Aspects of Temporal Cognition in Children's Development:

Causality, Normativity, and Perspective Understanding

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Karoline Lohse

aus Kaltenkirchen

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Betreuungsausschuss

Hannes Rakoczy, Abt. Biologische Entwicklungspsychologie, Georg-Elias-Müller-Institut für Psychologie, Georg-August-Universität Göttingen

Michael Waldmann, Abt. Kognitionswissenschaft und Entscheidungspsychologie, Georg-Elias-Müller-Institut für Psychologie, Georg-August-Universität Göttingen

Mitglieder der Prüfungskommission

Referent: Hannes Rakoczy, Abt. Biologische Entwicklungspsychologie, Georg-Elias-Müller-Institut für Psychologie, Georg-August-Universität Göttingen

Korreferent: Michael Waldmann, Abt. Kognitionswissenschaft und Entscheidungspsychologie, Georg-Elias-Müller-Institut für Psychologie, Georg-August-Universität Göttingen

Weitere Mitglieder der Prüfungskommission:

Tanya Behne, Abt. Biologische Entwicklungspsychologie, Georg-Elias-Müller-Institut für Psychologie & Courant Forschungszentrum „Evolution des Sozialverhaltens“, Georg-August-Universität Göttingen

Roland Grabner, Abt. Pädagogische Psychologie, Georg-Elias-Müller-Institut für Psychologie, Georg-August-Universität Göttingen

York Hagmayer, Abt. Kognitionswissenschaft und Entscheidungspsychologie, Georg-Elias-Müller-Institut für Psychologie, Georg-August-Universität Göttingen

Annekathrin Schacht, Nachwuchsgruppe Experimentelle Psycholinguistik, Courant Forschungszentrum „Textstrukturen“, Georg-August-Universität Göttingen

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Note to the Reader

Throughout this thesis I have used the pronoun ‘we’ instead of ‘I’. The work here is my own in terms of hypotheses, analyses and conclusions, but it is effectively the product of close collaboration and constructive debate with my colleagues at the Department of Developmental Psychology.

1 GENERAL INTRODUCTION

What then is time? If no one asks me, I know. If I wish to explain it to him who asks, I know not.

Saint Augustine, *Confessions*

Time is a fundamental category that is pervasive in all our thinking. It is expressed in language when we refer to things that happened just some seconds ago, things that are about to happen next year or literally at any point in the eternal flow of time. Temporal awareness generates desires, and it shapes our behavior, e.g. when we seek to keep souvenirs of specific moments to preserve the fugacious past for the future. We try to prepare for the near and distant future when we scribble to-do-lists, design building plans or formulate our last will. On the individual level memory for the past and images of the future are essential for the conception and the development of personality (e.g. Singer & Salovey, 1993). On the collective level the transmission of traditions, past experiences and inventions, over generations creates history and identity of diverse human communities; it forms the basis of human cultural evolution (Tomasello 1999). Compared to other species human temporal cognition is impressively flexible - and possibly unique (e.g. Clayton, Russell, & Dickinson, 2009; Roberts & Feeney, 2009; Suddendorf & Corballis, 2007), but it is also an ability of high complexity that shows up in many different forms and facets of human cognition. In the famous quote above, Saint Augustine expresses the problem to capture the concept of time in simple words. It is just as well not trivial to answer the question of what exactly human temporal cognition is and what cognitive resources it is relying on. The aim of this thesis is to investigate the emergence of specific aspects of temporal cognition in childhood in order to gain deeper insight into the embedding and the relation of temporal cognition with other, overlapping abilities that do not relate to the temporal domain at first glance. In the first sections characteristics of temporal cognition and their early manifestations in children will be presented. In section 1.3, three aspects of temporal cognition which are important for the development of mature temporal thought will be identified. In chapter 2 three studies conducted to test children's competence in these aspects will be presented and discussed in chapter 3.

1.1 What does it take to perceive time?

> […] *die Zeit ist ein wesentliches Problem. Ich denke, dass wir nicht von der Zeit absehen können. Unser Bewusstsein bewegt sich unaufhörlich aus einem Zustand in den anderen, und dies ist die Zeit: die Abfolge.“*
>
> Jorge Luis Borges, *Die letzte Reise des Odysseus* (1992)

As Borges puts it the essential characteristic of time perception is the perception of sequence; an impression perceived by any sense can neglect spatial reference, but it will always be associated with its occurrence relative to other impressions. Perceptually, single events or impressions take place at specific points on an imaginary timeline and they are interrelated in different ways. The relation that anchors one event with another is essential, as it determines the event's location on the timeline: if no such temporal connection would be possible, than a single event (or an impression) could not be represented as real. It would be separated from real-world experiences, e.g. as a piece of the imagination, and independent from the timeline. Important ingredients of our conception of time are, therefore, the conceptions of objective reality and interrelatedness of events in the real world (Bieri, 1986). Parts of this reality are diachronically existing entities, e.g. objects that are permanent over time, and also temporally restricted entities like events and actions.

But what is the nature of the interrelations between these entities? Things in the real world change over time and events occur as a consequence of preceding events. That is, every representation of an object or an event elicits causal connections to "earlier" or "later" states in the flow of time. But the kinds of connections can be manifold according to the type of event. For example, actions of intentional agents are normatively related with each other in the sense that an action (e.g. a communicative act like the verbal utterance "It is cold in here.") can evoke, or even call for, a set of normatively adequate possible reactions (e.g. a verbal response like "Yes, I feel the same", the action of closing a window, etc.) (Searle, 1969, 1998). Representing one of these actions as a communicative act means representing anterior and posterior events as well, which are parts of the action's communicative context. Someone witnessing only the first action is likely to expect a reaction to follow, whereas witnessing only the second action might generate assumptions on preceding actions. Similar to these normative connections, the picture of a broken mug might elicit the causal connection to another state where the mug is still intact. Knowledge about cause-effect relations determines the expected temporal direction of the mug's states, with the intact state being very likely to be temporally prior to the state where it is broken (Kutach, 2011; Le Poidevin, 2007). Taken together, our mature conception of time entails the representation of events as occurring in a temporal sequence. The structure of this sequence is determined by the connections between events, which are mainly causal in nature, but they can also rely on normative relationships.

Another important component necessary for temporal cognition is the conception of a temporally extended self (Moore & Lemmon, 2001; Nelson, 2001). This means, in addition to representing objective facts like temporally restricted events and permanent objects and their causal connections in the world, it is necessary to represent the self as causally involved and continuously existing in this world (Bieri, 1986). Without such self-representation the succession of events in time could not be represented from an external viewpoint. Instead temporal relations could only be represented as abstract distances between one another. This external viewpoint is a second level of representation, often referred to as meta-representation (Bieri, 1986; Perner, Brandl, & Garnham, 2003). Crucially, with time "passing by" the self is changing perspective constantly and consequently its representation of representations changes. This means that representations of objective facts, e.g. 'I see the mug falling down the table', are formed at specific points in time (e.g. simultaneously with, or directly after the unfolding of the event). In contrast to the real event, the subjective representation persists over time as part of the identity of the self. With time elapsing, only temporal markers of representations are added and changed as a process of embedding representations into representations, e.g. 'I remember seeing the mug falling down the table'. This form of meta-representation allows for unlimited recursion in our event representations (see Corballis (2011) for a detailed analysis of the recursive structure of thought).

In conclusion two major prerequisites for the human perception of time are (i) the conception of time as a causally structured sequence of events, and (ii) the conception of a continuously existing, or temporally extended self. In the following section evidence for the early possession of these conceptions will be examined with the focus on important abilities that are expected to emerge with the development of temporal cognition.

1.2 Manifestations of temporal cognition in children

1.2.1 Remembering the past

Children around age four start to identify with their past selves in the present and show delayed self-recognition (Povinelli, Landau, & Perilloux, 1996; Zelazo, Sommerville, & Nichols, 1999). It is around the same time when they begin to remember specific events of their individual past and represent them as their own experiences, i.e. when they form autobiographical memories (Nelson, 1993; Perner & Ruffman, 1995). This specific kind of memory for events as personally experienced was termed "episodic memory" in distinction to "semantic memory" by Tulving (1972). The difference between episodic and semantic memory is often exemplified by the difference in "remembering" specific events as opposed to "knowing" certain facts (see, e.g., McCormack, 2001; Suddendorf & Corballis, 1997). A major characteristic of episodic memory is its embedded autobiographic (or "autonoetic") component, which allows for a recursive structure in the sense of remembering something by representing the experience as an original experience of the past self (Perner, 1991, 2000, 2001; Tulving, 1985). A description by Corballis emphasizes the role of recursion and its significance for the developing conception of a temporally extended self:

> *Autonoetic awareness, then, is recursive, in that one can insert previous personal experience into present awareness. This is analogous to the embedding of phrases within phrases, or sentences within sentences. Deeper levels of embedding are also possible, as when I remember yesterday that I had remembered an event that occurred at some earlier time.* (Corballis, 2011, p. 85)

Besides the theoretical possibility of representing an infinite number of past representations, empirical evidence suggests that with four years, children are at least able to identify with their past self (when shown a photo or a video) and they can link that past event with the present (e.g. when checking one's body for a sticker that the photo shows to be sticking there) (Povinelli, 2001). Moreover, children of this age begin to reason systematically about the temporal-causal relations of past events, e.g. when inferring current consequences from the order of two events they recently experienced (McColgan & McCormack, 2008; McCormack & Hanley, 2011; McCormack & Hoerl, 2007; Povinelli, Landry, Theall, Clark, & Castille, 1999). This suggests that young children appreciate the fact that the order of past events is causally significant for present states of the world. Still, it is unclear how much information about the particular temporal locations of past events children represent when engaging in this kind of tasks (McCormack & Hoerl, 1999).

1.2.2 Planning for the future

Advanced temporal cognition allows humans to foresee future desires in order to act in the present and prepare for future states of the self (Bischof-Köhler, 2000; Suddendorf & Corballis, 2007). Such future-oriented behavior requires at least two capacities: (i) the capacity to inhibit salient current desires and (ii) the capacity to engage in "self-projection" to the future (McCormack & Atance, 2011). The first part of requirements has been tested in various adaptations of the classical "delay of gratification" paradigm (Mischel, Shoda, & Rodriguez, 1989). In these tasks children are asked to choose between receiving either a less desired reward immediately or receiving a larger or more desirable reward later in time. Beginning with four years, and with increasing competence in the following years, children are able to inhibit their present desire for the smaller reward in favor of the larger future reward (e.g. Lemmon & Moore, 2001; Thompson, Barresi, & Moore, 1997) and even young children are sensitive to the length of the expected delay (Garon, Johnson, & Steeves, 2011). Self-projection into the future, which is the second part necessary for flexible future planning, closely resembles what was described earlier as episodic memory in the past context. In the future context the ability to mentally project oneself to (and imagine the self at) temporally distant events has been termed "episodic future thinking" or "episodic foresight" (Atance & O'Neill, 2001; Suddendorf & Moore, 2011).

A variety of experimental tasks has been designed to test children's ability to mentally "project the self forward in time in order to pre-experience an event" (Atance &

O'Neill, 2001, p. 537; see Suddendorf & Redshaw, 2013 for a review). Results indicate, again, that children around the age of four are able to save resources for a future need (Metcalf & Atance, 2011). Furthermore, they are likely to foresee what they themselves or another person will need in the near future and organize resources in the present to meet these anticipated needs (Russell, Alexis, & Clayton, 2010; Suddendorf, Nielsen, & von Gehlen, 2011). Studies have shown that for tapping episodic foresight experimentally, it is crucial to differentiate contexts that appeal to rather semantic or script-like knowledge (Hudson, Sosa, & Shapiro, 1997) from those contexts truly requiring flexible (episodic) forecasting of specific future events; for example Atance and Meltzoff (2005) found that when choosing an item that would be useful in a specific future scenario, specifically younger children had a tendency to base their choices on semantic associations between item and scenario rather than the item's future use (e.g. choosing to take ice cubes to a snow-scenario instead of the winter coat). Furthermore, even knowledge-based routine decisions (e.g. the default to prefer pretzels over water) are discarded by children's current physical states, to the end that a current desire (e.g. thirst) impedes children's future-oriented decision-making even at the age of 7 (Atance & Meltzoff, 2006; Mahy, Grass, Wagner, & Kliegel, in press). These examples demonstrate that future oriented behavior in children, besides the underlying conception of time generally recurs to, and depends on the availability of other cognitive resources, like semantic knowledge and executive functions.

1.2.3 Mental Time Travel

A growing body of work has focused on the combined capacity of episodic thought into both temporal directions. The ability to mentally re-experience the past and to pre-experience the future is often called "mental time travel" (MTT) (Atance, 2008; Suddendorf & Corballis, 1997, 2007). Theoretically, the basic idea behind research on mental time travel is that there is a unitary capacity to cognitively travel in time that underlies our thinking about both past and future events (Atance & O'Neill, 2001; Bischof-Köhler, 2000; Tulving, 1999, 2005). Empirically, MTT research suggests that the two capacities (reasoning about the past and reasoning about the future) emerge in synchrony and in a correlated fashion between three and five years of age (see, for a review Suddendorf & Redshaw, 2013). Joint emergence and systematic correlations between past and future cognition have been documented, for example, in language comprehension (“yesterday” / “tomorrow”) (Busby & Suddendorf, 2005; Harner, 1975), and tasks involving both the concept of a past self (delayed self-recognition), and the concept of a future self (delay of gratification) (Lemmon & Moore, 2001). In addition, neuropsychological research on adults suggests shared underlying neural substrates of episodic memory and episodic foresight (Addis, Wong, & Schacter, 2007; Klein, Loftus, & Kihlstrom, 2002). Converging evidence for fundamental cognitive changes around the ages of three to five comes from related lines of research on the development of temporal language (Friedman, 2004; Harner, 1980; Hudson, Shapiro, & Sosa, 1995), episodic memory (Gopnik & Graf, 1988; Nelson, 1993; Perner & Ruffman, 1995) and future planning (Atance & Jackson, 2009; Atance & O’Neill, 2005; Russell et al., 2010; Thompson et al., 1997). Less emphasis, however, has been put on the question which *conceptual capacities* exactly underlie children’s temporal cognition: Which aspects of time do children represent, and in which ways?

1.3 Open questions about the development of temporal cognition

In section 1.1 different characteristics of the conception of time were described, among these the representation of temporal succession which helps to anchor and order single events in the temporal framework. What comes along with this characteristic, is the perceived direction of time, or the so called “arrow of time” (e.g. Kutach, 2011; Le Poidevin, 2007). Evidence for temporal skills in children as presented in the above section, does not provide insight into the underlying temporal representations that children might have. Do children, who start to reflect on past experiences and plan for their future, grasp the generic difference between past and future events? Do they represent temporal direction? The temporal order of events is determined by their cause-effect relationships - may these be physical or social-normative in nature -, and these relationships imply the asymmetry that future events can possibly be influenced by events that are brought about in the present, but this does not apply for the past (Kutach, 2011). Similarly, present actions are often normatively bound to anterior actions and are understood in the context of past events, but they actively create the framework for future actions and therefore impact on our beliefs of what is likely to happen in the future (Bratman, 1984, 2000). Is children’s understanding of causality and normativity flexible in such a way that it evaluates the relations between past, present and future events appropriately? Additionally, the significance of meta-representation in the sense of representing the self as a continuously existing entity that changes over time, has been carved out in the above section. Do children represent events in time in the described way and understand their relations to the present self? The following sections review and critically examine existing research on the aspects of temporal cognition that are considered to be necessary for the development of mature temporal thought in children.

1.3.1 The aspect of causality in temporal understanding

In specification of the above thoughts and arguments we can summarize the following essential properties of temporal matters: minimally, time is conceived of as a sequence of events, such that (i) each event in time bears some temporal relations to the present (having happened *before* the present or going to happen *after* it). Relatedly, any two events in time (ii) stand in a definite temporal relation to each other, and (iii) are linked by causal relations such that – asymmetrically - earlier events may causally impact on later events, but not vice versa (Hoerl & McCormack, 2011; Kutach, 2011; Le Poidevin, 2003). Mature thinking about time thus involves the appreciation of temporal-causal relations between events and the capacity to apply this explicit conceptual representation flexibly to past and future contexts. When we know that effect E is usually brought about by cause C, and witness E taking place, we infer that C must have happened before. And when we plan for the future, we know that when we would like E to happen at a certain point in time t_E, we would have to bring about C at some point in time before t_E.

This kind of explicit reasoning on the basis of temporal and causal information is sometimes called "temporal-causal reasoning" (TCR) (Hoerl & McCormack, 2011; McCormack & Hoerl, 2005). Crucially, this form of reasoning needs to be distinguished from simpler cognitive processes with which it might easily be confused, most importantly from processes that are sensitive to temporal-causal relations without explicitly representing them. One example of such simpler processes is children's capacity to keep track of the causal flow of events over time (without representing it explicitly) in varieties of invisible displacement object permanence tasks (Haake &

Somerville, 1985; Piaget, 1954; Somerville & Capuani-Shumaker, 1984). In typical invisible displacement tasks, subjects see an object O being occluded, say in the experimenter's fist, at t_1. Then the fist moves into box 1 at t_2, reappears at t_3 and moves into box 2 at t_4 before the empty hand re-appears from box 2 at t_5. Crucially, at t_3, the experimenter opens her fist and - in different conditions - either shows that O is still there or that it is not there anymore before closing the fist again. The child's task is now to determine where O is. Arguably, this task can be solved in much simpler ways: subjects do not have to explicitly reason about temporal and causal relations. Rather, over time the child can simply update her representation of the whereabouts of O based on the current perceptual information (in the one case: seeing directly that O got lost in box 1 when the hand at t_3 is empty; in the other case: seeing the object at t_3 in the hand, then keeping track of the hand with the object and seeing directly at t_5 that the object got lost in box 2 (see McColgan & McCormack, 2008).

In contrast to explicit temporal-causal reasoning, such updating, however, is limited in fundamental ways: While TCR works flexibly into the past and future on the basis of information about the order of events and potential causal relations (in the past, present or future), updating can only be made use of in the present in a given situation on the basis of perceptually available information.

This is analogous to the scopes and limits of different forms of spatial cognition: Implicit egocentric representations of spatial matters (relative to one's own body) allow a subject to solve certain tasks. For example, a subject may keep track of and constantly update the egocentric relations of her current position P to her own home base H while foraging and can use this information to get home (much like the "homing vectors" used in insect navigation, (e.g. Fujita, Loomis, Klatzky, & Golledge, 1990)). However, this egocentric information is of only limited use: Imagine the subject is transferred to some other place Q in the environment. An egocentric representation specifying the relation of P to H is of no use then (it would move the subject at Q in the direction in which H would be seen from P – that is, quite the wrong direction). Explicit allocentric representations, in contrast, in the form of mental maps or the like, allow a more flexible and systematic form of thought about spatial relations from various positions (Burgess, 2006). Implicit (temporal and spatial) representations are thus limited in their application to certain points (in space or time), while explicit forms of temporal and spatial representations allow flexible reasoning from any point (in space or time).

Evidence for the development of such flexible temporal-causal reasoning comes from recent studies by Povinelli et al. (1999) and McCormack and colleagues (McColgan & McCormack, 2008; McCormack & Hoerl, 2005, 2007). The basic logic of the tasks used in these studies is that subjects had to mentally re-construct (or pre-construct) a sequence of causally linked events in order to correctly infer a present (or an anticipated future) state of the world (e.g. an object's location). Importantly, these tasks were designed in such a way that they required proper temporal-causal reasoning as children could not perceptually update their representations of the location of the object in question. Instead, children had to combine information about the temporal relations of some events with their knowledge of possible causal relations between the events. In one task designed to assess past-directed TCR, children learned that an action A produced effect E_A and another action B caused effect E_B, and that the effect of one action was overridden and replaced by the effects of temporally successive actions. On the basis of information about the order of two successive events, only 5-year-olds were able to flexibly combine this information and infer the ultimate effect correctly (if A was before B, E_B would hold in the end, but if B was before A, E_A would hold in the end) (McCormack & Hoerl, 2005, 2007; see also Povinelli et al., 1999).

