eventi Non-Personali
Distrattori
Passato

1 Incidente Schumacher
2 Mondiali Materazzi
3 Morte David Bowie
4 Attentati Nizza
3 Oscar DiCaprio
6 Referendum Brexit

Distrattori
Futuro

1 Terza Guerra Mondiale
2 Nobel Bergoglio
3 Viaggio su Marte
4 Morte Merkel
5 Prossime Olimpiadi
6 Pace Medio Oriente

B.2 English Version: Table of personal and non-personal events (targets and distractors) chosen and used in the Mental Time Travel task in the Italian experiments.

Personal Events **Target** **Past**	**Personal Events** **Distractors** **Past**
1 First Exam	1 First Day of School
2 Graduation Exam	2 First Birthday
5 Start University	3 First Mobile Phone
4 Eighteenth Birthday	4 Driving Test
5 First Kiss	3 First Flight
6 Last Holiday	6 Last New Year Eve's
Target **Future**	**Distractors** **Future**
1 First Marriage	1 First Child's Wedding
2 Master's Degree	2 First Mortgage
3 Become Grandparents	3 Retirement
4 40th Birthday	4 80th Birthday
5 First Child	5 Silver Wedding
6 Next Holiday	6 Next Ferragosto
Non-Personal Events **Target** **Past**	**Non-Personal Events** **Distractors** **Past**
1 Obama's Election	1 Schumacher's Accident
2 Concordia Disaster	2 Materazzi World Cup
5 George Michael's Death	3 David Bowie's Death
4 Paris Attack	4 Nice Attack
5 Twin Towers	3 DiCaprio's Oscar
6 Last Sanremo	6 Brexit Referendum
Target **Future**	**Distractors** **Future**
1 Murder of Trump	1 Third World War
2 The End of European Union	2 Bergoglio's Nobel
3 Berlusconi's Death	3 Land on Mars
4 African Pope	4 Merkel's Death
5 Buffon's Retreat	5 Next Olympic Game
6 Next Giro d'Italia	6 Peace in Middle East

APPENDIX C

C.1 Qualtrics Vividness and Possibility Survey used for the Italian experiment.

Il presente questionario verrà utilizzato a fini di ricerca. Ti chiediamo di compilarlo in ogni sua parte. Il questionario è strutturato in 2 Sezioni: Sezione 1, Memoria Personale (eventi che sono accaduti nella tua vita in passato o che probabilmente accadranno nel tuo futuro); Sezione 2, Memoria Non Personale (eventi accaduti o che probabilmente accadranno in Italia o nel mondo). Per rispondere alle domande dovrai barrare una delle caselle della scala di valori riportata sotto ogni evento: 1 (per niente) a 7 (del tutto). La compilazione richiederà circa 15 minuti.

[5]Valori scala Likert: Per niente; Pochissimo; Poco; In parte; Abbastanza; In gran parte; Del tutto.

Sezione 1: Memoria Personale

1.a) Passato

Di seguito sono elencati 6 eventi accaduti nel tuo **PASSATO**. Sulla base delle tue esperienze di vita dovrai indicare **CON QUANTA CHIAREZZA/VIVIDEZZA** riesci a ricordare questi eventi. Barra una delle caselle della scala di valori riportata sotto ogni evento: da 1 (per niente) a 7 (del tutto).

1) Primo Esame
2) Esame di Maturità
3) Inizio Università
4) Diciottesimo Compleanno
5) Primo Bacio
6) Ultimo Viaggio

[5]Accanto ad ogni evento, nella sezione rievocazione il partecipante indicava la casella corrispondente al valore della scala Likert

1.b) Futuro

Di seguito sono elencati 6 eventi personali probabili. Sulla base delle tue prospettive di vita e dei tuoi obiettivi, dovrai indicare **QUANTO è PROBABILE** che questi eventi **ACCADANO** nella tua vita in **FUTURO**. Barra una delle caselle della scala di valori riportata sotto ogni evento: da 1 (per niente) a 7 (del tutto).

1) Primo Matrimonio
2) Laurea Magistrale
3) Diventare Nonni
4) Quarantesimo Compleanno
5) Primo Figlio
6) Prossima Vacanza

Memoria Episodica Non Personale

2.a) Passato

Di seguito sono elencati 6 eventi accaduti in **PASSATO** in Italia o nel mondo. Sulla base delle tue conoscenze dovrai indicare **CON QUANTA CHIAREZZA** riesci a ricordare questi eventi. Barra una delle caselle della scala di valori riportata sotto ogni evento: da 1 (per niente) a 7 (del tutto).

1) Elezione Obama
2) Naufragio Concordia
3) Morte George Michael
4) Attentati Parigi
5) Torri Gemelle
6) Ultimo Sanremo

2.b) Futuro

Di seguito sono elencati 6 eventi che potrebbero accadere in Italia o nel mondo. Ti chiediamo di indicare, **QUANTO**, secondo te, è **PROBABILE CHE** questi eventi **ACCADANO** in **FUTURO**. Barra una delle caselle della scala di valori riportata sotto ogni evento: da 1 (per niente) a 7 (molto).

1) Omicidio Trump
2) Fine Unione Europea
3) Morte Berlusconi
4) Papa di Collore
5) Ritiro Buffon
6) Prossimo Giro d'Italia

C.2 English Version: Qualtrics Vividness and Possibility Survey used for the Italian adults experiment.

This survey will be used for research purposes. We ask you to complete every section in full. The survey is divided in 2 Section: Section 1: Personal Memory: (you have to indicate how clearly you can remember some past events of your life, and how probable some future events); Section 2: Non-Personal Memory: you have to indicate how clearly you can remember some past events, and how probable some future events are to occur in Italy or in the world; Please indicate on a scale from 1 (not at all) to 7 (completely). The survey will take about 15 minutes to complete.

[6]Likert scale values: Not at all; Very poorly; Poorly; Fairly Well; Well; Very Well; Extremely Well

Section 1: Personal Events

1.a) Past

Based on your life experience, please indicate on a scale from 1 (not at all) to 7 (Extremely Well) **HOW CLEARLY** you remember each of the following events from your **PAST**.

1) First Exam
2) Graduation Exam
3) Start University
4) Eighteenth Birthday
5) First Kiss
6) Last Holiday

1.b) Future

Based on your life experience, please indicate on a scale from 1 (not at all) to 7 (Extremely Well) **HOW LIKELY** it is that each of the following events **WILL OCCUR** in your **FUTURE**.

1) First Marriage
2) Master's Degree
3) Become Grandparents
4) 40th Birthday
5) First Child
6) Next Holiday

[6] Close to each event, in Section 1 and 2, the participant indicated the corresponding Likert scale value.

Section 2: Non-Personal Events

2.a) Past

Based on your knowledge, please indicate on a scale from 1 (not at all) to 7 (Extremely Well) **HOW CLEARLY** you remember each of the following **HISTORICAL** events.

1) Obama's Election
2) Concordia Disaster
3) George Michael's Death
4) Paris Attack
5) Twin Towers
6) Last Sanremo

2.b) Future

Based on your knowledge and your point of view, please indicate on a scale from 1 (not at all) to 7 (Extremely Well) **HOW LIKELY** it is that each of the following events **WILL OCCUR** in **FUTURE**.