In a different study McColgan and McCormack (2008) compared children's TCR skills in both temporal directions using separate yet structurally analogous tasks for reasoning about the past and reasoning about the future. In a *search task* children observed a puppet walking through a miniature-zoo, passing different cages and taking a Polaroid picture at the kangaroo's cage. At the end of the visit the puppet noticed the camera to be missing. In view of the photo of the kangaroo children were asked to indicate where in the zoo the camera might have been lost. If children correctly combined knowledge about the temporal order of events (determined by the direction of the path) with causal evidence provided by the photo, then they would only choose locations that were visited *after* the kangaroo's cage. 4- and 5-year-olds, but not 3-year-olds, succeeded in this task.

Reasoning about the future was assessed in a similar *planning task*: children were told that a puppet wanted to visit the zoo and take a picture of the kangaroo. The children's task was to preposition the camera in the zoo and enable the puppet to take the desired picture when passing by the kangaroo's cage. Again, children had to combine spatiotemporal knowledge about the direction of the path with causal knowledge about the course of events ('picking up the camera' is a causal prerequisite for 'taking a picture'). In a series of five experiments, 5-year-olds solved this task correctly by prepositioning the camera at a location *before* the kangaroo's cage, whereas 3- and 4-year-olds did not perform above chance level.

In sum, these studies thus suggest that temporal-causal reasoning emerges around the age of four to five years, and that there might be an asymmetry such that past-directed TCR precedes future-directed TCR. However, these studies leave open a number of important questions. First, children's competence might have been underestimated due to specific task demands (for example, having to do with the background knowledge about the workings of cameras the task requires– which, as we know, is not trivial for young children (Zaitchik, 1990)). Second, there is the contrary possibility that existing tasks might have overestimated children's competence, producing false positives. This might have been the case because there was a fundamental confound between type of task and the correct answer: in the search task the correct answer was always the location(s) *after* the kangaroo whereas in the planning version it was always the location(s) *before* the kangaroo. Children's responses might therefore result from a bias to the particular side in the respective task. Results would be more convincing if children would also succeed in tasks where a future location *after* the kangaroo's cage had to be inferred, and a location *before,* in the *search task* respectively. Third, in light of this confound between condition and correct answer, the asymmetry found between past- and future-directed TCR (the former preceding the latter) is difficult to interpret. The pattern of responses in the 4-year-olds (mastering only past-directed tasks) might have come from a default tendency to choose locations after the kangaroo's cage (resulting in correct answers in the past but incorrect answers in the future condition). Finally, the underlying assumptions of these studies are (i) that the tasks require TCR and cannot be solved by simpler processes like mere updating and (ii) that very similar tasks that do not necessarily require TCR should be solved earlier in development. Since, however, these assumptions have not been empirically tested in those studies, whether they are in fact true is a very interesting open empirical question (but see McCormack and Hoerl (2005) for such a minimal contrast pair of another temporal task that had two versions: a version that can be solved by mere updating in contrast to another version that requires TCR). Study Set 1 approaches this interesting question building upon and extending earlier research on children's TCR.

1.3.2 The aspect of normativity in temporal understanding

One defining characteristic of temporal cognition is the conception of the *temporally extended self* (see section 1.1). Part of this conception is the understanding of the self not only as *persisting in time*, but also as *acting in time.* Temporally extended agency is what enables humans to make plans and coordinate activities (Bratman, 2000). Mental states, like desires and beliefs, create the motivation - the internal basis - for actions, while communicating these internal plans creates social obligations. An agent A, who commits himself to do X, can create under certain circumstances (as will be specified below) another agent's belief e.g. of the kind: [*A will do X*]. Noticeably, in this example the commitment of A binds A over *time*: the utterance of the intended action as intended action has normative outreach into the future (Mant & Perner, 1988). How is children's understanding of this normative outreach? Do they track obligations over time that originate from communicative acts? Do they differentiate the kinds of obligations entailed in specific utterances? The following section provides a closer look at what kinds of speech acts entail what kinds of normative commitments.

Our speech acts can refer to events in time that are different from the present, and they have normative outreach into the past and the future. When reaching out into the future, e.g., a speech act can do this - even with the same propositional content - in two fundamentally different normative ways: (i) representing the future as it (subjectively) will be, or (ii) representing the future as it (subjectively) ought to be from one's point of view. Paradigmatic mental states of type (i) are beliefs about the future, and the paradigmatic corresponding speech acts are assertions about the future (predictions), such as "Peter will eat the cake". These have the so-called *mind-to-world* direction of fit (Searle, 1969, 1983), aiming at representing the world truly and accurately. If the propositional content of “Peter will eat the cake” is not fulfilled, the mistake is on the part of the speaker. Paradigmatic mental states of type (ii) are desires about future events, typically expressed in imperative speech acts like “Peter, eat the cake!” These have the so-called *world-to-mind* direction of fit, aiming at bringing the world in line with the content of the mental state/speech act. When the propositional content of “Peter, eat the cake!”, - which is in fact the very same propositional content as in the case of the prediction “Peter will eat the cake” - namely the proposition <that Peter will eat the cake> is not fulfilled, the mistake is now not on the part of the speaker, but on the part of the addressee.

Different kinds of speech acts such as assertions and imperative speech acts can take the very same content (e.g. the proposition <that Peter will eat the cake>) but differ in their mode – much like different kinds of propositional attitudes such as believing and desiring can have the same content (e.g. <that Peter will eat the cake>) while differing in psychological mode. Now, what determines the mode of a propositional attitude or a speech act? In the case of propositional attitudes, the mode is essentially constituted by the functional role of a given type of attitude – by what job this attitude does in the mental economy of the subject (e.g. beliefs are attitudes that aim at tracking reality and are therefore sensitive to perceptual evidence, that lead inferentially to other beliefs, and that together with desires rationalize and lead to actions (Fodor, 1985; Putnam, 1960; Sellars, 1956). The mode of a speech act, in contrast, is largely, but not exclusively determined by the psychological attitude of the speaker. For example, although imperative speech acts are largely constituted by the expression of a desire to someone else, not any utterance that expresses a desire towards someone constitutes an imperative speech act. For each given type of speech act, there are specific background conditions, varying from one type of speech act to another, that have to be met in order for such a speech act to successfully materialize (Searle, 1969). More specifically, imperative speech acts have some such success conditions that do not apply to other speech acts, assertions in particular. These conditions include the following: the imperative is reasonable, the speaker is in a position to reasonably ask the addressee to perform the action (for example, if I step up to a stranger and say” Give me the moon!”, this fails to constitute a successful imperative speech act…), and the addressee acknowledges the imperative (e.g. "Okay!"). Only if these conditions are met, has the speaker performed a successful imperative and has an obligation been transferred on the addressee.

If such conditions are met, due to their different logical structures and normative forces, future-directed assertive and imperative speech acts engender very different normative relations to the future in speakers and addressees: speakers of assertions are committed to the truth of predicted future states of affairs whereas addressees of imperatives are committed to bringing about the desired states of affairs.

From the point of view of cognitive development, the fundamental question is how children's grasp of these different kinds of *cognitively reaching out into the future* emerges and develops. Existing studies on pragmatic development suggest that children's understanding of the logical structure of future-directed speech acts develops rather late, between the ages of seven and nine (Astington, 1988, 1990; Maas & Abbeduto, 1998). This research shows that children around five to six years of age find it difficult to distinguish the different kinds of commitments engendered by predictions and promises (note that promises are basically imperatives to oneself (Searle, 1969)): When asked whether someone promised or predicted something, children judged any speech acts –predictions and promises alike – as predictions when they were unfulfilled, and as promises when their content came true. Only beginning with age nine did children discriminate predictions and promises by holding speakers *responsible* for the fulfillment when the speech act was a promise, but not if the speech act was a prediction.

What these results might suggest is that it is not before well into school age that children come to differentiate the underlying normative force and directions-of-fit of different types of future-oriented speech acts. However, such a strong conclusion clearly might not be warranted by the data. First, the tasks used so far are quite demanding, as children had to follow, memorize and to judge hypothetical stories instead of perceiving the critical events directly. Second, participants had to judge the stories they were presented with by verbally responding to a series of experimenter-questions, which again draws on the presence of sophisticated memory, and particularly, on language skills. It is thus possible that the methodology of previous studies might have seriously underestimated young children's competence and produced false negatives.

In fact, recent research investigating children's understanding of speech acts with alternative methods might be compatible with this hypothesis; For *present-tense* speech acts, it has been shown that children as young as two to three years of age are able to differentiate the *direction of fit* of speech acts with the same propositional content. They selectively criticized a speaker for a false assertion of the type "Actor does X" (to the effect that the actor was doing Y at the time of the utterance), but the actor for not complying with a speaker's imperative ("Actor, do X!" with the actor performing a different action at the time of the utterance) (Rakoczy & Tomasello, 2009).

Yet, there is no research that tackles the question when children start to temporally track commitments that are implicate in speech acts referring to times different from the present. Sensitivity for such normative outreach of language would be evidenced, e.g. by the differentiation of directions of fit, as shown for the present tense by Rakoczy and Tomasello (2009). Therefore Study Set 2 aims to contribute to our understanding of children's grasp of the underlying normative structure of *future-directed* speech acts, by the application of less demanding, action-based measures that require less memory and verbal skills than the methodologies used in the experiments discussed above.

1.3.3 The aspect of perspective in temporal understanding

The third aspect that plays an essential role in the development of temporal cognition is temporal perspective. Our thinking comprises temporal perspective in the same way that it comprises spatial perspective: we think of an event as happening before, simultaneously with, or after other events, just as we represent an object as being located next to, behind, on top of, etc. other objects in space. This idea was alluded to already in terms of meta-representation, or the representation of a temporally extended self (see section 1.1). As for spatial perspective, the representation of the self as a "permanent" entity that is located in (space and) time is necessary for understanding temporal perspective. A mind endowed with this representation is able to represent one and the same event from different temporal perspectives. Its present self is able to refer to an infinite number of certain points in time while constantly changing perspective: referring to something as "now" is having referred to it yesterday as "tomorrow" (Bieri, 1986). In this view, temporal perspective changes as soon as a new representation - be it an impression, the perception of an event, or another form of representation - is added to the individual's storage of representations. It is due to this meta-representation (of representations formed at specific points in time) that a single representation that is perceived as "present" (although it already belongs to the past at the time it is represented, see Le Poidevin (2007)) doesn't simply vanish. Instead it is stored (represented) in relative position to the new current event (i.e. relative to the perceived present) within our temporal framework.

But there is a second interpretation of temporal perspective, which, instead of focusing on the permanent change of perspective in the flow of time, applies to our ability to represent event-relations from different temporal mental viewpoints. Similar to the different possible angles from which the relation of two objects is represented differently (see Figure 1) the temporal relation between two events *in time* can be represented according to different *points of reference*. As an example, imagine the boy Abe to visit the exhibition of a rock. At this time (t_1) he will form the representation '*I am seeing the rock'*. Leaving the exhibition hall he stumbles across a bar which is lying on the ground (t_2: '*I am stumbling across a bar'*). When he later (t_3) tells his friend Bea (a) "*I had just seen* the rock, when *I stumbled* across a bar.", Abe is coordinating the actual *time of the event* (stumbling across the bar, t_2) with an earlier *reference time* (seeing the rock, t_1), see Figure 2. The other way around, he could have used t_1 as the event time and making reference to t_2 by saying (b) "*When I saw* the rock, I didn't expect that *I would stumble* later." In the two sentences the same event sequence is described from different temporal perspectives: in (a) the point of view rests on t_2, whereas in (b) the point of view is his representational state at t_1. That is, apart from the present time, i.e. the *speech time*, when he talks to Bea, Abe coordinates two additional points in time, *event time* and *reference time* (Weist, 1989). In analogy to the concept of "spatial decentering" (Piaget & Inhelder, 1956), this kind of temporal perspective taking has been termed "temporal decentering" by some authors (Campbell, 2001; Cromer, 1971; McCormack & Hoerl, 1999). In the above example, in order to take different perspectives on the two past events, the speaker is required to mentally "decenter" from his present view, in order to represent the sequence in an "event-independent" fashion, i.e. from any possible temporal perspective that is different from the speaker's present (see McCormack & Hoerl, 1999; McCormack & Hoerl, 2008).

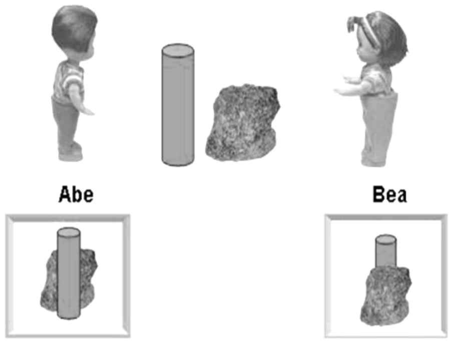


Figure 1. Representing the spatial relation of two objects differently from different perspectives: Abe represents the objects' relation as *[the bar is in front of the rock]*, Bea's representation is *[the bar is behind the rock]*). Reprint from Perner et al. (2003).

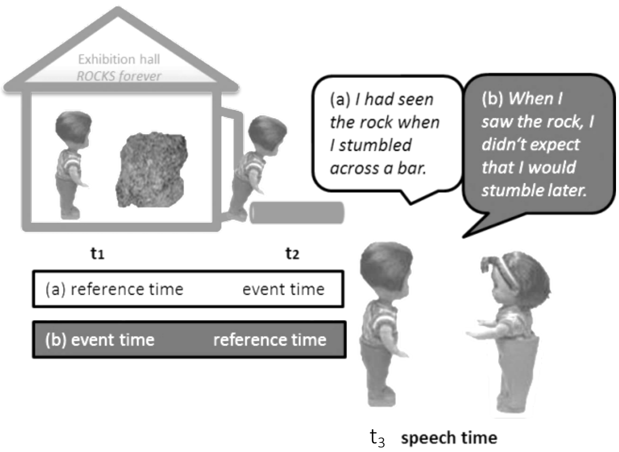


Figure 2. Representing the temporal relation of two events from different perspectives: the viewpoint taken (i.e. the *event time*) in utterance (a) is t_2, in utterance (b) *event time* is t_1.

To our knowledge, there is only one study that has directly aimed to investigate temporal decentering in children so far: Richard Cromer (1971) presented four- to seven-year-old children with short stories consisting of a series of pictures, one picture after another in left to right direction, while the story was told. On each picture a speech bubble indicated the protagonist saying something. After being told the story, children were asked at which point in time (i.e. in which picture) the protagonist might make a certain utterance (or, in another condition, which other picture of the same story the protagonist is talking *about* in a certain picture). For example, in one story a girl visited a farm in the country and experienced different things (seeing a cow, picking some flowers etc.). In the subsequent test children were asked to indicate, e.g., "*in which picture can the little girl say: I'll pick flowers*." or "*I have seen a cow*" alternatively. According to Cromer, answering these questions required temporal decentering when the correct picture to point to was different from the one depicting the event itself (e.g., a correct response to the first example, "I'll pick flowers", would have been identifying a picture left from, i.e. before, the one where the girl picked flowers.) Results suggested that children of four and five years were able to give decentered responses.

Early research on children's ability to represent the *spatio-visual* perspective of another person (which differs from their own perspective), suggested that spatial decentering emerges somewhat later in development than Cromer's results suggested for temporal decentering (Piaget & Inhelder, 1956). Though, from later investigations and building upon Piaget's work it was conveyed that children around age three understand that a person that is located in a different angle to an object than they themselves, has a different perception of the object, accordingly (level I perspective taking). With age four children already begin to represent and take into account the specific kind of the other's representation in addition to their own (level II perspective taking) (Flavell, Everett, Croft, & Flavell, 1981; Masangkay et al., 1974; Moll, Meltzoff, Merzsch, & Tomasello, 2013). The different levels of visual perspective taking are reflected in the wording used to describe the different underlying cognitive abilities, e.g. "taking" versus "confronting" perspectives (Moll et al., 2013), or "switching" versus "taking" perspectives (Perner et al., 2003). McCormack and Hoerl (1999) argue that the different levels of representing perspectives apply to more domains than only spatial or temporal representations. As an example for perspective "switching" as an early form of decentering they propose young children's understanding of fictional narratives as not being real:

> *We think that this early kind of decentering can be understood as being analogous to the abilities involved in early pretense. Numerous authors have argued that in early pretense children can switch perspectives without a proper grasp of the relation between the pretend and actual perspective [...]. For*

> *example, they can switch from the representation ''This is a banana'' to a representation ''This is a telephone,'' and, hence, pretend that the banana is a telephone without representing the nature of relation between these representations (i.e., without representing ''I am pretending of the banana 'This is a telephone' '').* (p. 171 f.)

Furthermore, McCormack and Hoerl claim that full-blown temporal decentering requires the more sophisticated form of both abilities that comprises understanding the *nature of relation* between different perspectives. Perner and colleagues argue that a simultaneous integration of different representations which are incompatible from one single point of view (as shown e.g. in Figure 1, *[the bar is in front of the rock]* vs. *[the bar is behind the rock]*) is only possible by introducing different points of view through the concept of meta-representation (to use the bar-rock example, meta-representation allows for the integration of both perspectives in the sense of representing that "*Abe represents* the bar in front of the rock <u>*and*</u> *Bea represents* the bar behind the rock). According to Perner et al. (2003) a characteristic of *perspective problems* per se is that they "*can be solved only by relying on a meta-representational integration*" (p. 362). In support of this domain-general account of perspective taking, there is evidence from developmental research for the joint emergence of perspective taking skills in different domains in children. Correlations have been found for, e.g. children's mental and spatio-visual perspective taking (Bigelow & Dugas, 2009; Hamilton, Brindley, & Frith, 2009).

To conclude, understanding temporal perspective involves two major components: firstly, it requires the understanding that events can be represented from different temporal viewpoints (i.e. from points that are different from the subjective present). According to Weist (1989), *temporal decentering* requires the mind to coordinate at least three points in time (i.e. speech time, event time and reference time, and the relations between each other). Secondly, according to Perner's definition, *perspective understanding* means to integrate and simultaneously represent perspectives that are incompatible without reference to different viewpoints on a meta-representational level. Cromer introduced one possibility to test children's skill in *temporal decentering*. However, successful performance in this task heavily relied on children's verbal skills, specifically their understanding of tense (for a discussion see Cromer, 1971; McCormack & Hoerl, 2008). Still, for testing *perspective understanding* it seems necessary to include the second component of taking - in the sense of mentally confronting - different perspectives, when testing for children's *temporal perspective* understanding. In the current literature there is no example of a task that combines both components in order to investigate temporal perspective understanding in children. Furthermore, it is an open question whether the development of children's understanding of temporal perspective is related to the development of understanding perspective in other domains. Study 3 aims to further investigate these open questions.

1.4 Focus of the dissertation

The aim of this thesis is to broaden to our knowledge about the underlying conceptions of human temporal thought and their development in early childhood. Research on children's skill in future planning and their memory for the past suggests substantial changes in this domain between the ages of three to six years (see section 1.2). In order to gain a more detailed picture of what kinds of representations might underlie these emerging skills in section 1.3 three aspects of mature temporal thought were introduced.

First, causal connections determine the order of events in time and are therefore crucial for locating specific events in relation to the present or to other events. Existing research suggests that children around age four are able to infer a current state on the basis of temporal-causal information on past events. And it is possibly somewhat later in development that they begin to consider cause-effect relations when preparing for specific future events in the present. Still, children's flexibility in temporal-causal reasoning (TCR) and their performance in similar but simpler tasks have not been tested so far. In Study Set 1 existing methodologies were adapted and further developed in order to close the gap in our knowledge about children's temporal-causal reasoning.

Second, the appreciation of normativity in children's understanding of communicative acts was presented as an essential aspect for the appropriate evaluation of actions (and speech acts) in time. While studies on children's explicit conceptions of certain types of future-directed speech acts suggest that before age seven to nine, children do not properly understand concepts such as promises, there are indications of an earlier ability to discriminate basic normative differences in present-tense speech acts.

Study Set 2 was designed in order to combine these two lines of research and to test for children's grasp of the underlying normative implications of different types of speech acts that refer to future points in time (predictions, imperatives).

Third, the understanding of perspective provides the framework for subjective experience within the objective world. In the temporal domain perspective understanding enables us to represent an event from the viewpoint of an earlier or a later state of our (temporally extended) self. Furthermore, it allows us to flexibly change our perspective on the order of specific events in time in relation to the present. An earlier study (Cromer, 1971) tested for children's ability to decenter in time by asking children to connect events in a picture–book story with complexly tensed utterances. In Study 3 we used a different methodology to elicit children's inferences on subjective representations of the temporal order of two events.

2 STUDY SET 1: TEMPORAL-CAUSAL REASONING

The rationale of Study Set 1 was to systematically explore the early development of temporal-causal reasoning by following up on previous work and systematically testing for children's flexibility in temporal-causal reasoning. To this end, the (a-)symmetry of temporal-causal reasoning about past and future events was investigated by systematically comparing the performance of children in structurally analogous search and planning tasks in which potential confounds between the conditions were removed. In order to directly distinguish TCR from simpler cognitive processes, in particular mere updating, a minimal contrast was devised between two versions of the past-directed search task that could or could not be solved by updating. Potential task demands (such as complexities involved in understanding cameras) were controlled for.

Four- and six-year-old children were tested as previous studies have shown this to be the age where TCR emerges and undergoes fundamental development. Study 1a investigated past- and future directed temporal-causal reasoning in a future planning task and two structurally analogous search tasks (one of which required the structurally analogous TCR as the future planning task and the other one of which could be solved much simpler by updating). Study 1b followed up on the findings of Study 1a by testing for potential factors that could explain why some of the search tasks in Study 1a were easier than others.

2.1 Study 1a

2.1.1 Method

Participants. Sixty 4-year-olds (48 – 60 months, mean age = 54 months, 30 boys) and sixty 6-year-olds (72-83 months, mean age = 77 months, 30 boys) were tested. Five additional children were excluded from the final sample due to technical error (one boy, four years old), uncooperative behavior (two boys, four and six years old), or because of a delay in language development, that hindered the child's understanding of the stimuli (one boy, one girl, both four years). Children were native German speakers, came from a mixed socioeconomic background and were tested either in a quiet room in their daycare centers or in the child lab facilities of the authors' home institution.

2.1.2 Design & Procedure

In a between-subjects-design children were tested in three conditions: the *prospective reasoning group* received a planning task, whereas the *retrospective reasoning group* and the *updating group* engaged in a search task. Each child received four trials (2 in which “location 1” was the correct answer, the remaining 2 in which “location 2” was the correct answer; see below). For each trial, the child watched a video clip together with the experimenter (E) on a notebook computer. Dependent on test group E paused the video once or twice in order to make the child verbally recapitulate what happened so far, or to give certain hints (see below for details). At the end of each video, children saw a still image of the final scene and were asked to point towards a location in the scene’s setup where an object must have been lost throughout the story *(search tasks)*, or where an intervention should be performed in the future (*planning task*). For answering these questions children were prompted to choose between two possible locations, represented by two identical looking landmarks in the scenario which were positioned on the left side (= obstacle 1) and on the right side of the screen (= obstacle 2, see Figure 3). The side of the target location was alternated from trial to trial, resulting in two *target (location) = 1* trials and two *target (location) = 2* trials per child (with order counterbalanced across children)

All materials that appeared in the videos were small toy objects manipulated by the hands of an anonymous puppet player. Children listened to the narration of the story (voice off camera) whilst their attention towards the relevant elements on the screen was additionally supported by the puppet player’s gestures.

Tasks Irrespective of condition, children were presented with the same four scenarios of a character transporting goods in a container around a loop road (e.g. a girl walking on a loop road carrying a backpack, a train with wagons travelling on a circular track, etc., see Appendix S1). The direction of the round trip was always clockwise as indicated in Figure 3. In all scenarios character and container passed two obstacles behind (or under) which they disappeared from the observer’s view for an instant (e.g. the girl passing through hedges that overgrew the way, the train passing two tunnels). In between the obstacles there was a stopover where goods should be delivered to (planning) or picked up (search). The angle of the camera was fixed so that the entire setup was visible to the child throughout the video clip.

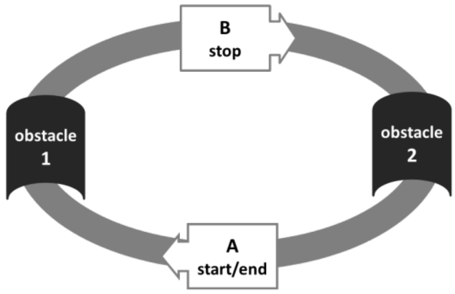


Figure 3. Schematic model of the setup children saw on the screen: A= starting point in all video clips, and ending point in search task (where loss of tool is recognized). B= destination for the delivery of objects, or stopover for picking up objects (planning task with *target location 2*, only). Obstacles 1, 2 = potential locations of a lost item (search task), or candidates for a future intervention (planning task). Obstacles 1, 2 are identical with *target locations 1*, *2*.

Planning In a demonstration video at the beginning of each trial children observed the character going on a circuit on the loop road, and loosing goods subsequently at both obstacles. A short verbal recapitulation together with E ensured that all children understood that goods fell out of the container when it passed the obstacles. Then, children learned about the character's future goal, which varied depending on the task's target location: for example, a girl intended to bring a picture to her friend's house which was located in between two hedges (transport object from A to B, target location = obstacle 1, see Figure 3). In trials where obstacle 2 was the target location, the goal in this case was to return an object from B (e.g. from the friend's house) to the starting point A. Together with the child E repeated the stated goal, she reinforced the path`s direction and the problem of losing goods at the obstacles. Children were then presented with a possible solution to that problem (e.g. a bridge was brought up, which could be built over a hedge). After careful explanation of the possible solution E clearly pointed out to the child that this intervention could only be performed once and at one single obstacle.

At the end of each trial E repeated the character's goal again, saying e.g.: *"The girl wants to bring the picture from here to there* (pointing towards A and B on the screen). *But this time the picture shall not get lost! What do you think, over which hedge do we* *need to build the bridge*?". Test questions in the planning task always followed the above structure, irrespective of scenario or target location (see Table 1 for an overview of the task's structure). If a child did not give an answer spontaneously, E repeated these final sentences up to two times.

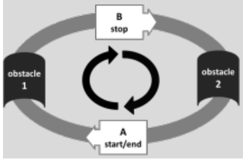
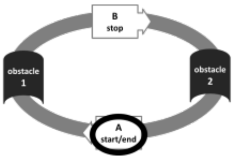
		Planning task (Study 1a) *Prospective reasoning condition*	
	Demo-clip	Cargo gets lost at obstacles 1and 2	
		Target location 1 Container is loaded with object	*Target location 2* Container is empty, object waits at B
	Goal & instruction	Transport object from… A to B	B to A …without losing it.
		Intervention at obstacle will prevent loss of cargo there!	
	Test question	"At which obstacle do we need to perform the intervention?"	

Table 1. Structure of the planning task.

Searching Two groups of children received very similar versions of a search task:

Retrospective condition. After a short introduction to the scenario children in the *retrospective reasoning condition* were immediately presented with the character's goal which was the same for *target location 1* and *2*, namely bringing an object from A to B (see Figure 3). But importantly, in the search tasks, the character's goal consisted of two sub-goals: (1) transporting the object to B and (2) performing a specific action with it (e.g. a girl wants to bring a picture to her friend's house in order to hang it up on an empty spot on the wall). Children observed the character's preparations for departure at the starting point, which always consisted of loading the object and an additional tool into the container (e.g. packing the picture into the girl's backpack, and also a tape-roll in order to fix the picture on the friend's wall). Children then saw the character disappearing behind obstacle 1, stopping at B and unloading the container. The character's subsequent actions differed as a function of the availability of the tool*:* in *target location 2,* trials object and tool were used so that the goal was fully accomplished (e.g. picture hangs on the wall, fixed with tape) and the tool was put back into the container. In contrast, in *target location 1*, when opening the container, there was *only the object* left inside. In this case only a sub-goal (1) was accomplished (e.g. the picture was put on the ground, the spot on the wall was left empty as it was before). Presence or absence of the tool at B was not commented on by the narrator and E showed no reaction to the opening of the container. It was only after travelling back to A (by passing obstacle 2) that the character realized the loss of the tool when finally unloading the container. The loss was emphasized in the last scene of the narration and directly linked to the test question, e.g.: "*Look, the tape-roll is not there anymore! It must have fallen out of the backpack in one of the two hedges!* "*What do you think, in which hedge did she lose the tape-roll*?". After the video had stopped with a still image of the last scene, E looked at the child, waiting for her to give an answer to the test question. As in the planning task, final sentences of the last scene were repeated up to two times if a child did not answer spontaneously.

Note, that in this task, in order to answer the test question correctly, children needed to remember if the tool had been present at B or not. This information was retrospectively available through the causal cue at B (the still image still showed if the goal had been fully or only partially accomplished).

Updating condition. The task for the *updating group* was different in this respect, although the very same video material was used. The difference resulted from three modifications which enabled children to track the relevant item, i.e. the tool, throughout the video: first, children tested in the this group received an additional demonstration video at the beginning of each trial, which was similar to the one used in the planning task (see description above), but in this group it served the purpose of accustoming children to the object-search context. Second, before the character's departure at A, children were prompted by the narrator and by E to focus their attention on the tool's whereabouts (for example, narrator: "*Now pay attention to what is going to happen to the tape-roll!*", E: "*Okay, what are we supposed to pay attention to*?"). Third, when unloading at B, E called children's attention in order to encourage a mental update of the tool's location (*"Look what's inside!")*. See Appendix S1 for a schematic comparison of both versions of the search task presented to the *retrospective reasoning*- and to the *updating group*.

Within all three test groups, the text and gestural hints of E and the narrator were kept parallel over all scenarios and for each of the conditions (*target location 1*, *2*).

2.1.3 Results & Discussion

Data points from two 4-year-olds were excluded from the final analysis (one from the retrospective, one from the prospective condition) because they failed to give unambiguous answers despite repeated questioning (choosing either both obstacles or none).

Children in each condition received two trials in which obstacle 1 was the correct answer (*target = 1*) and two trials in which obstacle 2 was correct (*target = 2*). Sum scores of *obstacle 1* and *obstacle 2* answers for both age groups and in both versions of each condition are depicted in Figure 4. For purposes of statistical analyses, in each condition a difference score was computed of *obstacle 1* minus *obstacle 2* answers (ranging from -2 to 2). A difference score of 2 would be the normatively correct pattern in *target = 1* versions, whereas a score of -2 would be the normatively correct pattern in *target = 2* versions. A 2 (target location: 1, 2) X 3 (condition: retrospective, updating, planning) X 2 (age group) mixed-factors ANOVA on this difference score yielded significant main effects of condition ($F(2, 114) = 39.57$, $p < .001$, $\eta_p^2 = .41$) and target location ($F(1, 114) = 164.59$, $p < .001$, $\eta_p^2 = .59$). There was a significant interaction of target location and age ($F(1, 114) = 13.54$, $p < .001$, $\eta_p^2 = .11$) and also an interaction of target location and condition ($F(2, 114) = 7.6$, $p = .001$, $\eta_p^2 = .12$).

To test for children's competence in each of the conditions, separate t-tests against chance were performed for both age groups (testing the difference score against the chance value of 0 – mathematically equivalent to testing the *obstacle 1* versus *obstacle 2* answers).

The 4-year-olds in the updating conditions performed above chance both in *target = 1* trials ($t(19) = 2.18$, $p < .05$, $d = .49$) [answering more often *obstacle 1* than *obstacle 2*] and in *target = 2* trials ($t(19) = -8.72$, $p < .001$, $d = 2.0$) [showing the reverse pattern]. In the *retrospective reasoning group* they performed above chance only in *target = 2* trials ($t(19) = -6.10$, $p < .001$, $d = 1.4$). In trials with *target = 1,* children of this group gave significantly more often incorrect *obstacle 2* than correct *obstacle 1* answers ($t(19) = -2.379$, $p < .05$, $d = .53$). In the *prospective reasoning group* 4-year-olds showed no preference for one of the obstacles in trials with *target location 2* ($p = .82$), but performed above chance in trials with *target location 1* ($t(19) = 5.48$, $p < .001$, $d = 1.2$).

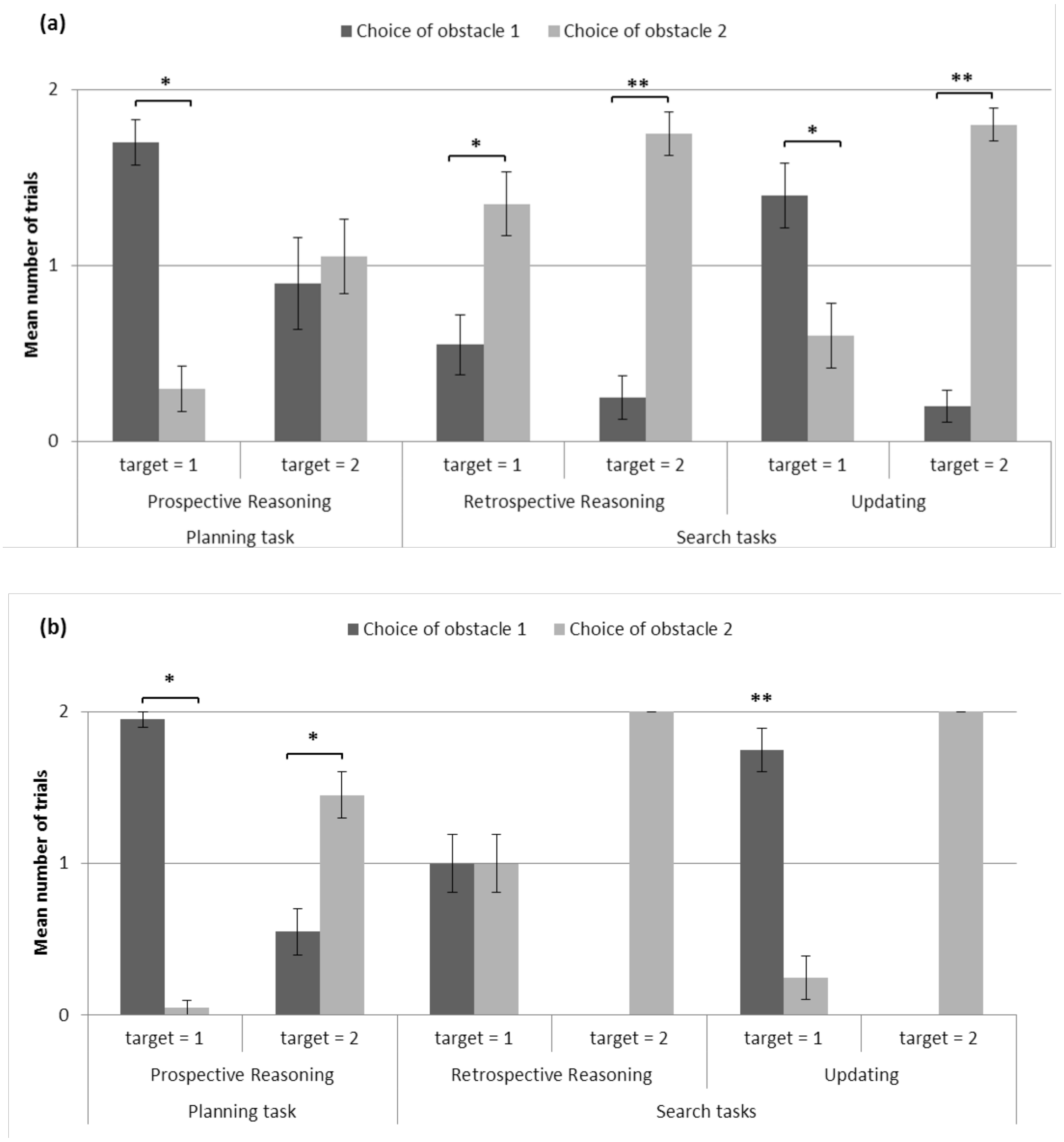


Figure 4. Mean choices of obstacle 1 and obstacle 2 as a function of condition (planning, retrospective, updating) and target location (1; 2), for the 4-year-olds (a) and the 6-year-olds (b), Study 1a.

Like the 4-year-olds, the 6-year-olds succeeded in both versions of the updating task, actually performing very close to ceiling (*target = 1*, $t(19) = 5.25$, $p < .001$, $d = 1.2$; for *target = 2* performance was perfect and so no inference statistics could be computed). In contrast to the 4-year-olds, the older children succeeded in both conditions of the planning task (*target = 1,* $t(19) = 19.0$, $p < .001$, $d = 4.3$; *target = 2,* $t(19) = -2.93$, $p < .01$, $d = .66$). In the retrospective conditions, 6-year-olds performed perfect in *target = 2* trials (all children chose *obstacle 2* in both trials) but performance did not differ from chance in the *target = 1* version ($p = 1.0$).

In sum, the present study tested 4- and 6-year-olds on structurally analogous retrospective searching and prospective planning tasks. The retrospective task was compared in a minimal contrast with an updating task that was supposed to be solvable without temporal-causal reasoning. The results revealed, first, that in fact, the updating task was the easiest and was mastered in all versions by both age groups. Second, the superficially very similar retrospective search task was indeed more difficult and was not fully mastered in all versions by any of the two age groups. Both 4- and 6-year-olds succeeded in *target (location) = 2* versions, but failed in *target = 1* versions (6-year-olds answering at chance, 4-year-olds even significantly below chance). Third, the structurally analogous prospective planning task was fully mastered by 6-year-olds who answered correctly in all versions, and only partly mastered by 4-year-olds who answered correctly in *target = 1*, but not in *target = 2* versions.

How are these findings to be interpreted, in particular regarding the failure of both age groups in the *target = 1* versions of the retrospective condition? Do these findings suggest true competence problems, or might they be indicative of some performance problems due to extraneous task demands? One possibility along the latter lines is that children's competence got masked by the use of a temporal-spatial primacy bias: it is conceivable that when engaged in temporal-causal reasoning, children travel along the time-line, so to speak, either backward or forward in time. When doing so, they then often settle on the first possible answer they encounter. And this would lead to the following pattern: in prospective reasoning, children travel forward in time (and therefore space), first encounter location 1 and settle on this answer. In the retrospective reasoning task, in contrast, they travel backwards in time (and therefore space), first encountering location 2 and settling on this answer.

Alternatively, another way in which Study 1a might have posed performance problems that masked children's competence is that the asymmetry in terms of evidential relations between the different versions played a crucial role. In *target = 2* versions of the retrospective conditions, there is positive evidence (still visible at the time of the test question, for example, in form of the tape which fixes the picture on the wall) that the object was still present at B, from which the subject can infer that it must have been lost at location 2 (along the following lines: "The picture is on the wall, fixed with tape. The tape was thus still present at B, and therefore it must have been lost at location 2"). In *target = 1* versions, in contrast, there is no such positive evidence, but only absence of evidence that the object was still present at B (embodied in the fact that the picture lies on the ground rather than hanging on the wall). Consequently, the line of reasoning required in order to infer the object's location seems much more complicated: "If the tape had been present at B, then the picture would have been fixed on the wall. As the picture lies on the ground, the tape must have been lost before B, so it must be in location 1". This chain of reasoning seems generally more complex, and more specifically requires rather sophisticated counterfactual reasoning –which is known to show protracted development from age four sometimes even until age 12 (Perner & Rafetseder, 2011; Rafetseder, Schwitalla, & Perner, 2013). It is thus possible that in the present study children failed to solve the *target location 1* condition, not because of constraints in their ability to reason about temporal-causal relationships, but because of the task demands, in particular in terms of counterfactual reasoning.