1) Murder of Trump
2) The End of European Union
3) Berlusconi's Death
4) African Pope
5) Buffon's Retreat
6) Next Giro d'Italia

APPENDIX D

Qualtrics survey used to choose the stimuli of the English adults computerized task

Participant Information

Please take time to read the following information and do not hesitate to contact us should you require any further details. This survey will be used for research purposes. We ask you to complete every section in full.

You are being asked to take part in a study of personal and non-personal memory.

You will complete a survey to indicate how clearly you can remember some past events, and how probable some future events are to occur. You will also be asked to specify how long-ago events happened in the past, or to estimate when events will occur in the future. The survey will take about 15 minutes to complete. Some of the events that you will read about are public events that may be unpleasant. If you are uncomfortable at any time, please terminate the survey.

[7]Likert scale values: Not at all; Very Poorly; Poorly; Fairly Well; Well; Very Well; Extremely Well; N/A (Not applicable).

Section 1: Personal Events

1.a) Past

Based on your life experience, please indicate on a scale from 1 (not at all) to 7 (Extremely Well) **HOW CLEARLY** you remember each of the following events from your **PAST**.

1) A-Level Exams
2) GCSE Exams
3) First Day of University
4) Eighteenth Birthday
5) Last Day of School
6) Last Holliday
7) First Day of School
8) First Birthday
9) First Mobile Phone
10) Driving Test
11) First Flight
12) Last New Year's Eve

[7] Close to each event, in Section 1 and 2, the participant indicated the corresponding Likert scale value.

1.b) Future

Based on your life experience, please indicate on a scale from 1 (not at all) to 7 (Extremely Well) **HOW LIKELY** it is that each of the following events **WILL OCCUR** in your **FUTURE**.

1) First Professional Job
2) Master's Degree
3) School Reunion
4) 40th Birthday
5) Buy a New Car
6) Next Holliday
7) Make a Will
8) First Mortgage
9) Retirement
10) 80th Birthday
11) Next Hospital Admission
12) Next Halloween Fancy Dress

Section 2: Non-Personal Events

2.a) Past

Based on your knowledge, please indicate on a scale from 1 (not at all) to 7 (Extremely Well) **HOW CLEARLY** you remember each of the following **HISTORICAL** events.

1) First Obama's Election
2) Brexit Referendum
3) Michael Jackson's Death
4) Last Vladimir Putin's Election
5) Theresa May Becoming Prime Minister
6) Prince William's Wedding
7) Schumacher Accident
8) Mandela's Death
9) Prince George's Birth
10) Martin Mc Guinness' Death
11) London Olympic Games
12) North Korean missile test over Japan

2.b) Future

Based on your knowledge and your point of view, please indicate on a scale from 1 (not at all) to 7 (Extremely Well) **HOW LIKELY** it is that each of the following events **WILL OCCUR** in **FUTURE**.

1) Murder of Trump
2) The End of the European Union
3) Queen Elizabeth's Death
4) Humans land on Mars
5) Prince Harry's Wedding
6) Next Olympic Games
7) Korean Reunification
8) Discovery of Aliens
9) Flying Cars
10) African Pope
11) Scottish Independence
12) Peace in Middle East
13) Next General Election
14) Woman President in USA

Section 3: Non-Personal Memory: Time Estimation[8]

3.a) Personal Memory Past

Based on your life experience, please **ESTIMATE** the year in which the following events **HAPPENED** in your **PAST**.

1) A-Level Exams
2) GCSE Exams
3) First Day of University
4) Eighteenth Birthday
5) Last Day of School
6) Last Holliday
7) First Day of School
8) First Birthday
9) First Mobile Phone
10) Driving Test
11) First Flight
12) Last New Year's Eve

[8] In the estimation section, the participant wrote the year in a box close to each event.

3.b) Personal Memory Future

Please **ESTIMATE** in which year of your life you would expect each of the following events **TO OCCUR** in the **FUTURE**.

1) First Professional Job
2) Master's Degree
3) School Reunion
4) 40th Birthday
5) Buy a New Car
6) Next Holliday
7) Make a Will
8) First Mortgage
9) Retirement
10) 80th Birthday
11) Next Hospital Admission
12) Next Halloween Fancy Dress

3.c) Non-Personal Memory Past

Based on your knowledge, please **ESTIMATE** the year in which the following **HISTORICAL** events **HAPPENED** on your **PAST**.

1) First Obama's Election
2) Brexit Referendum
3) Michael Jackson's Death
4) Last Vladimir Putin's Election
5) Theresa May Becoming Prime Minister
6) Prince William's Wedding
7) Schumacher Accident
8) Mandela's Death
9) Prince George's Birth
10) Martin Mc Guinness' Death
11) London Olympic Games
12) North Korean missile test over Japan

3.d) Non-Personal Memory Future

Based on your knowledge and your point of view, please **ESTIMATE** in which year you would expect each of the following events **TO OCCUR** in the **FUTURE**.

1) Murder of Trump
2) The End of the European Union
3) Queen Elizabeth's Death
4) Humans land on Mars
5) Prince Harry's Wedding
6) Next Olympic Games
7) Korean Reunification
8) Discovery of Aliens
9) Flying Cars
10) African Pope
11) Scottish Independence
12) Peace in Middle East
13) Next General Election
14) Woman President in USA

APPENDIX E

Table of Personal and Non-Personal events (targets and distractors) chosen and used in the Mental Time Travel task in the English/Irish experiment.

	Personal Events Target Past		Personal Events Distractors Past
1	A-Level Exams	1	First Day of University
2	GCSE Exams	2	Last Holiday
3	Eighteenth Birthday	3	First Day of School
4	Last Day of School	4	First Birthday
5	First Mobile Phone	5	Driving Test
6	Last New Year's Eve	6	First Flight
	Target Future		**Distractors Future**
1	Buy a New Car	1	First Mortgage
2	Next Holiday	2	Next Halloween Fancy Dress
3	Make a Will	3	First Professional Job
4	Retirement	4	School Reunion
5	80th Birthday	5	Next New Year's Eve
6	Next Hospital Admission	6	60th Birthday

	Non-Personal Events Target Past		Non-Personal Events Distractors Past
1	Obama's Election	1	Michael Jackson's Death
2	Brexit Referendum	2	Last Putin's Election
3	Prince William's Wedding	3	Theresa May Becoming Prime Minister
4	Mandela's Death	4	Schumacher Accident
5	Martin McGuinness' Death	5	Prince George's Birth
6	London Olympic Games	6	North Korean Missile Test over Japan
	Target Future		**Distractors Future**
1	Queen Elizabeth's Death	1	Murder of Trump
2	Humans land on Mars	2	The End of the European Union
3	Next Olympic Games	3	Prince Harry's Wedding
4	Scottish Independence	4	Flying Cars
5	Next General Election	5	African Pope
6	Woman President in USA	6	Peace in Middle East

APPENDIX F

Qualtrics Vividness and Possibility Survey used for the English adults computerized task

Participant Information

Please take time to read the following information and do not hesitate to contact us should you require any further details. This survey will be used for research purposes. We ask you to complete every section in full.

You are being asked to take part in a study of personal and non-personal memory.