2.2 Study 1b

Study 1b, therefore, followed up on the possible problem of differential task demands in the *retrospective conditions* of Study 1a. Children were tested on a new version of the search task with reversed evidential structure: This time conclusive (visible) evidence was provided for the identification of obstacle 1 as target location, whereas evidence was negative in case of obstacle 2 being the target location.

2.2.1 Method

Participants A different sample of twenty 4-year-olds (49 – 59 months, mean age = 54 months, 11 boys) and twenty 6-year-olds (72 – 83 months, mean age = 76 months, 8 boys), all native German speakers, was drawn from the same database as in Study 1a. Two additional children (one boy, one girl, four years old) were excluded from the final sample due to experimenter errors and problems in understanding the video stimuli. Participants were either tested in their day-care centers or in the child lab.

2.2.2 Design & Procedure

As in Study 1a, children received four trials of the new search task with the storyline varied over the same four scenarios. Materials and setup of the videos were identical to Study 1a and also the storyline was kept parallel apart from one crucial change to the plot: instead of *losing the* tool, in this new task the character would *find the* tool either in *obstacle 1* or *2*. This change became manifest in the course of events, first, when the character departed at A with the *object only* in the container (e.g. the picture). Second, in this new version the tool could not be presented when explaining the character's goal, but instead E asked the child what kind of tool would be useful in order to fully accomplish the stated goal (e.g. *"Look, she wants to hang the picture up there on the wall. What do you think, what would one need in order to hang it up there?"*). This was done to establish the connection between tool-use and full achievement of the goal. If the child did not name it spontaneously, E prompted the tool immediately (e.g. "*I think a piece of tape would do (as well), right?*") and both agreed on this one as suitable for the goal's achievement. Third, the container was unloaded at B just as in Study 1a, but this time, in trials with *target (location) = 1,* tool and object were inside, whereas in *target = 2* trials there was only the object. The action was performed accordingly with or without tool-use, resulting in a visible causal cue at B in the former, and a negative cue in the latter condition (e.g. *target = 1*: picture hangs on the wall fixed with tape, *target = 2*: picture lies on the ground). As in Study 1a, presence or absence of the tool at B was not commented on by the narrator and E showed no reaction to the opening of the container. It was only when returning to A and when the container was finally unloaded, that the presence of the tool was emphasized (puppet player pointing towards the tool, "*Look! On her way Lisa found a tape-roll! She must have found it in one of the two* *hedges!*"). Test questions followed the very same structure of those in Study 1a, e.g. "*What do you think, in which hedge did she find the tape-roll*?" See Appendix S1 for a schematic comparison of both versions of the retrospective reasoning task used in Study 1a and 1b.

2.2.3 Results & Discussion

The mean sum scores of children's *obstacle 1* and *obstacle 2* choices in each condition are depicted in Figure 5. Data on the new retrospective reasoning task were processed in the same way as in Study 1a, by computing a difference score of *obstacle 1* minus *obstacle 2* answers (range -2 to 2) per condition: A 2 (target location: 1, 2) X 2 (age group) ANOVA on this difference score yielded a significant main effect of target location ($F(1, 38) = 63.33$, $p < .001$, $\eta_p^2 = .63$) and a significant interaction effect of target location and age group ($F(1, 38) = 15.83$, $p < .001$, $\eta_p^2 = .29$). Subsequent analyses tested children's competence in each condition and for each age group separately against chance (t-tests on difference scores against the chance value of 0).

Just like in Study 1a, the 6-year-olds performed at ceiling in the new *target = 2* trials $t(19) = -8.72$, $p < .001$, $d = 2.0$). But in contrast to Study 1a, they now answered the new *target =1* condition correctly ($t(19) = 5.48$, $p < .001$, $d = 1.2$). The 4-year-olds, like in Study 1a, performed above chance in only one version of the task. In spite of the new evidential structure this was again the *target location 2* version, ($t(19) = -2.37$, $p < .05$, $d = .53$). Performance in the *target =1* condition did not differ from chance performance ($t(19) = .62$, $p = .54$).

In order to test whether the crucial modifications introduced in Study 1b in form of the reversed evidential structure made a difference to children's answer patterns, performance across Studies 1 and 2 was compared. To this end, a three-way ANOVA with the factors Study 1a/1b (between-subjects), target location (within-subjects), and age group (between subjects) on the difference score of *obstacle 1* minus *obstacle 2* answers (range -2 to 2) was computed. This ANOVA revealed significant main effects of target location ($F(1, 76) = 78.18$, $p < .001$, $\eta_p^2 = .51$) and study ($F(1, 76) = 17.49$, $p < .001$, $\eta_p^2 = .19$), and a significant interaction of target location and age group ($F(1, 76) = 18.97$, $p < .001$, $\eta_p^2 = .20$).

Separate follow-up comparisons of performance in each condition across studies showed that the 6-year-olds performed better in Study 1b than in Study 1a in both the *target =1* condition ($t(38) = -3.04$, $p < .01$, $d = .96$), and in the *target =2* condition ($t(38) = -2.18$, $p < .05$, $d = .69$). The 4-year-olds did not perform significantly better in Study 1b compared to Study 1a in the *target = 2* condition ($t(38) = -1.68$. $p > .05$); but performance improved significantly from Study 1a to Study 1b in the *target = 1* condition ($t(38) = -2.15$, $p < .05$, $d = .68$ – from below-chance performance in Study 1a to at-chance performance in Study 1b (see above).

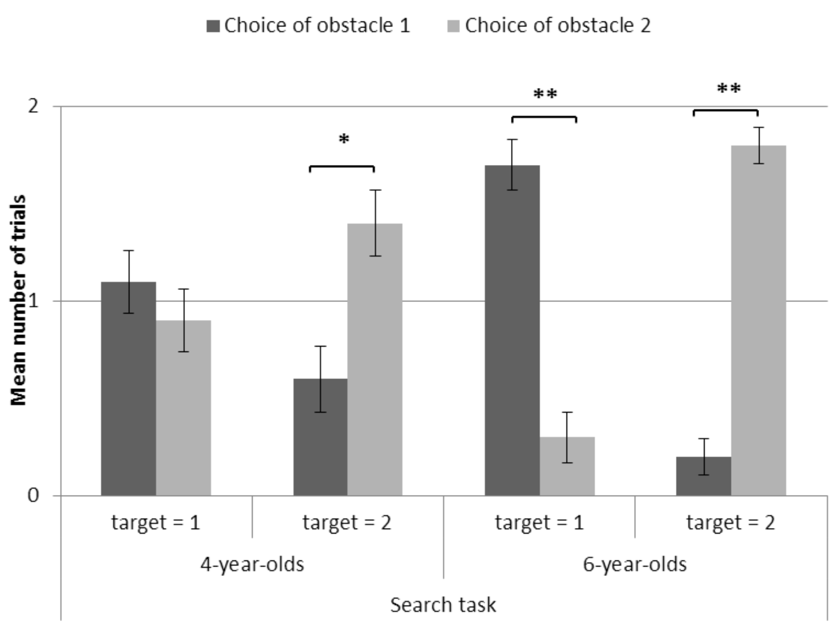


Figure 5. Mean choices of obstacle 1 and obstacle 2 as a function of age and condition in the (retrospective reasoning) search task, Study 1b.

These results suggests that 6-year-olds have a solid competence to reason flexibly about temporal causal relations between past and present events, but that this competence was masked in some versions of Study 1a by the specific task structure. In particular, it seems that the asymmetry of the evidential structure of the different versions of the retrospective tasks played a crucial role in Study 1a: while children failed the *target location 1* version in Study 1a, when there was only indirect evidence for what the correct answer was, they easily solved the adapted *target location 1* version in Study 1b – which, with a reversed evidential structure, now involved positive evidence for the correct answer.

However, this interpretation leaves open two questions: first, why did the 6-year-olds in Study 1b now solve both versions of the task (location 1 with direct positive evidence and location 2 with only indirect evidence) whereas the 6-year-olds in Study 1a only solved the version with the direct positive evidence (location 2)? Second, why did the 4-year-olds improve from Study 1a to Study 1b in the *target location 1* version, moving from below chance to chance performance, but still failed in Study 1b? Quite clearly, what these findings suggest is that additional task demands were at play. In particular, the *target location 1* versions of the task in both studies pose some additional demands (beyond evidential structure) that the *target location 2* versions do to not pose to the same degree. What could these additional demands be? One possibility is that they could have to do with temporal-spatial distance: when mentally reconstructing the course of events, one might take different directions in retrospection (backward) and prospection (forward) in mentally travelling along the track, and thus hits on different locations first (location 1 in prospection and location 2 in retrospection) that become more salient as answers – resulting in what could be called a temporal-spatial proximity bias (see below).

2.3 Discussion Study Set 1

Study Set 1 investigated the early development of temporal-causal reasoning (TCR) – the capacity to reason flexibly about the temporal and causal relations of past, present and future events in the service of retrospection and prospection. Building on previous work, we pursued the following open questions: first, when does the capacity to engage in TCR emerge ontogenetically, and how robust and systematic is it from early on? Second, are past-directed TCR and future-directed TCR based on the same capacity and therefore emerge and develop together? Third, is temporal-causal reasoning a qualitatively different capacity than simpler forms of keeping track of temporal matters? To address these questions, 4- and 6-year-olds were tested in analogous retrospective and prospective TCR task. Following up on earlier research, retrospective and prospective versions were closely structurally matched, extraneous factors were systematically controlled for, and the retrospective task was compared to a closely matched, structurally similar task that differed in the crucial respect that it did not require TCR.

The results suggest, first, that the capacity for TCR emerges by age four in some form, but undergoes important subsequent development until the age of six, where fully-fledged competence about the past (Study 1b) and about the future (Study 1a) was found. Second, the findings speak in favor of the view that past-directed TCR and future-directed TCR are based on the same capacity by showing clear developmental symmetry of retrospective and prospective reasoning; 4-year-olds showed analogous competences and limitations in past- and future-directed versions of the task, and 6-year-olds showed the same robust competence – under suitable conditions - in both temporal directions. Third, findings from both age groups provide clear evidence that TCR is a qualitatively different, more complex form of temporal cognition than other forms of tracking temporal matters, in particular temporal updating: 4-year-olds found structurally matched past-directed tasks that could be solved by mere updating much easier than the structurally matched search tasks that did require TCR.

These results replicate previous findings on children's developing competence in temporal-causal reasoning and extend them in important ways (McColgan & McCormack, 2008; McCormack & Hanley, 2011). In line with earlier research, conclusive evidence for full-blown TCR was found towards the end of the preschool years around age five to six. In contrast to previous work, however, no evidence for an asymmetry between past and future-directed TCR was found. And with a more stringent methodology controlling for potential confounding factors, the present work showed a less clear and more fragile pattern of competence in the 4-year-olds who managed to solve only one version of the search task (in which location 2 was the correct answer) and only the complementary version of the planning task (with location 1 as the correct answer).

So, how is this more fragmented pattern of performance in the younger children in the search and the planning tasks to be interpreted? The results of Studies 1a and 1b together suggest that at least two factors might underlie the limitations in the younger children's performance: first, at least for the past-directed search tasks, the evidential structure seems to matter. The conditions of the search tasks mastered in Study 1a were exactly those in which there was direct positive evidence for the correct answer to the test question. This test question was where some object had been lost, and the child had direct positive evidence that the object must have been used in between location 1 and location 2 because it left a definite causal trace, and from this trace children could infer that the object had been present after location 1 and thus must have been lost at location 2. The other condition, in which location 1 was the correct answer, required more complex reconstruction of the correct answer: From the fact that there was no causal trace of the object in between locations 1 and 2, together with the counterfactual premise that there would have been such a trace if the object had been present there, the child had to infer that the object must have been lost already at location 1. The conditions in Study 1b, therefore, were exactly reversed by implementing stories in which objects were found rather than lost: now there was direct positive evidence that an object must have been found at location 1 in one condition and a more indirect reconstruction from the absence of such evidence that the object must have been found at location 2 in the other condition. With this reversed structure, 4-year-olds now still performed competently in the location 2 condition, and performed significantly better than in Study 1a in the location 1 condition. The evidential structure thus made a difference.

However, it was far from making the whole difference since though performing better, younger children still did not perform above chance in the location 1 condition in Study 1b. A second factor that seems to underlie the limited performance of the 4-year-olds might thus be a general bias towards locations that are closer to one's starting point when mentally travelling through time. Children might have been subject to a spatial-temporal proximity bias such that in the direction in which one travels along the path (backward in retrospective and forward in prospective tasks), the first location encountered becomes more salient and thus favored as an answer. Future research will need to explore the role of these (and potentially other) factors more closely and systematically. From a practical point of view, this is technically difficult. Naturally, the evidential asymmetry applies primarily to retrospective tasks, but it is not clear at all whether such an asymmetry has any role to play in future-directed planning tasks. And the spatial-temporal proximity bias is technically difficult to study because there seems to be a necessary confound such that this bias always favors one answer for retrospection and the reverse one for prospection.

Apart from these more practical difficulties, however, findings from such limitations in performance, in particular in the younger children, are difficult to interpret and remain in need of theoretical clarification. Such a pattern of limited performance as was found in the 4-year-olds allows two broad classes of interpretation: One possibility is that the findings do reveal early competence that is only masked by performance factors in some conditions – the ones with complex inferential structure, and the ones in which cognitive biases get in the way of the general competence. This would be analogous to one interpretation of heuristics and biases in judgment and decision making according to which reasoning biases are conceptualized as showing not that adults cannot reason rationally, but only that their competence is often overridden by the works of such biases (e.g. Cohen, 1981; Stanovich & West, 2003; Stein, 1996). With regard to previous findings of competence in 4-year-olds (at least in past-directed tasks) this would mean that the present findings would basically replicate these findings and extend them by showing some accidental performance limitations. Alternatively, however, the fragile pattern of performance might be taken as indicative of fragile competence itself. The fact that the younger children only showed performance under limited conditions, this interpretation goes, implies the very lack of a flexible and general capacity to reason about temporal-causal relations. This would be analogous to another interpretation of heuristics and biases according to which the extant use of such heuristics and biases shows that humans do not reason rationally in the first place (e.g. Stich, 1990). With regard to previous findings of competence in 4-year-olds (at least in past-directed tasks) this would mean that the present findings fail to replicate and actually contradict them. It is a challenging open question for future research to systematically explore which of these two interpretations is correct. Like in the debate about the implication of reasoning biases for theories of human rationality, this might require the development of new experimental designs – in the present cases, designs that allow testing for the generality and flexibility of temporal-causal reasoning under conditions that lend themselves to the application of the biases in question to varying degrees.

3 STUDY SET 2: TEMPORAL-NORMATIVE UNDERSTANDING

The rationale of Study Set 2 was to investigate children's understanding of the normative dimension of future-oriented thought and language with a similar methodology to that introduced by Rakoczy & Tomasello (2009). In particular, we tested whether young children understand the normative commitments of different types of future-directed speech acts (predictions vs. imperatives) that are characterized by different directions of fit. In Study 2a the differentiation of directions of fit was measured by children's spontaneous protest in the case of mismatches (criticizing the speaker more often than the actor after unfulfilled predictions, but showing the reverse pattern after unfulfilled imperatives). Study 2b followed up on the same paradigm introducing a forced-choice measure of children's differential pointing towards either action or speech act in response to the question whose mistake caused the mismatch.

3.1 Study 2a

3.1.1 Method

Participants. Sixteen 4-year-olds, (48 – 58 months, mean age = 53 months; 8 boys) were tested (one additional child was excluded due to experimental error). Children were native German speakers, came from diverse socioeconomic backgrounds and were tested either in their daycare centers or in the child lab facilities. Parents gave their written consent for the participation of the children.

3.1.2 Design & Procedure

Warm-Up. Children were introduced to two hand puppets (a sheep and a hedgehog) that were located in separate rooms of a large toy house, both facing the child. The puppets were operated by a second experimenter (E2) sitting behind the toy house. After a short familiarization phase the first experimenter (E1) presented two warm-up games which were played by the child and the puppets taking turns. First, E1 asked one after another to label objects depicted in a picture book. In the second game a small hammer was used to push one of three differently colored balls through a hole. In the course of these games both puppets repeatedly made mistakes by mislabeling objects and by hitting balls of the wrong color. The aim of the warm up phase was to establish the fact that the puppets might need the child's help. Therefore children were asked to take care that the puppets' actions (verbal and physical) were all correct. In case of a child not correcting mistakes spontaneously, E1 encouraged her to help the puppets play the game the right way.

Test game. In a within-subjects design each child participated in two kinds of test trials administered in two blocks of four trials each (order counterbalanced). Both kinds of test trials followed the same structure and consisted of the same sliding game: one of the puppets (the speaker) uttered a speech act referring to the other puppet's (the actor's) future action (sliding an object (e.g. a bird) into its corresponding container (e.g. a nest) – with the child placing the corresponding container at the end of the slide). As the actor's object choice was invisible to the child, the child relied on the content of the speech act in order to choose which container would match the object that the actor would later send down the slide. In all test trials the propositional content of the speech act was never fulfilled by the action. This became obvious by the mismatch of object (e.g. fish) and container (e.g. nest) after the action. The crucial difference between the two test blocks was the type of speech act: in the *prediction (future-assertive)* condition, the speaker's prediction about the actor's action did not come true, e.g. "I guess/I think the hedgehog will slide the bird." ("Ich glaube, der Igel wird den Vogel rutschen lassen" – where the German "Ich glaube" translates with "I guess" or "I think"), with the actor sliding the fish later on, whereas in the *imperative (future-directive)* condition the speaker's imperative was not fulfilled by the actor, e.g. "Hedgehog, slide the bird next!" ("Igel, lass gleich mal den Vogel rutschen!"), again with the actor sliding the fish afterwards (see Appendix S2-C for a detailed script of the two conditions).

It might look like the propositional content of the assertion "I guess/ I think the hedgehog will slide the bird." is actually not about the hedgehog and what it will do, but rather about the speaker and her belief what the hedgehog will do and therefore has quite a different propositional content from the imperative which clearly is about what the hedgehog will (ought to) do. But the appearances are misleading here. The standard use of "I guess" and "I think" is not to report a belief but to express it ((Malcolm, 1991), see (Diessel & Tomasello, 2001) for developmental data), more specifically to qualify the belief as not utterly certain (one wouldn't say "I guess/ I think 1+1=2"). Mostly, "I guess"/"I think" function as a qualifier expressing some degree of uncertainty, much like "probably", and this is also the way it was used here. There were two specific reasons for adding such a qualification to the expression of the speaker's prediction: first, to make the speech act more natural. The speaker made a prediction without good evidence, in which case a prediction without such a qualification would have sounded strange. The second reason was to avoid possible mis-readings of the prediction as indirect imperative. The underlying problem here is that the surface form of predictions "the actor will do X" can be and often are used to make indirect imperatives ("all students will do their coursework until next week", "you will clean up your room").