You will complete a survey to indicate how clearly you can remember some past events, and how probable some future events are to occur. You will also be asked to specify how long-ago events happened in the past, or to estimate when events will occur in the future. The survey will take about 15 minutes to complete. Some of the events that you will read about are public events that may be unpleasant. If you are uncomfortable at any time, please terminate the survey.

[9]Likert scale values: Not at all; Very Poorly; Poorly; Fairly Well; Well; Very Well; Extremely Well; N/A (Not applicable).

Section 1: Personal Events

1.a) Past

Based on your life experience, please indicate on a scale from 1 (not at all) to 7 (Extremely Well) **HOW CLEARLY** you remember each of the following events from your **PAST**.

1) A-Level Exams
2) GCSE Exams
3) Eighteenth Birthday
4) Last Day at School
5) Last Holliday
6) First Mobile Phone

[9] Close to each event, in Section 1 and 2, the participant indicated the corresponding Likert scale value.

2.c) Future

Based on your life experience, please indicate on a scale from 1 (not at all) to 7 (Extremely Well) **HOW LIKELY** it is that each of the following events **WILL OCCUR** in your **FUTURE**.

1) Buy a New Car
2) Next Holliday
3) Make a Will
4) First Mortgage
5) Retirement
6) 80th Birthday

Section 2: Non-Personal Events

2.a) Past

Based on your knowledge, please indicate on a scale from 1 (not at all) to 7 (Extremely Well) **HOW CLEARLY** you remember each of the following **HISTORICAL** events.

1) Obama's Election
2) Brexit Referendum
3) Prince William's Wedding
4) Mandela's Death
5) Martin Mc Guinness' Death
6) London Olympic Games

2.c) Future

Based on your knowledge and your point of view, please indicate on a scale from 1 (not at all) to 7 (Extremely Well) **HOW LIKELY** it is that each of the following events **WILL OCCUR** in **FUTURE**.

1) Queen Elizabeth's Death
2) Humans land on Mars
3) Next Olympic Games
4) Scottish Independence
5) Next General Election
6) Woman President in USA

Section 3: Non-Personal Memory: Time Estimation[10]

3.a) Past Years

Based on your life experience, please **ESTIMATE** the year in which the following events **HAPPENED** in your **PAST**.

1) A-Level Exams
2) GCSE Exams
3) Eighteenth Birthday
4) Last Day at School
5) Last Holliday

3.b) Future Years

Based on your life experience, please **ESTIMATE** in which year of your life you would expect each of the following events **TO OCCUR** in the **FUTURE**.

1) Buy a New Car
2) Next Holliday
3) Make a Will
4) First Mortgage
5) Retirement
6) 80th Birthday

3.c) Past Years

Based on your knowledge, please **ESTIMATE** the year in which the following **HISTORICAL** events **HAPPENED** in the **PAST**.

1) Obama's Election
2) Brexit Referendum
3) Prince William's Wedding
4) Mandela's Death
5) Martin Mc Guinness' Death
6) London Olympic Games

3.d) Future Years

Based on your knowledge and your point of view, please **ESTIMATE** in which year you would expect each of the following events **TO OCCUR** in the **FUTURE**.

1) Queen Elizabeth's Death
2) Humans land on Mars
3) Next Olympic Games
4) Scottish Independence
5) Next General Election
6) Woman President in USA

[10] In the estimation section, the participant wrote the year in a box close to each event.

APPENDIX G

G.1 Form of year estimation administered at the end of the line experiment.

Quanti anni fa si sono verificati questi eventi.

1) Esame di Maturità	1) Elezione Obama
2) Primo Bacio	2) Torri Gemelle
3)Ultimo Viaggio	3) Ultimo Sanremo

Tra quanti anni si verificheranno questi eventi.

1)Quarantesimo Compleanno	1)Papa di Colore
2) Laurea Magistrale	2)Morte Berlusconi
3) Prossima Vacanza	3)Prossimo Giro d'Italia

Please estimate in which year each events are happened in the past.

1)Graduation Exam	1)Obama's Election
2)First Kiss	2)Twin Towers
3)Last Holiday	3)Last Sanremo

Please estimate in which year each events could occur in the future.

1)40th Birthday	1)African Pope
2)Master's Degree	2)Berlusconi's Death
3)Next Holiday	3)Next Giro d'Italia

G.2 Mental Time Line: Paper and Pencil task.

Lines in the conditions horizontal and sagittal differed for orientation only.

APPENDICE H

1. IAT Baseline - Congruente

Ora dovrai svolgere lo stesso compito, ma con parole e categorie diverse. Le categorie e le parole che incontrerai sono:

'Fiore' (rosa, girasole, margherita)
'Insetto' (mosca, zanzara, moscerino)
'Positivo' (amore, gioia, felicità)
'Negativo' (male, odio, pianto)

Così, per esempio, per ogni nome della categoria "Fiore" dovrai mettere una X sul cerchio sottostante la categoria '**Fiore' (**cerchio a sinistra**)** mentre per ogni nome della categoria 'Insetto' dovrai mettere una X sul cerchio sottostante la categoria '**Insetto' (**cerchio a destra**)**. Se la parola non indica né la categoria 'Fiore' né la categoria 'Insetto' dovrai fare la stessa cosa indicando se la parola, secondo te, rappresenta qualcosa di '**Positivo' (**cerchio a sinistra**)** o '**Negativo'** (cerchio a destra)**.**

Fiore Positivo		Insetto Negativo
○	Rosa	○
○	Amore	○
○	Mosca	○
○	Male	○
○	Girasole	○

Ti chiediamo di non guardare le pagine successive e di svolgere il compito nella sequenza che ti verrà proposta. **Dovrai guardare i nomi del foglio e segnare le X il più rapidamente possibile.** Alcune pagine potranno essere più difficili ed in queste potrai essere più lento. Questo è normale, perciò non ti scoraggiare e non ti preoccupare se fai alcuni errori, l'importante è non farne troppi. Comunque, se fai un errore, **non tornare indietro a cambiare la tua risposta,** ma continua a scorrere la lista. Ricorda: la tua prestazione viene cronometrata! Per non perdere tempo, **NON riempire i cerchi.** ***Ci sono domande?***

Fiore Positivo		Insetto Negativo
○	Rosa	○
○	Male	○
○	Mosca	○
○	Amore	○
○	Girasole	○
○	Sorriso	○
○	Margherita	○
○	Veleno	○
○	Zanzara	○
○	Allegria	○
○	Moscerino	○
○	Bellezza	○
○	Grillo	○
○	Gioia	○
○	Tulipano	○
○	Pianto	○
○	Lavanda	○
○	Tristezza	○
○	Violetta	○
○	Felicità	○
○	Ragno	○
○	Odio	○
○	Rosa	○
○	Pianto	○

Fiore Positivo		Insetto Negativo
○	Girasole	○
○	Amore	○
○	Scarafaggio	○
○	Sorriso	○
○	Margherita	○
○	Male	○
○	Tulipano	○
○	Veleno	○
○	Lavanda	○
○	Amore	○
○	Mosca	○
○	Sorriso	○
○	Zanzara	○
○	Male	○
○	Violetta	○
○	Allegria	○
○	Moscerino	○
○	Veleno	○
○	Rosa	○
○	Pianto	○
○	Girasole	○
○	Bellezza	○
○	Tulipano	○
○	Tristezza	○

2. IAT Baseline - Incongruente

In questo compito troverai di nuovo le stesse parole e categorie del precedente, ma la **posizione** delle categorie nelle colonne a destra e a sinistra è cambiata. Le categorie e le parole che incontrerai sono:

'Fiore' (rosa, girasole, margherita)
'Insetto' (mosca, zanzara, moscerino)
'Positivo' (amore, gioia, felicità)
'Negativo' (male, odio, pianto)

Così, per esempio, per ogni nome della categoria "Fiore" dovrai mettere una X sul cerchio sottostante la categoria '**Fiore' (**cerchio a sinistra**)** mentre per ogni nome della categoria 'Insetto' dovrai mettere una X sul cerchio sottostante la categoria '**Insetto' (**cerchio a destra**)**. Se la parola non indica né la categoria 'Fiore' né la categoria 'Insetto' dovrai fare la stessa cosa indicando se la parola, secondo te, rappresenta qualcosa di '**Positivo' (**cerchio a destra**)** o '**Negativo'** (cerchio a sinistra)**.**

Fiore Negativo		Insetto Positivo
○	Rosa	○
○	Amore	○
○	Mosca	○
○	Male	○
○	Girasole	○

Ti chiediamo di non guardare le pagine successive e di svolgere il compito nella sequenza che ti verrà proposta. **Dovrai guardare i nomi del foglio e segnare le X il più rapidamente possibile.** Se fai un errore, **non tornare indietro a cambiare la tua risposta,** ma continua a scorrere la lista. Ricorda: la tua prestazione viene cronometrata! Per non perdere tempo, **NON riempire i cerchi.** ***Ci sono domande?***

Fiore Negativo		Insetto Positivo
○	Rosa	○
○	Male	○
○	Mosca	○
○	Amore	○
○	Girasole	○
○	Sorriso	○
○	Zanzara	○
○	Veleno	○
○	Moscerino	○
○	Pianto	○
○	Margherita	○
○	Allegria	○
○	Tulipano	○
○	Tristezza	○
○	Grillo	○
○	Bellezza	○
○	Lavanda	○
○	Odio	○
○	Violetta	○
○	Pianto	○
○	Rosa	○
○	Gioia	○
○	Ragno	○
○	Felicità	○

Fiore Negativo		Insetto Positivo
○	Scarafaggio	○
○	Amore	○
○	Girasole	○
○	Male	○
○	Margherita	○
○	Sorriso	○
○	Mosca	○
○	Amore	○
○	Tulipano	○
○	Veleno	○
○	Lavanda	○
○	Sorriso	○
○	Zanzara	○
○	Male	○
○	Violetta	○
○	Allegria	○
○	Rosa	○
○	Veleno	○
○	Moscerino	○
○	Pianto	○
○	Girasole	○
○	Bellezza	○
○	Grillo	○
○	Tristezza	○

3.IAT Time - Congruente

Ora dovrai svolgere lo stesso compito, ma con parole e categorie diverse. Le categorie e le parole che incontrerai sono:

'Passato' (ieri, prima, precedente)
'Futuro' (domani, dopo, prossimo)
'Dietro' (spalle, schiena, posteriore)
'Davanti' (fronte, faccia, anteriore)

Così, per esempio, per ogni nome della categoria "passato" dovrai mettere una X sul cerchio sottostante la categoria '**Passato' (**cerchio a sinistra**)** mentre per ogni nome della categoria 'futuro' dovrai mettere una X sul cerchio sottostante la categoria '**Futuro' (**cerchio a destra**)**. Se la parola non indica né la categoria 'passato' né la categoria 'futuro' dovrai fare la stessa cosa indicando se la parola, secondo te, rappresenta qualcosa di '**Dietro' (**cerchio a sinistra**)** o '**Davanti'**(cerchio a destra)**.**

Passato Dietro		Futuro Davanti
○	Ieri	○
○	Spalle	○
○	Domani	○
○	Fronte	○
○	Prima	○

Ti chiediamo di non guardare le pagine successive e di svolgere il compito nella sequenza che ti verrà proposta. **Dovrai guardare i nomi del foglio e segnare le X il più rapidamente possibile.** Alcune pagine potranno essere più difficili ed in queste potrai essere più lento. Questo è normale, perciò non ti scoraggiare e non ti preoccupare se fai alcuni errori, l'importante è non farne troppi. Comunque, se fai un errore, **non tornare indietro a cambiare la tua risposta,** ma continua a scorrere la lista. Ricorda: la tua prestazione viene cronometrata! Per non perdere tempo, **NON riempire i cerchi.** ***Ci sono domande?***

Passato Dietro		Futuro Davanti
○	Ieri	○
○	Fronte	○
○	Domani	○
○	Spalle	○
○	Prima	○
○	Schiena	○
○	Precedente	○
○	Faccia	○
○	Dopo	○
○	Anteriore	○
○	Prossimo	○
○	Ritirata	○
○	Nuovo	○
○	Retrocede	○
○	Vecchio	○
○	Posteriore	○
○	Giocò	○
○	Avanzata	○
○	Mangiò	○
○	Arretra	○
○	Giocherò	○
○	Avanza	○
○	Ieri	○
○	Progredisce	○

Passato Dietro		Futuro Davanti
○	Prima	○
○	Spalle	○
○	Mangerà	○
○	Schiena	○
○	Precedente	○
○	Fronte	○
○	Vecchio	○
○	Faccia	○
○	Giocò	○
○	Anteriore	○
○	Domani	○
○	Ritirata	○
○	Dopo	○
○	Posteriore	○
○	Mangiò	○
○	Retrocede	○
○	Prossimo	○
○	Avanzata	○
○	Ieri	○
○	Avanza	○
○	Prima	○
○	Arretra	○
○	Nuovo	○
○	Progredisce	○

4.IAT Time – Incongruente

In questo compito troverai di nuovo le stesse parole e categorie del precedente, ma la **posizione** delle categorie nelle colonne a destra e a sinistra è cambiata. Le categorie e le parole che incontrerai sono:

'Passato' (ieri, prima, precedente)
'Futuro' (domani, dopo, prossimo)
'Dietro' (spalle, schiena, posteriore)
'Davanti' (fronte, faccia, anteriore)

Così, per esempio, per ogni nome della categoria "passato" dovrai mettere una X sul cerchio sottostante la categoria '**Passato' (**cerchio a sinistra**)** mentre per ogni nome della categoria 'futuro' dovrai mettere una X sul cerchio sottostante la categoria '**Futuro' (**cerchio a destra**)**. Se la parola non indica né la categoria 'passato' né la categoria 'futuro' dovrai fare la stessa cosa indicando se la parola, secondo te, rappresenta qualcosa di '**Dietro' (**cerchio a destra**)** o '**Davanti'** (cerchio a sinistra**).**

Passato Davanti		Futuro Dietro
○	Ieri	○
○	Spalle	○
○	Domani	○
○	Fronte	○
○	Prima	○