Procedure. Before each test block, E1 introduced the object-container pairs to the child, asking her to help and find the correct match for each object (for details regarding the material, see Appendix S2-A). After the child had played with the slide, the objects and the containers herself, the game was given to the puppets. Only the containers remained with the child. At the beginning of each *prediction (future-assertive) trial* the actor puppet disappeared behind the slide in order to choose an object which he placed at the opening of the slide. Then, while the actor was still absent, the speaker puppet told the child which object he thought the actor might play with (see Figure 6, time 1b). For the *imperative (future-directive) trials* the speaker puppet declared which object the actor should play, the actor agreed (see Introduction for the necessity of agreement on an imperative for it being valid) and then disappeared behind the slide in order to select the object. After the child had prepared the slide's end with a container, in both conditions the actor slid an object different from the type that was announced by the speaker (see Figure 6, time 2). When the object had gone down the slide, the puppets remained visible to the child in their rooms (time 3). Children could first react spontaneously to the situation. Second, E1 asked them to explain what had happened.

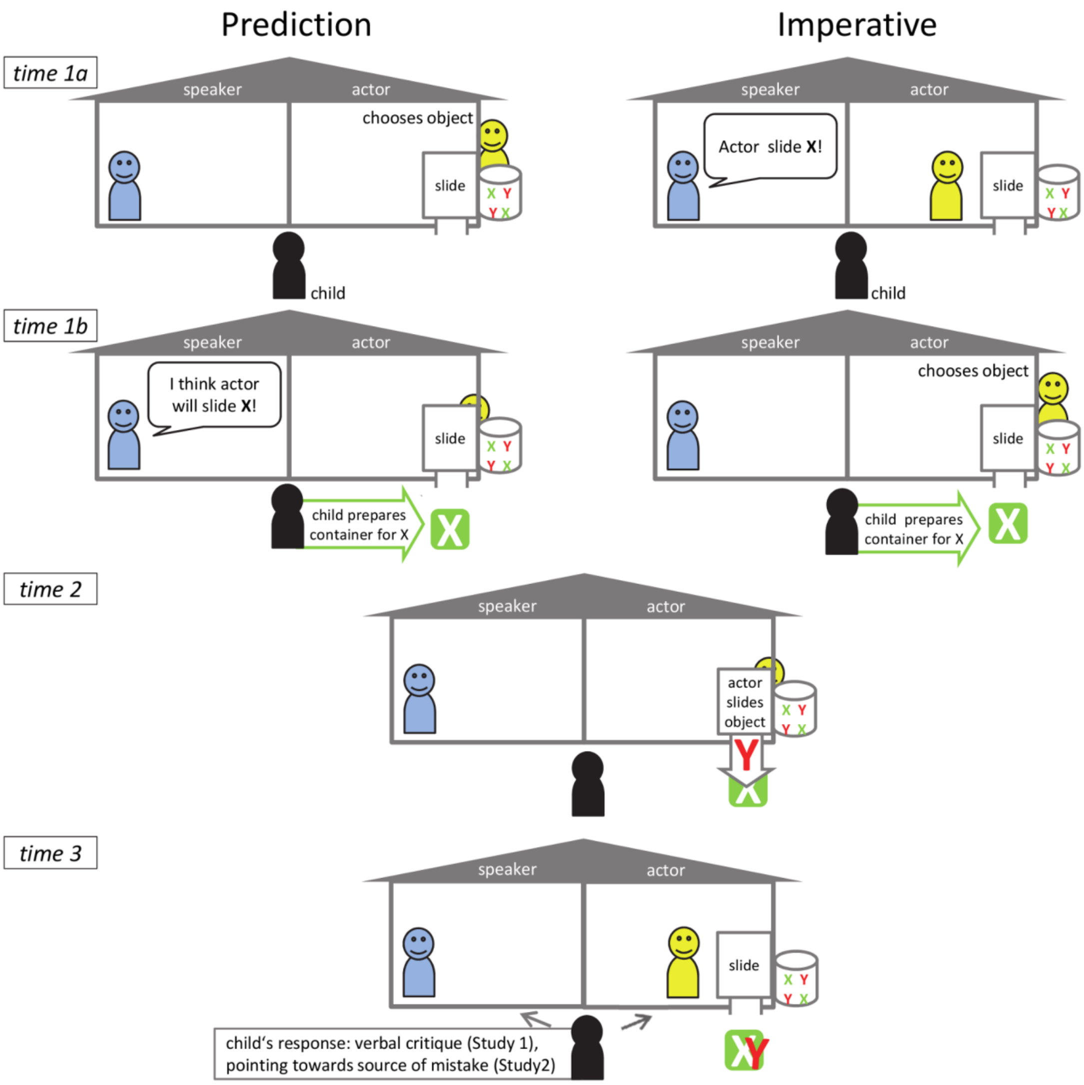


Figure 6. Schematic overview of the procedure in imperative and the prediction conditions (Study 2a and Study 2b).

The puppets' roles of speaker and actor alternated from trial to trial. In order to prevent children from habituating to mismatches in the course of the session, we included a non-test correct trial in the middle of each block where speech act and action matched. Sets of objects and containers were introduced to the child at the beginning of each test block. The first set consisted of miniature animals that were to be slid into their corresponding housings (e.g. bird-nest, fish-aquarium). In the second block miniatures of common object-container pairs were used (e.g. fried egg-pan, car-garage). The order of conditions, the assignment of games to conditions, and the order of the puppet's roles (speaker vs. actor) within each condition were counterbalanced across all children.

Coding. All sessions were videotaped, one camera capturing the child's face and another capturing gestures and interactions towards the puppets. The data were coded from tape by a single observer. For all 8 test-trials coding started with the moment where the mismatch between speech act *[object type expected]* and action *[object type played]* was visible to the child, i.e. when the object had gone down the slide. Children's verbal responses towards the puppets, as well as their explanations towards E1 were assigned to the following hierarchical categories:

(1) *Speaker- or actor-directed protest*: The child clearly criticized one of the puppets by calling its name and/or referencing to its mistake (e.g. "You said he slides the bird but you were wrong!" in response to the speaker, or "Hedgehog, look, this is not the bird! You did it wrong! " in response to the actor).

(2) The code *ambiguous protest* was assigned in two cases: Either when it was indeterminable for the observer which of the puppets was being criticized (e.g. "No! That's wrong!" without observable direction of gaze and/ or gesturing). Or, when the child explicitly criticized both puppets (e.g. to E1 "Oh no, the puppets were wrong again!")

As the focus was on the most sophisticated forms of protest children produced, each trial received as score the highest score observed in the child's response; e.g. in case of a child first criticizing the actor directly (1) and then simply saying to E1 "It was wrong!" (2), this trial was scored as *actor-directed protest* (1). In the very rare case of a child criticizing in the same trial one puppet first and later on the other, the code for *ambiguous protest* was assigned to that trial, as the child's criticism was directed to both speaker and actor.

A second independent observer blind to the hypothesis of the study coded a random sample of 25% of the sessions for inter-rater reliability which was very good (κ =.79).

3.1.3 Results

For each child, and for the two types of unambiguous protest (speaker-directed and actor-directed) and for ambiguous protest, sum scores across the four tasks per condition were computed in which the child showed this kind of protest. The mean sum scores are depicted in Figure 7.

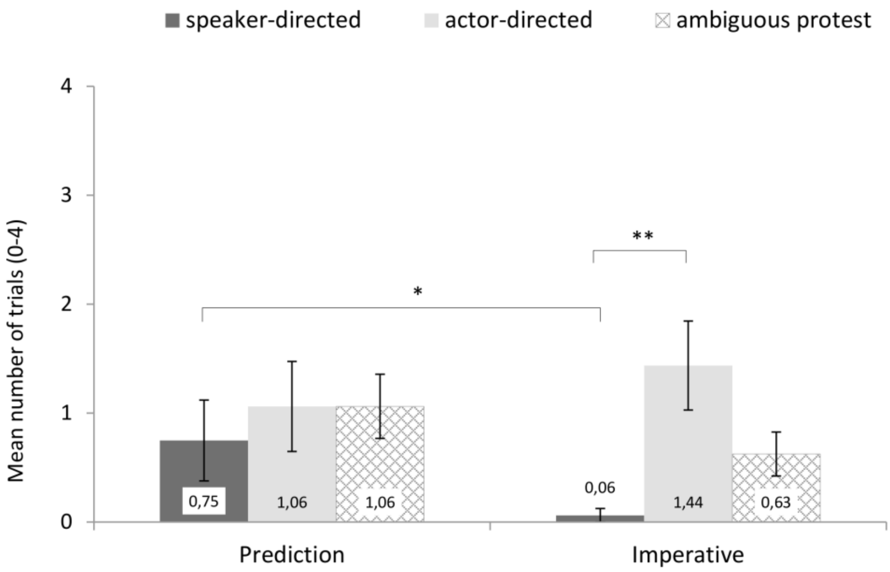


Figure 7. Responses to mismatches in Study 2a (verbal protest measure). Mean scores of trials (0-4) per condition (Prediction, Imperative) with each kind of protest (speaker-directed, actor-directed, ambiguous).

As preliminary analyses found no significant effects for the order of test blocks (mixed factors ANOVAs, n.s.), this factor was not included in the subsequent analyses. As the crucial analyses were based on specific, directed hypotheses (more protest against the speaker than against the actor after unfulfilled predictions, and vice versa after unfulfilled imperatives. And relatedly, more protest against the speaker after unfulfilled predictions than after unfulfilled imperatives, and vice versa for protest against the actor), one-tailed tests were used. In light of the relatively small sample size, the results of parametric analyses were complemented by non-parametric ones.

First, we compared actor-directed vs. speaker-directed protest within each condition. In the imperative condition, children criticized the actor significantly more often than the speaker ($t(15) = 3.22$, $p < .01$, $d = .81$). This was confirmed by non-parametric analyses, Wilcoxon test, $T = 10$, $p < .05$, $r = .65$. In the prediction condition, however, there were no significant differences between actor-directed and speaker-directed responses, $t(15) = .49$, $p = .32$ (Wilcoxon test, $T = 32.5$, $p = .30$), with a large proportion of children's responses coded as ambiguous protest (see Figure 7).

Testing for differences within conditions might neglect performance factors, such as the prepotency of one response type: in both conditions the actor's action directly preceded the apparent mismatch between object and container and so the actor (and her action) was much more salient than the speaker and her previous speech act. Therefore, when deciding who caused the mismatch and who to criticize, especially in case of predictions, children needed to overcome a bias towards the actor, induced by the temporal succession of events (a bias that might have contributed to the high proportion of ambiguous responses in the prediction condition).

Thus, in a second analysis we tested for differences in a given form of directed critique as a function of condition: Do children criticize the speaker more often in the prediction condition than in the imperative condition, and analogously for actor critique? These comparisons showed that children directed critique towards the speaker in prediction trials significantly more often than in imperative trials ($t(15) = 2.03$, $p < .05$, $d = .51$). Again, non-parametric tests confirmed this result, Wilcoxon test, $T = 44$, $p < .01$, $r = .46$. Regarding actor critique, differences between conditions were non-significant, $t(15) = .79$, $p = .22$, (Wilcoxon test, $T = 29.5$, $p = .20$.).

3.1.4 Discussion

All in all, these findings suggest that children do differentiate between the different kinds of speech acts to some degree, criticizing speaker or actor systematically as a function of condition. These findings were very clear regarding the imperative condition, and regarding the critique of the speaker, but were somewhat less clear regarding the prediction condition, and the critique of the actor.

One fundamental difficulty with the prediction condition compared to the imperative condition might lie in the ambiguity of the linguistic form vis-à-vis different speech act types: in the prediction condition, the linguistic form "The actor will do X" is more ambiguous in that this form can be used to make predictions (the paradigmatic case), but in exceptional circumstances also to utter commands (think of the coach saying to his players "All players will be on the pitch 10 minutes before the game"). The imperative form "Actor, do X!", in contrast, admits of less ambiguity. Three points should be mentioned in response to this concern: First, given this is a general asymmetry on the level of linguistic form, there is no way around this asymmetry in tests of children's understanding of the two kinds of *direct* future-directed speech acts (it is an interesting question, of course, when children come to understand *indirect* future-directed commands such as "All players will be at the pitch…". This, however, is a much more complex achievement going well beyond the more fundamental competence under study here). Second, since one can utter an indirect imperative only by talking to an addressee, the ambiguity in the prediction cases arises pragmatically only in situations where the speaker (e.g. the coach) talks to the actor(s) (e.g. the players). Given in our prediction-scenario the actor was not attending to the speech act (the actor puppet left the house and was invisible behind the slide) and the speaker did not explicitly address the actor, this ambiguity does not even seem to apply. Third, and crucially, the structural difference between linguistic forms in imperative and prediction speech acts only poses a problem given the current negative findings in the prediction condition. If one could improve the tasks by removing other potential limiting performance factors, and then document competence after both imperatives and predictions (and for both actor critique and speaker critique), this would show children can track the different directions-of-fit and their normative implications *despite* superficial ambiguities.

Now, one such potential factor in the current study was the dependent measure: A fundamental problem, in particular in the prediction condition, was the high rate of ambiguous responses, i.e. forms of critique that could not be unambiguously assigned to one of the two puppets. Now, these responses *might* reflect children's lacking understanding of the normative structure of predictions. Alternatively, however, the measure might have been too insensitive to uncover children's true competence and thus might have underestimated children's understanding.

3.2 Study 2b

Study 2b, thus, followed up on the first study with a modified methodology that aimed to disambiguate children's responses. The same basic scenarios were used, but instead of the verbal protest measure a forced choice paradigm was introduced: children were asked to decide which of the puppets made a mistake. Thereby the focus of the elicited response was changed from detecting errors in general to the more specific determination of *where* in the puppets' play the error had occurred.

3.2.1 Method

Participants. A different sample of fourty-eight 4-year-olds (48– 59 months, mean age = 54 months, 24 boys) was recruited from the same local database as in Study 2a (11 additional children were excluded from the final sample, three due to uncooperative behavior, four for not passing the training phase, four due to experimenter errors or technical failure). Children were native German speakers, came from diverse socioeconomic backgrounds and were tested either in their daycare centers or in the child lab facilities.

3.2.2 Design & Procedure

Warm-Up. As in Study 2a, the rationale for the warm-up phase was to familiarize children with the fact that there might be verbal and/or action mistakes on the parts of the puppets.

The only modification compared to Study 2a aimed at shifting the focus from the detection of puppets' errors in general towards a specific differentiation between correct and incorrect actions of the two puppets. Hence, the exact same warm-up games as in Study 2a were used but with the difference that in Study 2b the puppets always played together performing comparable actions. In case of the picture book, the puppets both claimed that they knew the book already, and therefore each stated its opinion on what picture would appear on the next page, in advance. That means the puppets played two rounds, both times making divergent utterances about which picture would show up, and with each puppet predicting the outcome correctly once. In the game with hammer and balls, the puppets performed simultaneously with duplicate apparatuses. Again, this game was played for two rounds with one puppet pushing the correct ball while the other simultaneously made a mistake by hammering on the wrong color (roles were alternated).

To establish the forced choice paradigm, after each round E1 presented two cards to the child, each depicting one of the puppets together with a speech bubble (or with a hammer in hand, respectively (for details regarding the material, see Appendix S2-B). E1 then explained: “Look at these cards. This is the sheep saying something (*or:* the sheep hammering) and here is the hedgehog saying something (*or:* the hedgehog hammering). Show me what was wrong!” Dependent on the child’s readiness to point to the correct card, E1 used up to three additional prompts in order to encourage the child to respond in form of pointing to one of the cards. Four children failed to report on the mistake by pointing to the cards, and were therefore excluded from the final sample.

Test game. Design and procedure of the test game were identical to Study 2a, except for two changes: first, the object-container pairs were changed into sets of two-dimensional sorting games in order to facilitate children’s handling of containers. This afforded children to choose one out of only two possible containers (e.g. the puzzle with round holes for marbles or the one where cubic objects fit in). Second, after the puppets performance in each trial E1 presented two cards to the child, similarly to the warm-up phase; the speech act-card showed the respective puppet with a speech bubble, the action-card showed the actor puppet manipulating the slide. The cards were placed in front of the corresponding room of the puppet house, i.e. if, say, the sheep was the speaker and in the left room, then the sheep’s speech act card on the left, and the hedgehog’s action card on the right from the child’s point of view. As children were used to the pointing task from the warm-up already, E1 only looked at the cards (alternating her gaze between the pictures) asking “Show me what was wrong!”. Or, in case of a child responding verbally however, she insisted “Just *show* me what was wrong!”. As in Study 2a, children received a total of eight trials, four *future-assertive (prediction)* and four *future-directive (imperative)* trials which were presented in successive blocks. The order of blocks, the assignment of games to conditions, and the order of the puppet’s roles within each block (speaker vs. actor, alternating over trials) were counterbalanced across children.

Coding. Children’s responses were coded as pointing to the speech act-card or to the action-card (or as behavior that did not fall in either of these categories if children did not point at all, or failed to follow the forced choice in some other way (which was very rare)). In case a child's first response was not a clear pointing gesture (e.g. moving the hand over both cards while pointing) or in case of a child switching from her first choice to the other card, E1 repeated her request up to two times until the child produced a clear response which was then coded as the child's final and valid decision.

The directed hypotheses and rationale for the statistical analyses were the same as in Study 2a.

3.2.3 Results & Discussion

For each child, for each of the decisions (speech act-card / action-card) and the non-decisions, sum scores across the four trials per condition were computed. The means of these sum scores as a function of condition and order of test blocks are depicted in Figure 8.

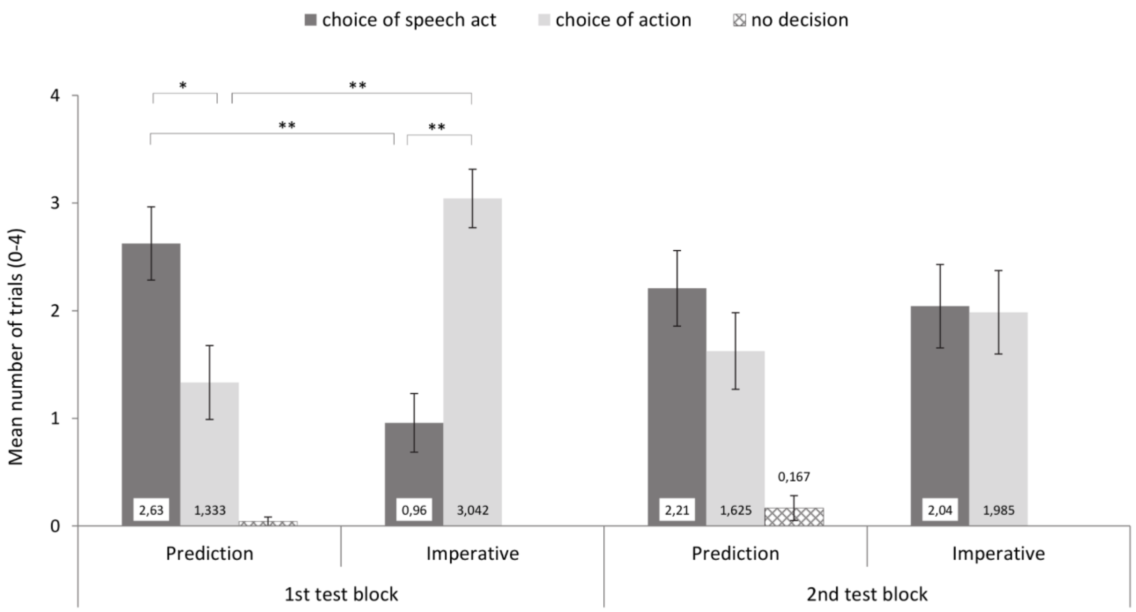


Figure 8. Responses to mismatches in Study 2b (forced-choice measure). Mean sum scores of trials (0-4) with each type of decision (choice of picture depicting speech act, action, or no decision) as a function of condition (Prediction, Imperative) and order of test blocks (conditions were presented in blocks, with the order counterbalanced).