Ti chiediamo di non guardare le pagine successive e di svolgere il compito nella sequenza che ti verrà proposta. **Dovrai guardare i nomi del foglio e segnare le X il più rapidamente possibile.** Se fai un errore, **non tornare indietro a cambiare la tua risposta,** ma continua a scorrere la lista. Ricorda: la tua prestazione viene cronometrata! Per non perdere tempo, **NON riempire i cerchi.** ***Ci sono domande?***

Passato Davanti		Futuro Dietro
○	Ieri	○
○	Fronte	○
○	Domani	○
○	Spalle	○
○	Prima	○
○	Schiena	○
○	Dopo	○
○	Faccia	○
○	Prossimo	○
○	Posteriore	○
○	Precedente	○
○	Anteriore	○
○	Vecchio	○
○	Avanzata	○
○	Nuovo	○
○	Ritirata	○
○	Giocò	○
○	Avanza	○
○	Mangiò	○
○	Progredisce	○
○	Ieri	○
○	Retrocede	○
○	Giocherà	○
○	Arretra	○

Passato Davanti		Futuro Dietro
○	Mangerà	○
○	Spalle	○
○	Prima	○
○	Fronte	○
○	Precedente	○
○	Schiena	○
○	Domani	○
○	Anteriore	○
○	Vecchio	○
○	Faccia	○
○	Giocò	○
○	Ritirata	○
○	Dopo	○
○	Posteriore	○
○	Mangiò	○
○	Retrocede	○
○	Ieri	○
○	Avanzata	○
○	Prossimo	○
○	Avanza	○
○	Prima	○
○	Arretra	○
○	Nuovo	○
○	Progredisce	○

5.IAT Distanza – Congruente

Ora dovrai svolgere lo stesso compito, ma con parole e categorie diverse. Le categorie e le parole che incontrerai sono:

'Corto' (secondo, minuto, presto)
'Lungo' (mese, anno, tardi)
'Vicino' (addosso, Milano, Terra)
'Lontano' (distante, Parigi, Luna)

Così, per esempio, per ogni nome della categoria “corto” dovrai mettere una X sul cerchio sottostante la categoria '**Corto' (**cerchio a sinistra**)** mentre per ogni nome della categoria 'lungo' dovrai mettere una X sul cerchio sottostante la categoria '**Lungo' (**cerchio a destra**)**. Se la parola non indica né la categoria 'corto' né la categoria 'lungo' dovrai fare la stessa cosa indicando se la parola, secondo te, rappresenta qualcosa di '**Vicino' (**cerchio a sinistra**)** o '**Lontano'** (cerchio a destra**).**

Corto Vicino		Lungo Lontano
○	Secondo	○
○	Addosso	○
○	Mese	○
○	Distante	○
○	Minuto	○

Ti chiediamo di non guardare le pagine successive e di svolgere il compito nella sequenza che ti verrà proposta. **Dovrai guardare i nomi del foglio e segnare le X il più rapidamente possibile.** Alcune pagine potranno essere più difficili ed in queste potrai essere più lento. Questo è normale, perciò non ti scoraggiare e non ti preoccupare se fai alcuni errori, l’importante è non farne troppi. Comunque, se fai un errore, **non tornare indietro a cambiare la tua risposta,** ma continua a scorrere la lista. Ricorda: la tua prestazione viene cronometrata! Per non perdere tempo, **NON riempire i cerchi. *Ci sono domande?***

Corto Vicino		Lungo Lontano
○	Secondo	○
○	Distante	○
○	Mese	○
○	Addosso	○
○	Minuto	○
○	Centimetri	○
○	Presto	○
○	Chilometri	○
○	Anno	○
○	Attaccato	○
○	Tardi	○
○	Unito	○
○	Remoto	○
○	Milano	○
○	Prossimo	○
○	Distaccato	○
○	Inizio	○
○	Separato	○
○	Partenza	○
○	Terra	○
○	Fine	○
○	Parigi	○
○	Secondo	○
○	Luna	○

Corto Vicino		Lungo Lontano
○	Minuto	○
○	Addosso	○
○	Arrivo	○
○	Centimetri	○
○	Presto	○
○	Distante	○
○	Prossimo	○
○	Chilometri	○
○	Inizio	○
○	Addosso	○
○	Mese	○
○	Centimetri	○
○	Anno	○
○	Distante	○
○	Partenza	○
○	Attaccato	○
○	Tardi	○
○	Chilometri	○
○	Secondo	○
○	Distaccato	○
○	Minuto	○
○	Unito	○
○	Presto	○
○	Separato	○

6.IAT Distanza – Incongruente

In questo compito troverai di nuovo le stesse parole e categorie del precedente, ma la **posizione** delle categorie nelle colonne a destra e a sinistra è cambiata. Le categorie e le parole che incontrerai sono:

'Corto' (secondo, minuto, presto)
'Lungo' (mese, anno, tardi)
'Vicino' (addosso, Milano, Terra)
'Lontano' (distante, Parigi, Luna)

Così, per esempio, per ogni nome della categoria "corto" dovrai mettere una X sul cerchio sottostante la categoria '**Corto' (**cerchio a sinistra**)** mentre per ogni nome della categoria 'lungo' dovrai mettere una X sul cerchio sottostante la categoria '**Lungo' (**cerchio a destra**)**. Se la parola non indica né la categoria 'corto' né la categoria 'lungo' dovrai fare la stessa cosa indicando se la parola, secondo te, rappresenta qualcosa di '**Vicino' (**cerchio a destra**)** o '**Lontano'** (cerchio a sinistra)**.**

Corto Lontano		Lungo Vicino
○	Secondo	○
○	Addosso	○
○	Mese	○
○	Distante	○
○	Minuto	○

Ti chiediamo di non guardare le pagine successive e di svolgere il compito nella sequenza che ti verrà proposta. **Dovrai guardare i nomi del foglio e segnare le X il più rapidamente possibile.** Se fai un errore, **non tornare indietro a cambiare la tua risposta,** ma continua a scorrere la lista. Ricorda: la tua prestazione viene cronometrata! Per non perdere tempo, **NON riempire i cerchi.** ***Ci sono domande?***

Corto Lontano		Lungo Vicino
○	Secondo	○
○	Distante	○
○	Mese	○
○	Addosso	○
○	Minuto	○
○	Centimetri	○
○	Anno	○
○	Chilometri	○
○	Tardi	○
○	Distaccato	○
○	Presto	○
○	Attaccato	○
○	Prossimo	○
○	Separato	○
○	Remoto	○
○	Unito	○
○	Inizio	○
○	Parigi	○
○	Partenza	○
○	Luna	○
○	Secondo	○
○	Milano	○
○	Fine	○
○	Terra	○

Corto Lontano		Lungo Vicino
○	Arrivo	○
○	Addosso	○
○	Minuto	○
○	Distante	○
○	Presto	○
○	Centimetri	○
○	Mese	○
○	Addosso	○
○	Prossimo	○
○	Chilometri	○
○	Inizio	○
○	Centimetri	○
○	Anno	○
○	Distante	○
○	Partenza	○
○	Attaccato	○
○	Secondo	○
○	Chilometri	○
○	Tardi	○
○	Distaccato	○
○	Minuto	○
○	Unito	○
○	Remoto	○
○	Separato	○

H.2 English Version

1. IAT Baseline - Congruent

In this task, you will find words that belong to different categories. The categories and words you will encounter are:

'Flower' (rose, sunflower, daisy)
'Insect' (fly, mosquito, gnat)
'Positive' (love, joy, happiness)
'Negative' (evil, hate, cry)

For example, for each name of the category '**Flower**' you will have to put an X on the circle below the category '**Flower**' (circle on the left) while for each name of the category '**Insect**' you will have to put an X on the circle below the category '**Insect**'(circle on the right). If the word does not belong to the categories '**Flower**' or '**Insect**', you will have to indicate whether the word, in your opinion, represents something of '**Positive**' (circle on the left) or '**Negative**' (circle on the right).

Flower **Positive**		**Insect** **Negative**
○	**Rose**	○
○	**Love**	○
○	**Fly**	○
○	**Evil**	○
○	**Sunflower**	○

We ask you not to look at the following pages and to carry out the task in the same order than it is presented. **You will have to look at the name of the sheet and mark the X as quickly as possible.** If you make a mistake, **don't go back and change your answer, but keep scrolling through the list**. <u>Remember: your performance is timed!</u> To avoid wasting time, **DO NOT fill the circles. Do you have any questions?**

Flower Positive		Insect Negative
○	Rose	○
○	Evil	○
○	Fly	○
○	Love	○
○	Sunflower	○
○	Smile	○
○	Daisy	○
○	Poison	○
○	Mosquito	○
○	Cheerfulness	○
○	Gnat	○
○	Beauty	○
○	Cricket	○
○	Joy	○
○	Tulip	○
○	Cry	○
○	Lavander	○
○	Sadness	○
○	Violet	○
○	Happiness	○
○	Spider	○
○	Hate	○
○	Rose	○
○	Cry	○

Flower Positive		Insect Negative
○	Sunflower	○
○	Love	○
○	Cockroach	○
○	Smile	○
○	Daisy	○
○	Evil	○
○	Tulip	○
○	Poison	○
○	Lavender	○
○	Love	○
○	Fly	○
○	Smile	○
○	Mosquito	○
○	Evil	○
○	Violet	○
○	Cheerfulness	○
○	Gnat	○
○	Poison	○
○	Rose	○
○	Cry	○
○	Sunflower	○
○	Beauty	○
○	Tulip	○
○	Sadness	○

2. IAT Baseline - Incongruent

In this task you will find again the same words and categories as the previous one, but the position of the categories in the right and left columns has changed. The categories and words you will encounter are:

'Flower' (rose, sunflower, daisy)
'Insect' (fly, mosquito, gnat)
'Positive' (love, joy, happiness)
'Negative' (evil, hate, cry)

For example, for each name of the category **'Flower'** you will have to put an X on the circle below the category **'Flower'** (circle on the left) while for each name of the category **'Insect'** you will have to put an X on the circle below the category **'Insect'** (circle on the right). If the word does not belong to the categories **'Flower'** or **'Insect'**, you will have to indicate whether the word, in your opinion, represents something of **'Positive'** (circle on the right) or **'Negative'** (circle on the left).

Flower **Negative**		**Insect** **Positive**
○	**Rose**	○
○	**Love**	○
○	**Fly**	○
○	**Evil**	○
○	**Sunflower**	○

We ask you not to look at the following pages and to carry out the task in the same order than it is presented. **You will have to look at the name of the sheet and mark the X as quickly as possible.** If you make a mistake, **don't go back and change your answer, but keep scrolling through the list**. <u>Remember: your performance is timed!</u>

Flower Negative		Insect Positive
○	Rose	○
○	Evil	○
○	Fly	○
○	Love	○
○	Sunflower	○
○	Smile	○
○	Mosquito	○
○	Poison	○
○	Gnat	○
○	Cry	○
○	Daisy	○
○	Cheerfulness	○
○	Tulip	○
○	Sadness	○
○	Cricket	○
○	Beauty	○
○	Lavender	○
○	Hate	○
○	Violet	○
○	Cry	○
○	Rose	○
○	Joy	○
○	Spider	○
○	Happiness	○

Flower Negative		Insect Positive
○	Cockroach	○
○	Love	○
○	Sunflower	○
○	Evil	○
○	Daisy	○
○	Smile	○
○	Fly	○
○	Love	○
○	Tulip	○
○	Poison	○
○	Lavender	○
○	Smile	○
○	Mosquito	○
○	Evil	○
○	Violet	○
○	Cheerfulness	○
○	Rose	○
○	Poison	○
○	Gnat	○
○	Cry	○
○	Sunflower	○
○	Beauty	○
○	Cricket	○
○	Sadness	○

3. IAT Time - Congruent

Now you have to do the same task, but with different words and categories. The categories and words you will encounter are:

‘Past’ (yesterday, before, previous)
‘Future’ (tomorrow, after, next)
‘Behind’ (shoulders, back, rear)
‘Front’ (in front of, face, forward)

For example, for each name of the **‘Past’** category you will have to put an X on the circle below the **‘Past’** category (circle on the left) while for each name of the **‘Future’** category you will have to put an X on the circle below the **‘Future’** (circle on the right). If the word does not belong to the categories **‘Past’** or **‘Future’**, you will have to indicate whether the word, in your opinion, is related to **‘Behind’** (circle on the left) or **‘Front’** (circle on the right).

Past **Behind**		**Future** **Front**
○	**Yesterday**	○
○	**Shoulder**	○
○	**Tomorrow**	○
○	**In Front Of**	○
○	**Before**	○

We ask you not to look at the following pages and to carry out the task in the same order than it is presented. You will have to look at the name of the sheet and mark the X as quickly as possible. Some pages may be more difficult, thus it may take you more time to answer them. Don't get discouraged and don't worry if you make some mistakes, the important thing is to do your best. If you make a mistake, **don't go back and change your answer,** but keep scrolling through the list. <u>Remember: your performance is timed!</u> To avoid wasting time, **DO NOT fill the circles. Do you have any questions?**

Past Behind		Future Front
○	Yesterday	○
○	In Front Of	○
○	Tomorrow	○
○	Shoulder	○
○	Before	○
○	Back	○
○	Forward	○
○	Face	○
○	After	○
○	In Front Of	○
○	Next	○
○	Retreat	○
○	New	○
○	Move back	○
○	Old	○
○	Rear	○
○	Played	○
○	Advance	○
○	Ate	○
○	Retreating	○
○	Will Play	○
○	Advancing	○
○	Yesterday	○
○	Progressing	○

Past Behind		Future Front
○	Before	○
○	Shoulder	○
○	Will Eat	○
○	Back	○
○	Forward	○
○	In Front Of	○
○	Old	○
○	Face	○
○	Played	○
○	In Front Of	○
○	Tomorrow	○
○	Retreat	○
○	After	○
○	Rear	○
○	Ate	○
○	Retreating	○
○	Next	○
○	Advance	○
○	Yesterday	○
○	Advancing	○
○	Before	○
○	Move Back	○
○	New	○
○	Progressing	○

4. IAT Time - Incongruent

In this task you will again find the same words and categories as the previous one, but the **position** of the categories in the right and left columns has changed. The categories and words you will encounter are:

'Past' (yesterday, first, previous)
'Future' (tomorrow, after, next)
'Behind' (shoulders, back, rear)
'Front' (in front of, face, forward)

For example, for each name of the "past" category you will have to put an X on the circle below the "Past" category (circle on the left) while for each name of the "future" category you will have to put an X on the circle below the "Future "(circle on the right).