Preliminary analyses suggested clear order effects: 2 (condition; within subjects) X 2 (order of test blocks; between subjects) mixed-factors ANOVAs on the mean number of trials with actor-card-decisions and speaker-card-decisions, respectively, yielded a significant condition X order of test block interaction effect in the case of actor-card-decisions ($F(1, 46) = 18.94$, $p < .001$, $\eta_p^2 = .29$) and speaker-card-decisions ($F(1, 46) = 15.68$. $p < .001$, $\eta_p^2 = .25$). Children's performance in the second block was significantly influenced by their behavior in the first block and was thus difficult to interpret. Why children showed this order effect we cannot tell from the present data. One possibility is that it was simply due to response perseveration: Given that the present tasks pose quite some performance demands, for example on working memory (keeping track of who said what when, and who did what when), children might have been overwhelmed after a while and simply stuck to previously successful answers (always pointing to the speaker-card or always to the actor-card). Alternatively, children might have suffered from more cognitive perseveration: after some trials in which there were always speech act mistakes, for example, they might have found it difficult to disengage from thinking of the speech act – action mismatches as due to mistakes on the part of the speaker. Subsequently, in the fashion of Piagetian assimilation, they then overgeneralized their mini-theory that truthfully captured the first trials (e.g. "speakers are always wrong here") inappropriately to trials in the second block. Clearly, future research is needed to explore these possibilities.

Regarding subsequent data processing, the focus for statistical analyses was on the more valid data of first test block (now in a between-subjects design such that half of the subjects was tested in the imperative condition and the other half in the prediction condition). First, analyses of children's choice of card within each condition revealed a significantly higher rate of speech act than action card choices in the prediction condition ($t(23) = -1.89$, $p < .05$, $d = .77$) and the reverse pattern in the imperative condition ($t(23) = 3.82$, $p < .001$, $d = 1.56$). These results were confirmed by non-parametric analyses for the prediction condition (Wilcoxon test, $T = 178$, $p < .05$, $r = .36$), and for the imperative condition (Wilcoxon test, $T = 38$, $p < .01$, $r = .61$). Second, analyses of each type of choice as a function of condition revealed that the action-card was chosen more often by children in the imperative condition than by children in prediction condition, $t(46) = 3.89$, $p < .001$, $d = 1.15$. Analogously, the speech act-card was chosen more often in the prediction condition than in the imperative condition, $t(46) = 3.89$, $p < .001$, $d = 1.13$. Again, non-parametric tests confirmed these results for speech act card choices in the imperative and prediction condition (Mann Whitney U-test, $U = 440.5$, $z = 3.28$, $p < .001$, $r = .47$) and for action-card choices, respectively (Mann Whitney U-test, $U = 133.5$, $z = 3.33$, $p < .001$, $r = .48$).

In sum, then, the modified response measure introduced in Study 2b succeeded in eliminating the high rate of ambiguous responses reported in Study 2a: the clear results for direction of fit recognition in situations of mismatches between imperative speech acts and actions were replicated in Study 2b. And now the rather unclear pattern of responses in the prediction conditions found in Study 2a turned into a distinct preference to recognize the speech act as source of the mismatch in future-assertive trials of Study 2b.

3.3 Discussion Study Set 2

The present findings show that by four years of age, children have developed a basic understanding of the underlying normative structure of future-directed speech acts with opposing direction of fit. They differentially track mismatches between the content of speech acts and temporally successive events in the world and are ready to intervene appropriately: In case of imperatives, the majority of children verbally criticized (Study 2a) and pointed to (Study 2b) the actor for being responsible for the mismatch. In the case of predictions, they criticized the speaker more often than they did after unfulfilled imperatives (Study 2a); and they explicitly identified the speaker as the source of the mistake under conditions of suitable prompting (Study 2b). In sum, the present results demonstrate that children understand that thoughts and speech acts have specific normative outreach into the future as a function of their direction of fit. And they demonstrate this at a much earlier age than suggested by previous research on speech act development. Probably this difference in findings between the present and previous studies is partly due to the very different methodologies: in contrast to the verbal interviews based on complex narratives in earlier work, the present studies used a much simpler action-based methodology. Another reason might be that the contrast pair between other-directed speech acts used here (predictions versus imperatives) might be inherently easier to grasp than the contrast between first person future-directed speech acts (predictions versus promises) that has mostly been studied in previous work (see below).

The present findings add to previous research in several ways: regarding children's grasp of normativity, they add to our knowledge that children understand the logical difference between different *synchronic* directions of fit of different speech acts by showing that children understand the *diachronic* normative structure of direction of fit over time. Regarding temporal cognition, they add to our knowledge of the development of thinking about matters in time by revealing the normative side of early future-oriented thought. Children understood that thought and speech can reach out into the future in normative ways: actions at one time can normatively bind and commit agents over time.

Relatedly, it remains to be explored in future studies how sophisticated and flexible the tracking of trans-temporal normative relations as documented here is. First, the distance that the speech acts reached out into the future in the present studies was in fact small, as the speech acts referred to the rather immediate future. This is in contrast to much research on mental time travel and temporal cognition, in which planning for and mentally traveling to the more distant future is investigated. It thus remains to be clarified whether similar cognitive foundations underlie these different forms of thinking about the future differing in the temporal distance between present and future. Second, the studies here suggest that children track the normative relations between one person's speech act at time 1 and another person's actions at time 2. An obvious question regards the relations within one person between her words today and her deeds tomorrow. When do children develop an understanding of the analogous difference in normative structure between first-person predictions ("When the wind comes, I will fall off my bike") and promises/declarations of intention ("When the summer comes, I will cut my hair")? This, it should be noted, is very difficult to study in an equally stringent way for practical reasons: It is very difficult to find plausible scenarios where the very same propositional content "I will X" can be used to declare an intention and make a prediction. Typically, "I will" is used to declare an intention when X is a verb for an intentional action ("cut one's hair") and is used to merely make a prediction when X is a verb for a mere happening ("fall off one's bike").

A broader open question is how children come to represent intentional normative self-binding over time in its complex subtleties. Our intentional states and speech acts today do have normative implications for actions tomorrow and do bind us and others over time – but they do not do so in inflexible and slavish ways (e.g. Bratman, 1984). We can change our minds. Correspondingly, it is one thing not to live up to one's own or others' standards set yesterday by failing to fulfill one's past future-directed intention or another's reasonable request. It is quite another thing, though, to give up an intention one had or to decide not to comply with a request. In all of these cases there are mismatches between mental states/speech acts at time 1 and actions at time 2 – but only in the former cases are there any mistakes involved.

4 STUDY 3: TEMPORAL PERSPECTIVE TAKING

The focus of Study 3 was on children's understanding of temporal perspective. The study's aims were twofold: firstly, we aimed to test for children's ability to represent different perspectives on the temporal succession of events (temporal perspective taking). To this end, two newly designed tasks presented children with two characters that moved in opposite spatial directions of a scenario and therefore perceived objects in different temporal orders on their way. Children were either asked to infer the event sequence seen by one of the characters, or to determine the character's current location on the basis of a given sequence. Secondly, we aimed to explore correlations of children's temporal perspective taking with their understanding of perspective in other domains. Therefore, in addition to the new temporal tasks, children also received standard perspective taking tasks from the mental and visual domain.

4.1 Method

Participants. Sixty children between the age of 3.5 and 5.5 years (40 – 66 months, mean age = 55 months, 25 girls) were tested. Four additional children were excluded from the final sample, either because of answering control questions incorrectly (two girls, one boy, 39 - 41 months old), or because of uncooperative behavior (one girl, 65 months old). Children came from a mixed socioeconomic background and were tested in a separate room of their daycare centers. Parents gave their written consent prior to testing.

4.2 Design & Procedure

Children were tested on five perspective taking tasks (two temporal, two mental and one visual) and two covariates (mental rotation and vocabulary). All tasks were presented within one session (together with two additional tests that were part of a different project). Altogether a session took 30 to 45 minutes. Throughout testing children were seated at a table together with the experimenter (E). Tasks were administered in three blocks of fixed order. The order of tasks within blocks was counterbalanced only in test block 3. Additionally, the presentation order of the two temporal tasks was counterbalanced across blocks 2 and 3 (see Table 2). All sessions started with assessment of the two covariates (block 1: the vocabulary test first, then *mental rotation*) and proceeded with a mental perspective taking task first (*change of location*), followed by one temporal (*path* or *carousel,* counterbalanced) and the visual perspective taking task (block 2). In test block 3 either the second mental perspective taking task (*unexpected content*) preceded a temporal task (*path* or *carousel*), or vice versa.

test block	category	task order	
1	covariates	K-ABC (vocabulary) mental rotation	
2	perspective taking (1)	mental *change of location* temporal *path* OR *carousel* visual task	
3	perspective taking (2)	mental *unexpected content*	temporal *path* OR *carousel*

Table 2. Order of task presentation. Systematically varied elements are gray-shaded.

Temporal perspective taking tasks. Two tasks were newly designed in order to assess children's temporal perspective taking skills. Each task was presented in two subsequent trials with each trial involving a story that was read out by E and visually accompanied by an animated slideshow on a notebook computer. At the end of each trial E posed two test questions about the story's characters (or objects) that were depicted on the slides. Children responded by selectively pointing towards one of the elements on the screen. The order of tasks and trials presented within each task was fixed.

In the *path task* children were introduced to the main setup on the presentation's first slide: the graphic of a path connecting four lineally arranged pictures (from the right to the left side on the screen, e.g.: a house, a wood, a bridge and another house, see Figure 9). In the training phase, two animal characters appeared and moved on the path, consecutively, with the first moving, e.g., from the right house to the left (training, part 1) and the other from the left house to the right (training, part 2). After naming all elements on the screen, E described the animations simultaneously (in case of a right-to-left animation E would say, e.g.: "*The dog wants to take a walk. Now it walks on the path: it* *passes the wood - and walks over the bridge – into the house."*). After the character had disappeared 'in the house', E asked two control questions in order make the child repeat the perceived event order, e.g. "*What came first, the wood or the bridge? What came after it?"* (For the original script, see Appendix S3). Subsequent to the child answering correctly, E always repeated the order using the term 'before', e.g.: *"Ok, the wood came before the bridge*". E's descriptions - and also the required answers to E's questions - differed accordingly for the other character that moved into the opposite direction. The training phase was repeated up to two times in case a child didn't give correct answers on the first presentation.

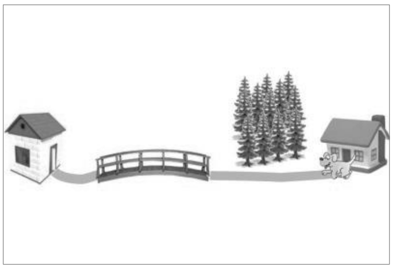


Figure 9. Scenario of the path task (picture from training phase).

In the test phase two new characters appeared below the path and the whole scenario was occluded by a huge cloud just before the characters were expected to start moving and take a walk on it (see Figure 10). Instead of the visual input, children now heard sounds of footsteps with E suggesting to hear them walk on the path: *"Oh, now we can't see the way they are walking! But do you hear the footsteps?".* After the clapping of a door was heard twice, sounds stopped and the cloud disappeared, revealing the main setup again with no characters visible. Suggesting that the characters "*have already arrived*" and asking herself where they might be, E provided a statement of each character as a hint for the child, e.g. *"Lucy says, the wood came before the bridge. Theo says, the bridge came before the wood."* Finally, E asked the child two test questions (Q1, Q2), first repeating each statement, e.g.:

Q1 "*Theo says, the bridge came before the wood. Where is Theo?"*

Q2 *"Lucy says, the wood came before the bridge. Where is Lucy?"*

E waited for the child to respond to the first question before posing the second. Both trials of the *path task* employed the above structure and scenario of a horizontal path. Trials differed in the pictures and characters presented, and in the order of spatial directions mentioned in the test questions (first asking for the left-side target in trial 1, and the right-side target in trial 2).

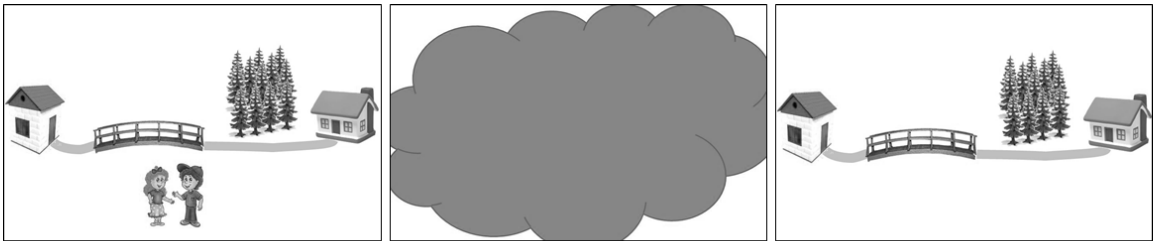


Figure 10. Test phase of the path task (pictures from left to right): (1) characters intend to walk on the path, (2) characters walking on the path are occluded by a cloud, (3) cloud has gone and characters have arrived inside the houses.

In contrast to the *path task*, where linear movements of opposing directions caused different perspectives on the occurrence of events, in the *carousel task* this difference originated from characters' different positions on a carousel. On the first presentation slide children saw the top view of a carousel whose real model was presented to them on the ground next to them. After assuring that children understood the pictorial representation of the carousel, E removed the model and directed children's attention to the notebook. Above and below the carousel two landmarks (e.g. playground and farm) were depicted (see Figure 11). In the training phase children learned (1) that each ride on the carousel would only take one round and (2) that the order of the two landmarks that a passenger witnessed passing by was dependent on her position at start (e.g. sitting on the tractor: playground first, then farm, sitting on the pony: farm first, then playground), see Appendix S3 for the original script. Two control questions tested whether children were able to reproduce the order of events for both positions.

In the test phase two characters appeared and were just about to take a ride on the carousel, when (similar to the *path task*) a rain cloud occluded the carousel (see Figure 11). After it had disappeared children were told that the characters had already taken their seat, but it was impossible to see who sat where, due to two large umbrellas that now covered the characters on the carousel. After the carousel had gone one round E asked who sat where. Previous to the first test question, she provided a character's statement as a hint for the child, e.g.:

Q1 *"Sarah says, the playground came first. Do you know where Sarah is?".*

After the child had answered the first test question, the umbrellas disappeared, revealing the actual positions of the characters. E directed the child's attention to the position of second character and posed the second test question, e.g.:

Q2 "*If we ask Tim 'What came first?', what will Tim say?"*

A second trial resembled the above structure and differed only in the given landmarks and characters, and in the target sides of the test questions (i.e., compared to trial 1, targeting at the opposite side in the first and at the opposite landmark in second question).

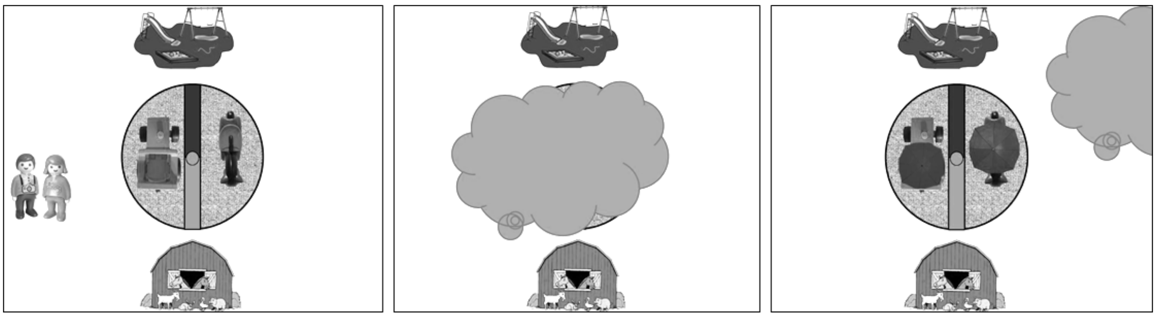


Figure 11. Scenario of the carousel task, test phase (pictures from left to right): (1) characters intend to ride on the carousel, (2) characters taking their seats are occluded by a cloud, (3) cloud has gone and characters are seated beneath umbrellas.

Coding. In the temporal perspective taking tasks, both children's pointing towards one of the pictures on the screen, or naming of a picture was coded as a valid response. In case an answer was not clear, or in case a child pointed to none or more than one picture on the screen, E repeated the character's statements and test questions up to two times. In case a child failed to answer the control questions correctly after the third completion of the training phase, E skipped this trial in order prevent the child from frustration. A sum score was computed over those trials where the training phase was completed successfully (valid trials). Scores ranged from 0 to 4 for the *path task* and 0 to 4 for the *carousel task*.

Mental perspective taking tasks. Two standard false belief tasks were used to assess children's ability to represent mental perspectives.

The *change of location* false belief task, after Wimmer and Perner (1983), was enacted by E as a puppet play in front of the child: a puppet (A) deposited an object in one of two boxes before she left the scene. In her absence the object was transferred by another puppet (B) into the other box. Before A returned the child was asked three control questions: (1) *"Where did A put the object first?",* (2) *"Where is the object now?",* (3) *"Who put it there?"*. When A returned, children were asked the test question: *"What does A think where the object is?"*. The procedure of the task was repeated up to two times in case a child didn't answer the control questions correctly on the first try.

In the *unexpected content* false belief task (Perner, Leekam, & Wimmer, 1987) children were presented with a candy box and shown that it contains (unlike their guessing) a pen instead of candy. Test questions targeted both at first and third person perspectives on the box's content: (1*)"Initially, before you looked into the box, what did you think was in the box?"*, (2) *"If we show your friend* [name of friend] *the box, what does she/he think is in the box?".* A control question finally asked children to reproduce the actual content of the box.

Children's responses to test questions were scored only if they had answered the control questions correctly. Correct answers were summed up to a total score for mental perspective taking, ranging from 0 to 3.

Visual perspective taking task. Modified versions of the tasks presented by Hamilton et al. (2009) were used to assess children's visual perspective taking skills, and also their ability to mentally rotate an object's orientation. As a covariate the latter will be presented further below.

The same materials were used for the *visual perspective taking* task and the *mental rotation* task and children therefore received only one training phase for both tasks: a square turntable with differently colored edges was placed in front of the child. A toy was placed on the turntable facing the child. On a cardboard depicting four different orientations of the toy (front, back, left and right side), the child was asked first to point to the picture that matched the child's current view, and again after turntable (and toy) were rotated 90°. Finally, the toy was covered with an opaque box and the child was asked again to choose the picture depicting the toy's current orientation. In case a child did not answer all three questions correctly, E gave feedback on the correct picture and repeated the procedure up to two times with new toys. E did not proceed to the test phase in case of a child failing to answer the three questions correctly in the training phase.

In the test phase three new toys were placed on the turntable in three consecutive trials (1. a pig oriented with its back to the child, 2. an elephant facing the child, and 3. a frog oriented left). In each trial a puppet was placed at one of the other sides of the turntable (1. at the left, 2. opposite, and 3. at the right side of the child). Children were asked to indicate on the cardboard (1) the side of the toy they see themselves (control) and (2) the side that the puppet sees (test question). If children gave an incorrect answer to one control question this trial was excluded from the analyses. If a child failed to answer more control questions correctly data from this task was excluded. The order of toys presented, their orientation and the puppet's orientation was fixed. Children received a total score for visual perspective taking ranging from 0 to 3.

Covariates. A task similar to the *visual perspective taking* task was used to assess children's skill in *mental rotation* (Hamilton et al., 2009). For a description of the materials used and the training phase see the section above. In the test phase the three toys were placed on the turntable, again in three consecutive trials and in three different orientations (1. the pig oriented left, 2. the elephant with its back to the child, and 3. the frog facing the child). In each trial, after the toy was covered with the opaque box, children were asked (1) to indicate on the cardboard the orientation of the toy under the box. In case a child didn't answer the control question correctly, E lifted the box for a moment and then posed the question again. (2) E rotated the turntable and asked the test question: *"When I lift the box, which side of [the toy] will you see?"*. Rotations were 90°-right in the first, 180°-right in the second, and 90°-left in the third trial. For each trial children's pointing to one of the four pictures on the cardboard was coded as response, resulting in a total score of 0 to 3 for this task. The order of toys presented, their initial position and rotation was fixed.

In order to assess children's verbal skills, a vocabulary test (Kaufmann & Kaufmann, 1999) was presented to each child at the beginning of the session. Children's task was to name the pictures of 24 items. A correct name was scored 1, resulting in a total score of 0 to 24.

4.3 Results

4.3.1 Temporal perspective taking tasks

Sum scores were computed over the 2 test questions for each trial and task. These were divided by the number of valid test questions. A trial was considered correct in case the resulting proportional score equaled the value of 1. Subsequently, proportional scores were computed over both trials for each task resulting in a proportion-correct score (out of two trials) for the path and the carousel task (see Figure 12). One child (40 months) was excluded from the analyses due to not answering control questions correctly in either task.

Chance level for solving a task (answering two trials correctly) was 25%. One sample t-tests on the mean proportional scores (against the value of .25) revealed that children's overall performance did not differ from chance in the carousel task (p = .07, two-tailed) but children performed significantly above chance level in the path task (p < .01). In order to check for age differences the sample was split into three age groups of 3-year-olds (N = 13, 40-47 months), 4-year-olds (N = 23, 48-59 months), and 5-year-olds (N = 23, 60-66 months). A two-way ANOVA, with task-correct proportional scores (path, carousel) X age group (3-, 4-, 5-year-olds) yielded a significant main effect of task (F(1, 54) = 7.97, p < .01, η_p^2 = .13). Subsequent t-test on performances of each age group suggested that this effect resulted from 3- and 4-year-old's lower performance in the carousel task. In this task only the 5-year-olds performed above chance (p < .01), whereas in the path task all groups were above chance level (see Figure 12). Subsequent analysis focused on the question why children of all age groups apparently succeeded on the path task while the younger groups failed to solve the carousel task.

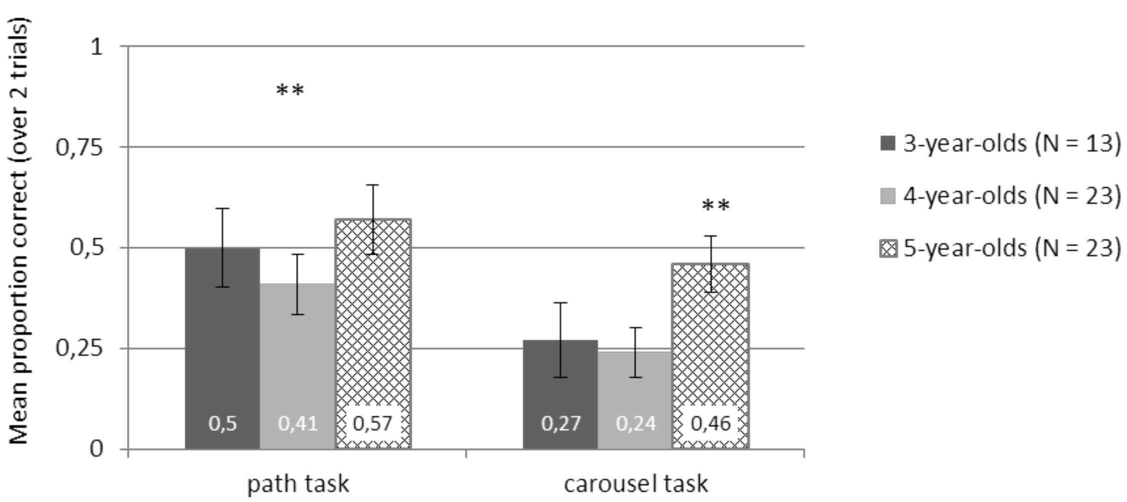


Figure 12. Mean proportions (trials correct out of two) in the temporal perspective taking tasks for each age group (chance level = .25, two tailed levels of significance).

The path task. A qualitative inspection of the data (59 children included, six of them with one trial only) was performed to reveal individual response patterns. First of all, success rates did not differ between trials in the path task (46% of all children solved trial 1, 55% trial 2), but individual performance was inconsistent for half of the sample (with 26 children out of 53 solving only one trial, see Table 3). In order to clarify this inconsistency, a within-trials analysis revealed (1) that answers to Q2 largely depended on answers to Q1 in both trials (see Table 4), and (2) that approximately half of the children chose the correct side in response to the first trial's Q1. The first finding makes pragmatic sense in that children simply chose the opposite side in Q2 to that chosen in Q1. The second finding raises the question if the one half of children that succeeded on trial 1 exhibited true competence on the task or if their success was simply due to guessing (i.e. guessing correctly in Q1 combined with strategically switching sides in Q2). Crucially, the target side of Q1 was alternated over trials. A comparison of responses to Q1 over trials, therefore, would show if children answered this question systematically correct. In fact only 57% of children who answered Q1 correctly in trial 1 were also correct in trial 2 (17 children out of 30), the remaining 13 children persevered their responses (choosing the same side in Q1 in both trials). This observation might be taken to suggest that correct responses were rather nonsystematic, and more likely due to guessing strategies, though the picture becomes clearer when differences between age groups are considered: only 18% of the 3-year-olds, 14% of the 4-year-olds, but 43% of the 5-year-olds solved both trials of the task correctly (answering Q1 and Q2 correctly in both trials), see Table 5. Therefore, it was concluded that in the path task some competence was found in the older children, whereas younger children's responses were mainly driven by guessing strategies.

Path task		Trial 2 correct	Trial 2 incorrect	total
Trial 1	correct	**14**	**11**	25
	incorrect	**15**	**13**	28
total		29	24	53

Table 3. Response patterns in the path task, absolute numbers of children giving correct/ incorrect answers in trial 1 and trial 2.

Trial 1		Q2 correct	Q2 incorrect	total
Q1	correct	**25**	**5**	30
	incorrect	**1**	**23**	24
total		26	28	54
Trial 2				
Q1	correct	**32**	**1**	33
	incorrect	**3**	**22**	25
total		35	23	58

Table 4. Responses to question 1 and 2 (crossed) separately for trial 1 and trial 2 (over all age groups). Absolute numbers depicted.

	No. of trials solved correctly		
	0 (consistent-failed)	**1** (inconsistent)	**2** (consistent-passed)
3-year-olds (N=11)	2 (18%)	7 (64%)	2 (18%)
4-year-olds (N=21)	7 (33%)	11 (52%)	3 (14%)
5-year-olds (N=21)	4 (19%)	8 (38%)	9 (43%)

Table 5. Absolute numbers of children (in age groups) solving none, one, or both trials of the path task correctly.

The carousel task. Data of 59 children were analyzed for the carousel tasks. From three children only one trial went into the analysis because they failed to answer control questions correctly in the other trial.

In contrast to the path task the two questions (Q1, Q2) asked within a trial in the carousel task did not only target at two alternative sides, but asked for the *location of a character* (left/ right side) on the carousel (Q1), and for the object seen first (i.e. the *event order perceived*) by another character (top/ bottom of the screen) (Q2). In order to detect potential differences in responses to the two types of questions, sum scores over trials were computed for each type of question (Q1, Q2) and were then converted into proportional scores ranging from 0 to 1, by dividing the sums by the number of valid trials (1-2). A 2 (type of question: Q1, Q2) X 3 (age groups) mixed factors ANOVA yielded a significant main effect of type of question ($F(1, 55) = 12.78$, $p = .001$, $\eta_p^2 = .19$). Subsequent t-tests revealed that overall, questions of type 2 were answered correctly significantly more often than type 1 questions (paired samples $t(58) = -3.66$, $p = .001$), and also significantly more often than expected by chance, with 45% of children solving both Q2 questions correctly ($p < .01$), see Table 6. A subsequent differentiation of age groups, revealed that success on Q2 questions was due to the performance of the 5-year-olds which was significantly higher than 4-year-olds' performance (independent samples $t(44) = -2.83$, $p < .01$), see Figure 13 for percentages of children in each age group that solved both questions of the same type correctly.

Q1		Trial 2		total
		correct	incorrect	
Trial 1	correct	**7**	**28**	35
	incorrect	**7**	**14**	21
total		14	42	56
Q2				
Trial 1	correct	**25**	**12**	37
	incorrect	**11**	**8**	19
total		36	20	56

Table 6. Responses to question 1 and question 2 in the carousel task, crossed for trial 1 and trial 2. Absolute numbers depicted.

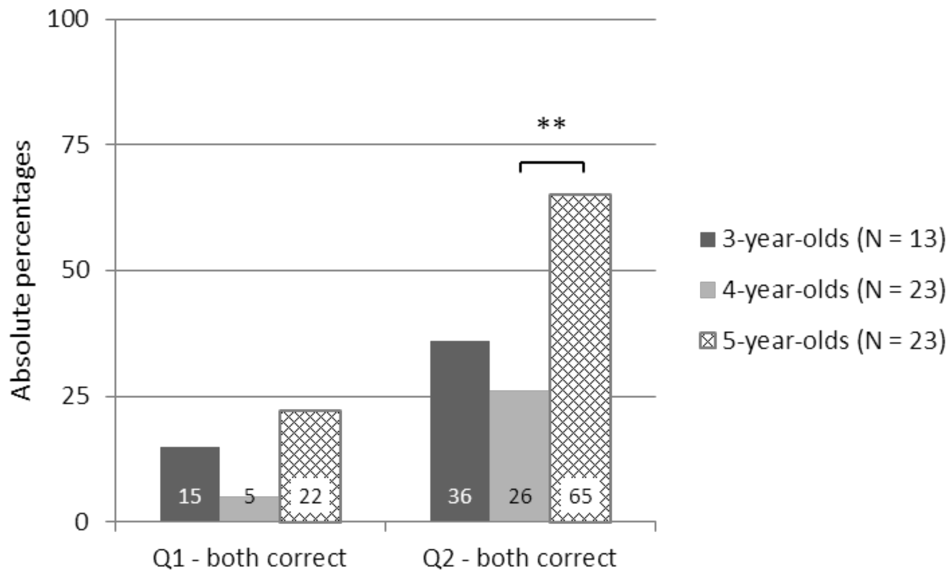


Figure 13. Percentage of children (per age group) solving questions of type 1 (Q1) and type 2 (Q2) correctly in both trials of the carousel tasks.

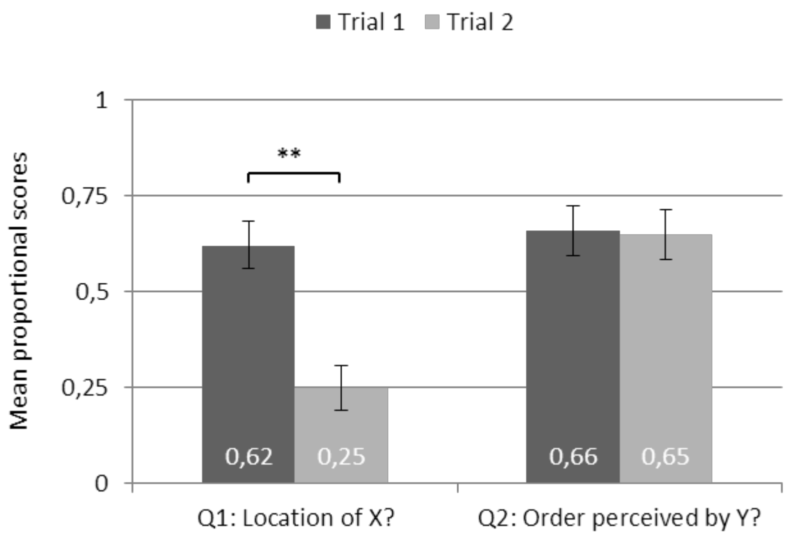


Figure 14. Mean proportions of correct answers by type of question and trial, in the carousel task.

Lower performance in type 1 questions (Q1) was due to a significant drop in trial 2 compared to trial 1 ($t(55) = 4.0$, $p < .01$, see Figure 14). A possible reason for this drop was identified by a closer examination of the task's structure: questions of type 1 (e.g. "*Sarah says the playground was first. Do you know where Sarah is?*") were primed in the training phase that preceded each trial (see methods section). Crucially, the order of events presented during training was fixed but the target of Q1 was alternated over trials to the end that the last sequence children had seen in the training phase matched the sequence E asked for in Q1 in the first trial, but inferring the opposite sequence was correct in trial 2. Therefore it is likely that responses to Q1 in the two trials reflect a carry-over effect from training to test phase possibly resulting in false-positive results for trial 1 and false-negatives in trial 2.

Preliminary conclusions. The tasks described and analyzed above do not provide evidence for children's competence in temporal perspective taking: qualitative inspections of the path task revealed that especially younger children's responses were primarily driven by pure guessing, combined with (i) the strategy to choose the alternative of the first in their second response and (ii) perseveration of responses from the first to the second trial. In the carousel task children's competence was possibly masked by a bias to transfer the preceding training situation to the following test (Q1).

Still, hints of children's competence were found in 5-year-olds who performed over chance level in specific parts of the tasks: in the path task 43% of 5-year-olds answered the first test question (Q1) correctly in both trials, whereas in the carousel task 65% succeeded on the second question in both trials (Q2).

4.3.2 Correlations

Perspective taking tasks and covariates. For a comparison of the perspective taking tasks, sum scores of correct answers were divided by the number of valid trials in each task, resulting in proportional scores ranging from 0 to 1.

For the visual perspective taking task preliminary analyses indicated that children's performance differed significantly in trials 1 and 2 (paired samples t-tests on mean sums $t(59) = -7.46$, $p < .001$), and in trials 2 an 3 ($t(57) = 5.51$, $p < .001$) with only 28% of children solving trial 1 where the puppet sat 90° left to the child, 80% solving trial 2 with 180° angle, and 41% solving trial 3 (90° right). In fact classical tasks only test for 180° visual perspective taking (e.g. Flavell et al., 1981), which most of the children mastered in our task. In order to balance the weight of the more difficult 90° trials only scores of trial 2 (180°) and trial 3 (90°) were used to compute the proportional score for visual perspective taking. A proportional score for mental rotation was computed from (at most three) valid trials. For mental perspective taking a pooled score was obtained by averaging over proportional scores of the *change of location* and the *unexpected content* false belief tasks. For the vocabulary test total sum scores went into the analysis. See mean values for all tasks in Table 7.

task		N	mean	(SE)	SD
vocabulary		60	16.15	(.38)	3.0
PT temporal	- path	59	0.55	(.08)	.37
	- carousel	59	0.53	(.04)	.27
PT mental		56	0.72	(.03)	.26
PT visual		58	0.6	(.05)	.37
mental rotation		58	0.36	(.04)	.29

Table 7. Mean values for each task (PT = perspective taking).

Children's performance in the path task was not related with the carousel task (*r* = .09) and neither of the temporal tasks correlated with measures of the other perspective taking tasks (see Table 8). There was a significant correlation of mental and visual perspective taking tasks that remained marginally significant after age and vocabulary were controlled for (*r* = .27, *p* = .05). As expected visual perspective taking did not correlate with mental rotation. However, there was a weak positive relationship between mental rotation and the temporal perspectives path task (*r* = .27).

	Vocabulary	PT temporal - path	PT temporal - carousel	PT mental	PT visual	Mental rotation
Age	.35** (60)	.09 (59)	.26* (59)	.49** (56)	.40** (58)	.06 (58)
Vocabulary		.23* (59)	.35** (59)	.27* (56)	.38** (58)	.07 (58)
PT temporal - path			.09/ .01 (59)	.21/ .18 (55)	.12/ .04 (57)	.27*/ .26* (57)
PT temporal - carousel				.21/ .07 (55)	.15/ .04 (57)	.14/ .12 (57)
PT mental					.40**/ .27* (54)	.01/ -.02 (54)
PT visual						.11/ .09 (57)

Table 8. Raw / partial correlations with valid numbers of subjects (N) for perspective taking tasks (different domains: PT temporal, PT visual, PT mental), mental rotation and controls (age, vocabulary). One-tailed levels of significance: * p < .05, ** p < .01.

4.4 Discussion

The present study aimed at investigating temporal perspective taking and its possible relation with other domains of perspective taking in preschool children. To this end, three- to five-year-old children were tested on two tasks that were developed in order to provide new measures for children's ability to mentally decenter from the present and to coordinate different perspectives on the temporal succession of events. Furthermore, performance in these new tasks was correlated with children's skill in solving standard visual and mental perspective taking problems.

Results indicate that the new tasks did not produce reliable data on children's grasp of temporal perspective; children's responses were explained by the use of guessing strategies in combination with pragmatic alternation within, and perseveration of responses across trials in the path task. In the carousel task carry-over effects from training to test phases were found. For the above reasons retest reliability from trial 1 to trial 2 cannot be assumed for either of the tasks. Therefore, tasks can also not be considered as valid tests.

However, some competence was found in the oldest age group where more children than expected by chance (43%) solved both trials of the path task correctly by flexibly adapting their responses over trials to the alternated targets. In the carousel tasks 5-year-olds were above chance performance in answering Q2, correctly judging (for different targets and in both trials) which landmark a character would have seen first on the basis of the character's current position on the carousel. But do correct answers to this question alone allow for concluding that these children understood the character's perspective on the previous event sequence? Going back to the initial analysis of previous work on perspective taking and temporal decentering in children, a closer look at the task's demands in comparison to demands imposed by this type of question might help to evaluate this part of the data appropriately.

Based on work by Weist (1989) and Cromer (1971), one important requirement for temporal decentering was defined as the ability to coordinate at least two points in time apart from the child's present. This requirement was operationalized in the temporal tasks by the presentation of two events that were passed by a character in succession. Coordination of these events in relation to the present was necessary, e.g. in type 1 questions in the carousel task, when children were asked to infer a character's current position from her statement about a temporal succession ("*Sarah says X was first.*") and from knowledge about the carousel's movement (circular, clockwise). Type 2 questions in contrast asked children to determine the landmark another character must have seen first on the basis of her actual position on the carousel ("*If we ask Tim 'What came first?', what will Tim say?"*). In this case knowledge about the direction of movement and the character's current position is sufficient to infer the landmark passed first. Therefore, this task can be solved quasi online from a present point of view by e.g. imagining the landmark that will be (!) visited next. Representing a third point in time is not particularly necessary.

The second requirement for perspective understanding followed a definition by Perner et al. (2003) and was defined as the ability to represent different perspectives on the same referent(s) simultaneously. This requirement was implemented in our tasks by differing spatial positions or movements of two characters that caused a difference in their (simultaneously formed) perceptions of the occurrence of two events. Representing this difference was necessary e.g. in the path task when statements that were incompatible at first view (A says: *X before Y*. B says: *Y before X*.) had to be combined with knowledge about the possibly opposite directions of movement and the consequential difference in event-order representations. But in case of the carousel task answering the second question alone [*What will B say what came first*?] did not require integration of incompatible statements or contradicting pieces of information. Instead, again, a simple heuristic based on non-temporal, presently available information on the character's position and knowledge about the carousel's direction of movement would have been sufficient to infer the nearest landmark and to answer this type of question correctly.

With respect to the correlations of perspective taking tasks from different domains inconclusive results in the temporal domain were expressed in the correlations as well. The temporal perspective taking tasks were not related to any other task, apart from a weak correlation of the path task with the (non-perspective) mental rotation task which might have been an artefact. Replicating a previous study from Hamilton and colleagues the methodologically similar level 2 visual perspective taking task and the mental rotation task were not related. As expected, the standard mental and visual perspective taking tasks adapted from the literature correlated with each other.

An important question that is raised by the present study - and that needs to be tackled in the future - concerns the validity of tasks measuring the understanding of temporal perspective. As discussed earlier, it is very likely that performance in the two temporal perspective taking tasks used in this study was biased (carousel task) or driven by guessing strategies (path task). Negative results in these tasks do not provide valid evidence for children's lack of competence. Therefore, this study has to leave open both the question of young children's understanding of temporal perspective and of the possible developmental relation between perspective taking skills in different domains.