Past Front		Future Behind
○	Yesterday	○
○	Shoulder	○
○	Tomorrow	○
○	In Front Of	○
○	Before	○

If the word does not belong to the categories "Past" or "Future", you will have to indicate whether the word, in your opinion, is related to "Behind" (circle on the right) or "Front" (circle on the left). We ask you not to look at the following pages and to carry out the task in the same order than it is presented. **You will have to look at the name of the sheet and mark the X as quickly as possible. If you make a mistake, don't go back and change your answer,** but keep scrolling through the list. Remember: your performance is timed!
To avoid wasting time, **DO NOT fill the circles. Do you have any questions?**

Past Front		Future Behind
○	Yesterday	○
○	In Front Of	○
○	Tomorrow	○
○	Shoulder	○
○	Before	○
○	Back	○
○	After	○
○	Face	○
○	Next	○
○	Rear	○
○	Forward	○
○	In Front Of	○
○	Old	○
○	Advance	○
○	New	○
○	Retreat	○
○	Played	○
○	Retreating	○
○	Ate	○
○	Progressing	○
○	Yesterday	○
○	Move Back	○
○	Will Play	○
○	Retreating	○

Past Front		Future Behind
○	Will Eat	○
○	Shoulder	○
○	Before	○
○	In Front Of	○
○	Forward	○
○	Back	○
○	Tomorrow	○
○	Rear	○
○	Old	○
○	Face	○
○	Played	○
○	Retreat	○
○	After	○
○	Rear	○
○	Ate	○
○	Move Back	○
○	Yesterday	○
○	Advance	○
○	Next	○
○	Advancing	○
○	Before	○
○	Move Back	○
○	New	○
○	Progressing	○

5. IAT Distance - Congruent

Now you have to do the same task, but with different words and categories. The categories and words you will encounter are:

'Short' (second, minute, before)
'Long' (month, year, late)
'Near' (on, Milan, Earth)
'Far' (distant, Paris, Moon)

For example, for each name of the **'Short'** category you will have to put an X on the circle below the **'Short'** category (circle on the left) while for each name of the **'Long'** category you will have to put an X on the circle below the **'Long'** category "(circle on the right).

Short **Far**		**Long** **Near**
○	**Second**	○
○	**On**	○
○	**Month**	○
○	**Far**	○
○	**Minute**	○

If the word does not belong to the categories **'Short'** or **'Long'**, you will have to indicate whether the word, in your opinion, represents something **'Near'** (circle on the left) or **'Far'** (circle on the right). We ask you not to look at the following pages and to carry out the task in the same order than it is presented. **You will have to look at the name of the sheet and mark the X as quickly as possible.** If you make a mistake, **don't go back and change your answer,** but keep scrolling through the list. <u>Remember: your performance is timed!</u> To avoid wasting time, **DO NOT fill the circles. Do you have any questions?**

Past Short		Future Long
○	**Second**	○
○	**Far**	○
○	**Month**	○
○	**On**	○
○	**Minute**	○
○	**Centimetres**	○
○	**Soon**	○
○	**Kilometres**	○
○	**Year**	○
○	**Attached**	○
○	**Late**	○
○	**Joined**	○
○	**Distant**	○
○	**Milan**	○
○	**Next**	○
○	**Detached**	○
○	**Beginning**	○
○	**Divided**	○
○	**Start**	○
○	**Earth**	○
○	**End**	○
○	**Paris**	○
○	**End**	○
○	**Paris**	○

Past Short		Future Long
○	**Minute**	○
○	**On**	○
○	**Arrival**	○
○	**Centimetres**	○
○	**Soon**	○
○	**Far**	○
○	**Next**	○
○	**Kilometres**	○
○	**Beginning**	○
○	**On**	○
○	**Month**	○
○	**Centimetres**	○
○	**Year**	○
○	**Far**	○
○	**Start**	○
○	**Attached**	○
○	**Late**	○
○	**Kilometres**	○
○	**Second**	○
○	**Detached**	○
○	**Minute**	○
○	**Joined**	○
○	**Soon**	○
○	**Divided**	○

6. IAT Distance - Incongruent

In this task you will again find the same words and categories as the previous one, but the position of the categories in the right and left columns has changed. The categories and words you will encounter are:

'Short' (second, minute, before)
'Long' (month, year, late)
'Near' (on, Milan, Earth)
'Far' (distant, Paris, Moon)

For example, for each name of the **'Short'** category you will have to put an X on the circle below the **'Short'** category (circle on the left) while for each name of the **'Long'** category you will have to put an X on the circle below the **'Long'** category "(circle on the right).

Short **Far**		**Long** **Near**
○	**Second**	○
○	**On**	○
○	**Month**	○
○	**Far**	○
○	**Minute**	○

If the word does not belong to the categories **'Short'** or **'Long'**, you will have to indicate whether the word, in your opinion, represents something **'Near'** (circle on the right) or **'Far'** (circle on the left). We ask you not to look at the following pages and to carry out the task in the same order than it is presented. **You will have to look at the name of the sheet and mark the X as quickly as possible.** If you make a mistake, **don't go back and change your answer,** but keep scrolling through the list. <u>Remember: your performance is timed!</u> To avoid wasting time, **DO NOT fill the circles. Do you have any questions?**

Short Far		Long Near
○	**Second**	○
○	**Far**	○
○	**Month**	○
○	**On**	○
○	**Minute**	○
○	**Centimetres**	○
○	**Year**	○
○	**Kilometres**	○
○	**Late**	○
○	**Detached**	○
○	**Soon**	○
○	**Attached**	○
○	**Next**	○
○	**Divided**	○
○	**Distant**	○
○	**Joined**	○
○	**Beginning**	○
○	**Paris**	○
○	**Start**	○
○	**Moon**	○
○	**Second**	○
○	**Milan**	○
○	**End**	○
○	**Earth**	○

Short Far		Long Near
○	**Arrival**	○
○	**On**	○
○	**Minute**	○
○	**Far**	○
○	**Soon**	○
○	**Centimetres**	○
○	**Month**	○
○	**On**	○
○	**Soon**	○
○	**Kilometres**	○
○	**Beginning**	○
○	**Centimetres**	○
○	**Year**	○
○	**Far**	○
○	**Start**	○
○	**Attached**	○
○	**Second**	○
○	**Kilometres**	○
○	**Late**	○
○	**Detached**	○
○	**Minute**	○
○	**Joined**	○
○	**Distant**	○
○	**Divided**	○

APPENDIX I

Table of Personal and Non-Personal events (targets and distractors) chosen and used in the Mental Time Travel task in the English schoolchildren sample experiment.

Personal Events
Target
Past

1 Your last Halloween
2 Your last birthday present
5 Your last doctor's visit
4 You starting primary school
5 Your fifth birthday
6 Your first lost tooth

Target
Future

1 Your next Christmas dinner
2 You starting secondary school
3 Your next museum visit
4 Your next Easter holiday
5 You learning to drive
6 Your next flight

Personal Events
Distractors

1 The Bear is White
2 The Cat is Black
3 The Dog is Brown
4 The Elephant is Grey
3 The Frog is Green
6 The Parrot is Blue

Non-Personal Events
Target
Past

1 Alex learning to read
2 Alex's last seaside visit
5 Alex learning to cycle
4 Alex learning to write
5 Alex's last school trip
6 Alex's last dentist visit

Target
Future

1 Alex's twelfth birthday
2 Alex's last day of primary school
3 Alex's next zoo visit
4 Alex's next picnic
5 Alex's next sleepover
6 Alex first car

Non-Personal Events
Distractors

1 The Apple is Green
2 The Banana is Yellow
3 The Blueberry is Blue
4 The Pommegranate is Fuchsia
3 The Strawberry is Red
6 The Tangerine is Orange

APPENDIX J

Personal and Non-Personal (Alex) events pictures (targets and distractors) chosen and used in the English schoolchildren's computerized task.

Personal Events

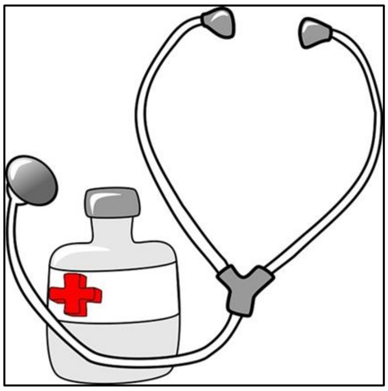
Past

You starting primary school

Your fifth birthday

Your first lost tooth

Your last birthday present



Your last doctor's visit

Your last Halloween

Personal Events

Future

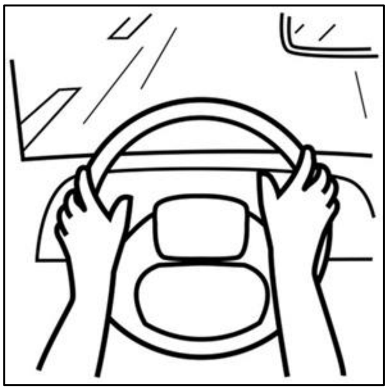
Your next Christmas dinner

Your next Easter holiday

Your next flight

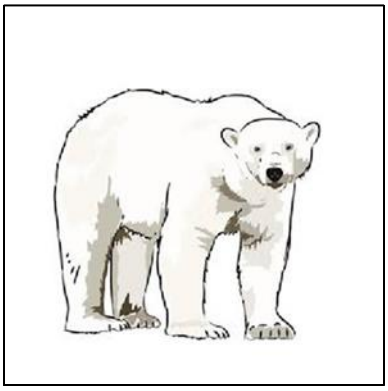
You next museum visit

Your starting secondary school



You learning to drive

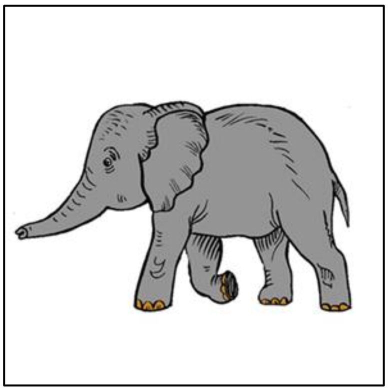
Distractor Personal Events Condition



The bear is white

The cat is black

The dog is brown



The elephant is grey

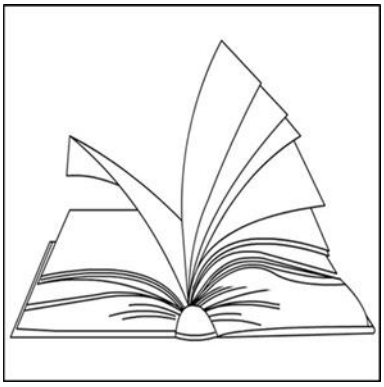
The frog is green

The parrot is blue

Non-Personal (Alex) Events

Past

Alex learning to cycle



Alex learning to read

Alex learning to write

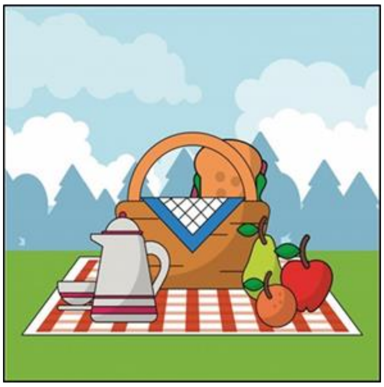
Alex's last dentist visit

Alex's last school trip

Alex's last seaside visit

Non-Personal (Alex) Events

Future



Alex’s next picnic

Alex’s next sleepover

Alex’s next zoo visit

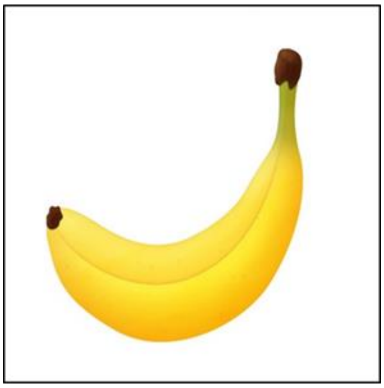
Alex’s twelfth birthday

Alex’s first car

Alex’s last day of primary school

Distractor Non-Personal (Alex) Events Condition

The apple is green



The banana is yellow

The blueberry is blue

The pomegranate is fuchsia

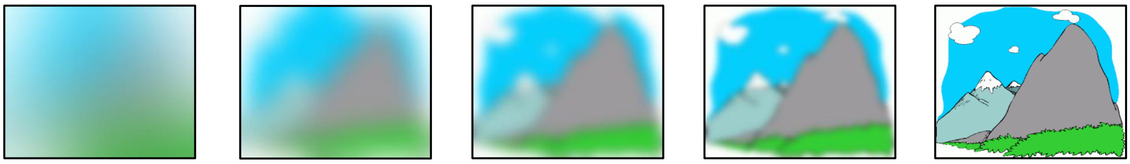
The strawberry is red

The tangerine is orange

APPENDIX K

Vividness and Possibility Survey used for the English children computerized task

"Often when we think about things that have happened to us or will happen to us we have a picture of them in our heads. In this bit I will ask you to think about different things that have happened to you or will happen to you and i want you to use these pictures to show me how clear each of these things look to you when you think about them. This means that it looked not at all clear (pointing left to right), pretty unclear, not so clear, somewhat clear, very clear and very very clear."



Past

1. How well do you remember your 'Last Halloween Fancy Dress'?
2. How well do you remember the 'Last Gift You Received'?
3. How you remember your 'First Bicycle'?
4. How you remember your 'First Day of School'?
5. How you remember your 'Last School Holiday'?
6. How you remember your 'First Lost Tooth'?

Future

1. How likely can be occur your 'Next Christmas Dinner' in the future?
2. How likely can be occur your 'First Car' in the future?
3. How likely can be occur your 'First Job' in the future?
4. How likely can be occur your 'First Day in Secondary School' in the future?
5. How likely can be occur your 'Next Museum Visit' in the future?
6. How likely can be occur your 'Twelfth Birthday' in the future?