Future research will have to explore further ways of designing tasks that directly tap children's temporal perspective taking skills. Determining the kind of contradicting representations in these tasks will not be a trivial endeavor: the necessary condition of such representations being simultaneously valid while referring to the same referent(s), rules out the possibility of e.g. representing an object that changes its external state over time. In this case an earlier representation of the referent (e.g. a flower in full bloom) would be considered as "outdated" compared to the representation of a later state (e.g. the same flower faded). Representations that refer to different points in time do not constitute perspective problems as they are by nature compatible over time (see Perner & Leekam, 2008). In order to circumvent this problem imposed by the general flow of time, temporal perspective in the present study was interpreted in the sense of representing different temporal relations between two events.

In the path and the carousel task the coupling of temporal occurrence with spatial direction provided an elegant way of construing temporal synchrony for the formation of contradicting representations. Still, this might not be the only and ideal way of operationalizing temporal perspective problems. In line with other researchers we would suggest that scaffolding temporal representations by translating them spatially in the test-setup should be advantageous for investigations of early temporal skills in children (see McCormack & Hoerl, 2008). Though, it might be the case that the specific material used in our tasks confused or misled children somehow in their temporal reasoning. One could as well argue that the verbal instructions and structure of test questions could have hindered children's understanding of the tasks. Still, compared to earlier research (e.g. the use of complex temporal forms in Cromer's work) in the present study language demands were reduced to a minimum, and - although desirable - designing this kind of task completely omitting temporal language seems unfeasible. A possible workaround in future projects might be to check children's understanding of the specific temporal terms used prior to testing. After all, the present research provides an important step towards increasing the research on temporal perspective understanding and it demonstrates a promising way of testing this theoretical concept in children.

5 GENERAL DISCUSSION

The aim of this thesis was to investigate three specific aspects of children's developing temporal cognition in order to gain deeper insight into the nature of the underlying temporal conceptions of early temporal thought. The following three sections provide an overview over the main findings regarding the aspects of temporal-causal, temporal-normative, and temporal perspective understanding. Section 5.4 relates the results to prominent theories in the field of human temporal cognition and concludes with an outline of promising future research directions.

5.1 Temporal-causal reasoning

Study Set 1 focused on children's ability to reason flexibly about the temporal-causal relations between events (TCR). Following up on previous work this set of studies aimed to explore (i) at what age children develop robust and systematic TCR skills, (ii) if these skills develop synchronously for past- and future-directed thought, and (iii) if TCR is a qualitatively different cognitive capacity than simpler forms of keeping track of temporal matters. Analogous versions of past and future event scenarios were designed in order to compare 4- and 6-year-olds performances in tasks of both temporal directions. Furthermore, performance in the past-directed TCR tasks was compared to children's ability to solve a structurally similar, object-tracking task (temporal updating). Results suggest (i) that fully fledged TCR develops until the age of six, while an early and limited form might already be present in 4-year-olds. In both age groups (ii) symmetrical levels of performance were found for past- and future-oriented TCR, supporting the view of both skills being based on the same cognitive capacity. Different levels of performance in the structurally matched TCR and updating tasks (iii) support the hypothesis that TCR is a qualitatively different and more sophisticated form of temporal cognition than the less demanding tracking (or updating) of information over time.

Apart from the finding that the evidential structure of the task plays an important role in children's temporal-causal reasoning, it was also temporal proximity that seemed to have an influence on children's performance and that complicated an interpretation of the younger children's performance. In this respect, our studies leave open two possible interpretations: either children's competence was masked by a bias towards temporally closer events, or children of this age were actually lacking competence in TCR, with their responses being driven primarily by heuristics and biases instead of reflecting temporal-causal reasoning. This ambiguity can only be resolved by future research. Still, it is an interesting idea and very important for the design of further studies that a subject's ability to reason about the temporal-causal relations of two events might be influenced by their temporal proximity relative to the subject's present. For human mental time travel (MTT) a bi-cone model of past and future representations has been suggested (Roberts & Feeney, 2009), with more detailed and clearer representations being accessible for events that are temporally closer to the subject's present and a linear decline in number and detail of information for more distant past and future events. This model makes sense in the context of MTT where the process of episodic thinking is described in terms of the subject mentally travelling from the present to past or future events. But this view seems to contradict with the idea of TCR as a capacity of *flexible and independent* reasoning about temporal-causal relations of any - in particular of novel - events in time (McCormack & Hoerl, 2008). That is, TCR should be applicable irrespective of self-conscious activity related with the events, and irrespective of the events' relative temporal distance to the subject's present. Although Study Set 1 was designed with the aim of reducing the length of event-sequences to a minimum, in the MTT view temporal distance was larger in the prospective reasoning version that was in fact more difficult for the 4-year-olds (target location = obstacle 2) than the distance in the version that was reliably solved (target location = obstacle 1). That is, in the latter task children had to mentally "travel a shorter distance" into the future. This was analogous in the retrospective tasks, where the target that was closer (in the view of travelling the way back from the present, target location = obstacle 2) was also chosen more often in Study 1a und Study 1b (see also section 2.1.3). An integrated view, combining both MTT and TCR theory, might therefore provide an adequate way of explaining the biases that influenced children's temporal-causal reasoning in the present studies – but more research on this issue has to show if this interpretation holds in the future.

5.2 Temporal-normative understanding

In Study Set 2 children's understanding of the underlying normative structure of speech acts with future reference was investigated. Previous research has left open the question if young children, before possessing an explicit concept of specific types of speech acts, are capable of an early, basic form of differentiating the normative implications of future-directed speech acts. In order to close this gap in research, children were presented with speech acts of opposite directions of fit, predictions and imperatives, which did not match the future action they referred to. Results indicate that by four years of age children understand that these types of speech acts have temporal-normative outreach to the immediate future and they can differentiate commitments of speaker and actor as a function of the speech act's direction of fit.

It is open to future research to explore if the present findings can be extended to other types of speech acts, specifically to children's understanding of past-directed speech acts. These, naturally have a mind-to-world direction of fit, which is the reason why the paradigm used in Study Set 2 is not appropriate to approach the question of how children understand or differentiate past-directed speech acts.

Another important future step in the investigation of children's temporal-normative understanding is, in our view, extending the temporal delay between actions or speech acts that originate temporally persistent commitments and the future point in time where they are supposed to be fulfilled. In the present studies the temporal distance was very short (with the action directly following the speech act) in order to reduce the task's demands. Though, it is an interesting question if young children handle information over longer periods and differently as a function of the entailed normative force of the speech act. That is, children might use normative implications of speech acts in order to form expectations also on temporally more distant events. In our studies throughout a session children repeatedly experienced that the exact alternative of a predicted or requested event was performed later on, and many of them adapted their behavior in the course of the session by prepositioning the alternative container under the slide than the one that would match the action referred to in the speech act. Although in these cases the object slid by the actor in fact matched the container (i.e. it matched the child's future-oriented action), children still charged the mismatch between the puppets' speech act and action, accordingly. That is, they tracked the propositional content of the speech act and its normative force over time, although they themselves did not act in compliance with it.

It is an open question to what extent children are able to evaluate and make use of, e.g., the varying degrees of certainty that different speech acts imply, in order to build accurate representations of what is likely to happen in the future. This competence would enable children to limit the number of possible future scenarios on the basis of the specific certainty value of information, and to determine which present actions or interventions might pay off in the future.

5.3 Understanding temporal perspective

Study 3, finally, aimed to explore the understanding of temporal perspective in relation to children's perspective understanding in other domains. Different lines of research were brought together by adopting and combining the concept of temporal decentering (Cromer, 1971; McCormack & Hoerl, 2008; Weist, 1989) and the concept of perspective taking (Perner et al., 2003), which resulted in the design of two new temporal perspective taking tasks. These tasks interpreted temporal perspective in terms of the subjectively different representations of temporal order that resulted from the subjects' opposite directions of movement in space. Children additionally received standard false belief (mental perspective taking) and visual perspective taking tasks in order to correlate their performances in the different domains. Overall, lacking validity of the newly designed tasks precludes any conclusion on children's temporal perspective understanding based on performances in these tasks. Likewise, conclusions on the possible developmental relation in perspective understanding in different domains cannot be made. Clearly, future research is necessary to follow up on this preliminary attempt of testing temporal perspective understanding in children.

As outlined in section 4.4 designing experimental tests for the capacity of temporal perspective taking is not trivial: in the ubiquitous flow of time representations are formed at specific points in time, and they exist diachronically while constantly changing temporal reference to this point in time. My representation of a mug that I placed on the table this morning might turn out to be outdated when I find only fragments of it on the ground in the evening. Even if I keep my outdated representation of the entire mug instead of updating it (e.g. because someone hides the fragments and prevents me from perceiving the current state of the mug), this situation would be best described as me having a false belief about the mug's state (Perner & Leekam, 2008). A perspective problem would be constituted only if someone else (e.g. the person who hid the broken mug) simultaneously represents the mug's actual state *and* my false belief of it (Perner et al., 2003). Though, all this is the description of a mental, not a temporal perspective taking problem.

We adopted the temporal decentering account, which was introduced by Weist (1989) and Cromer (1971) and put forward by (McCormack & Hoerl, 1999, 2008), to create temporal perspective problems in our experiments. Instead of relating a past or future event to the present (like in the broken mug example), these tasks required children to consider the temporal relationship between two events from different perspectives. The difference in perspective was resolved by the spatial direction of movements. This is to say, to circumvent the situation that the general flow of time causes different representations of the same object, different representations of the perceived *order of objects* were created by the characters movements in space. An integration of spatiotemporal information was necessary in order to resolve and understand the characters' contradicting assertions. To relate our tasks to Weist's terminology, consider one of the test questions, e.g. "*Theo says, the bridge came before the wood. Where is Theo?*". In order to answer this question, children had to coordinate the following three points in time: the question (Q) targets at Theo's current or present location (Q => $t_{present}$) and the assertion (A_{Theo}) indicates the temporal order of two events that Theo must have experienced in the past (passing the bridge, passing the wood) (A_{Theo}: bridge = t_1 and wood = t_2). In this example $t_{present}$ clearly represents the *speech time*, while we might agree on labelling t_1 *event time* (as "bridge" is the subject) and t_2 *reference time* (as "wood" marks the object in this sentence). In any case, in order to infer the current position of Theo correctly, children need to consider the temporal relation between two additional points in time in this task. The results of Study 3 do not warrant conclusions on children being able to temporally decenter in the required way when answering this single test question, but there are indications of older children succeeding on this isolated part of the tasks (see section 4.3.1).

In addition to temporal decentering, our tasks required children to integrate opposing perspectives on the temporal relation of the two events (e.g., A_{Theo} vs. A_{Lucy}) in order to determine the different positions of characters in a scenario. The capacity to simultaneously represent different perspectives on the temporal relation of the same events was considered a necessary component of full-blown perspective understanding. Future investigations will be necessary to overcome problems in the quality of measures for temporal perspective understanding. To extend the present approach, further developed tests could even aim to differentiate levels in children's developing understanding of temporal perspective in order to provide a more detailed picture of the different components entailed in this capacity.

5.4 Integrating aspects of temporal cognition

A broader question for future research concerns the cognitive and developmental relations of the aspects investigated here to other forms of temporal cognition. In the recent literature on mental time travel (MTT) in humans and other animals, it has been intensively debated which types of tasks require which levels of (implicit or explicit) representation of time (e.g. Clayton & Russell, 2009; Hoerl & McCormack, 2011; Russell & Hanna, 2012). Everyone agrees, for instance, that episodic memory involves representations of one's own past. But there has been considerable disagreement about the type of representation it requires: some think it requires explicit representations both of one's own past events as past events and of the way they causally relate to one's present memories (Perner, 2000; Tulving, 2005). Others, in contrast, have argued that episodic memory is well possible without such sophisticated representational machinery. Instead, it need only represent explicity where, when and what happened while only implicitly representing the relation of these events to the present (e.g. Clayton & Russell, 2009; Tulving, 1972).

Results from Study Set 1 suggest that temporal-causal reasoning (TCR) about past and future events emerges by age four and develops until the end of the preschool years. This is in line with findings from work on MTT suggesting that around the same time children acquire analogous competence in both episodic memory and episodic foresight to act upon past experiences and plan competently for the future (Suddendorf et al., 2011; Suddendorf & Redshaw, 2013). Conceptually, there is much overlap of TCR and MTT. For example, both describe capacities of flexibly representing and reasoning about the relations of past and future events – capacities that contrast with simpler forms of time-tracking processes and capacities that draw on rather inflexible semantic or script-like knowledge. TCR and MTT describe capacities that are taken to underlie both past- and future-directed thought in symmetrical ways. TCR, however, goes beyond MTT in that, apart from merely representing the relation between a (past or future) episode and the present, it also entails representations of temporal and causal relations between other episodes - in the past or in the future - that are used to make systematic and flexible inferences about past and future happenings. A major characteristic of MTT has been argued to be the distinctive phenomenology of re- and pre-experiencing personal events (Suddendorf & Busby, 2003; Tulving, 2005). TCR instead has been characterized as a form of reasoning that is independent from subjective experience (McCormack & Hoerl, 1999, 2008). Because of the large overlap of the two types of cognition, and the defining differences between them, it is likely that they describe closely related capacities, and we should therefore consider possible ways of how they might work together in temporal reasoning tasks, like McColgan and McCormack (2008) suggested:

> *Indeed, one way to think about the relationship between the two cognitive abilities is that MTT may deliver representations of specific past and future events, but frequently temporal – causal reasoning may be required to make use of the information given in such representations through a consideration of the causal connection between such events and other relevant events.* (p. 1494)

TCR and temporal decentering both involve the capacity to represent and coordinate more than two points flexibly in time – again with the difference that TCR goes beyond merely representing temporal relations between events by including reasoning about and from temporal-causal relations. The concept of temporal decentering, however, implies the necessity to mentally detach from subjective present perceptions. Temporal perspective taking (understood as a combined capacity of decentering and the ability to represent different perspectives on the temporal relation of events), finally, explicitly relies on the concept of a temporally extended self (and other). Work on the development of temporal language suggests that around the same time when TCR and MTT skills emerge, children begin to give verbal reports about their past and possible future experiences (Friedman, 2004; Hayne, Gross, McNamee, Fitzgibbon, & Tustin, 2011). Elsewhere, it has been argued that the use of tense in language production reflects developmental changes in children's episodic memory and consequently changes in their self-representation (Bischof-Köhler, 2000; Perner & Ruffman, 1995). Study Set 2 has shown that children also understand and differentiate the temporal-normative outreach of other's temporal language. Temporally extended agency is therefore a concept that young children can be accredited with. Still, our studies leave open the question if children ascribe the same normative obligations that they infer from other's speech acts in the same way to their own speech acts. Similar to the point discussed in section 5.2, the extent to which children might evaluate other's future-directed speech acts in order to adapt future-oriented behavior accordingly, it is unclear if they begin to reflect on their own normative obligations as early as they differentiate these in other's speech acts and actions.

Results from Study Set 1 might be interpreted as reflecting the convergence of a distinctive phenomenology, which is possibly similar to the one of self-projection described in MTT literature, with the flexible and event-independent strategy of TCR. Study 3, unfortunately, has left open the question of children's flexibility in taking different perspectives on temporal relations, but it was designed to test for children's understanding of *others'* differing perspectives just as Study Sets 1 and 2 aimed to involve self-independent reasoning about temporal matters. A seemingly different set of research questions could have focused on children's performance in tasks that were exclusively self-related. We do not know if personal experience makes a difference in children's TCR or temporal-normative evaluations. But evidence suggests this question to be important for our understanding of the interplay of different types of temporal cognition.

Despite the massive conceptual overlap of the aspects of temporal cognition studied here, little research so far has systematically investigated the development of the different capacities in relation to each other. The present thesis provides one step into the direction of an integrated understanding of temporal cognition and the development of its different components in childhood. A fundamental challenge for future research will be to develop appropriate measures for the specific capacities involved, and to systematically explore the empirical relations of these different forms and aspects of representing time.

In conclusion, this work helps to improve our understanding of children's developing temporal cognition in the following ways: first, previous work on children's understanding of the temporal-causal relations has been replicated and extended in important ways. Second, research on children's normative understanding of the temporal outreach of language has been extended, proving an earlier understanding of different normative implications of future-directed speech acts than documented before. Third, a first step has been made to broaden our knowledge of - and to contribute to the scarce empirical evidence on - temporal perspective taking in children. In the discussion and interpretation of our findings, important associations with other lines of research on children's temporal cognition were revealed and an integrated and systematic investigation of the interplay of the involved capacities was suggested.

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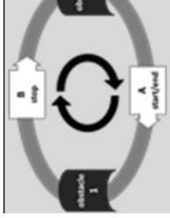
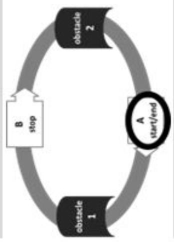
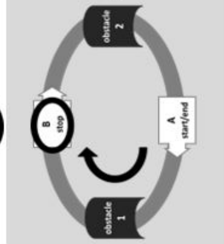
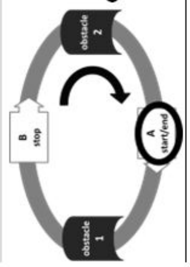
7 APPENDIX

7.1 S1

S1. Structure of the three versions of the search task, Study 1a and Study 1b.

	Search task (Study 1a)		Search task (Study 1b)
	Retrospective reasoning condition	*Updating condition*	*Retrospective reasoning condition*
 **Demo-clip**	-	Cargo gets lost at obstacles 1and 2	-
 **Goal & instruction**	Container is loaded with object & tool. **Transport object from A to B, use tool at B.**		Container loaded with *object only*. **Transport object from A to B, tool would be useful at B.**
	-	Hint: "Pay attention to the tool!"	-
 **Causal cue**	-	Hint (opening container at B): "Look what's inside!"	-
	Target location	***Target location***	***Target location***
	1 tool absent →no tool-use; *2* tool present → tool-use	*1* tool absent → no tool-use; *2* tool present → tool-use	*1* tool *present* → tool-use; *2* tool *absent* → no tool-use
 **Test question**	Tool is missing. "At which obstacle did s/he lose the tool?"		Tool is *discovered*. "At which obstacle did s/he *find* the tool?"

7.2 S2

S2-A. Examples of object-container pairs used in Study 2a (upper row), sorting games used in Study 2b (row below).

S2-B. Cards used to introduce the forced-choice paradigm in warm-up phase (left and reight pictures in the upper row), and cards used in test trials (row below), Study 2b.

S2-C. Script of puppet play preceding the response phases in prediction and imperative conditions in Study 2a and Study 2b.

	Prediction			Imperative		
	actions	*speech-acts*	*(German original)*	*actions*	*speech-acts*	*(German original)*
time 1a	*actor-puppet leaves the room*	It's my turn to choose something!	Ich geh mir was aussuchen!	*actor-puppet*	[Speaker], what shall I slide next?	[Speaker], was soll ich denn gleich rutschen lassen?
	-rummages around in the objects' box, prepares the slide, remains out of view	Now I know what I'll slide!	Oh ja, ich weiß auch schon was!	*speaker-puppet*	***speech-act 1*** [Actor], slide [X], next!	[Actor], lass gleich mal ein [X] rutschen!
				actor-puppet	Okay!	Okay!
time 1b	*speaker-puppet turns around as if trying to peek behind the wall*	Hm, let's see –	Hm, mal sehen –	*actor-puppet leaves the room, rummages around in the objects' box, prepares the slide.*		
		speech-act 1 I think [actor] will slide [X].	Ich glaube [actor] wird [X] rutschen lassen.			
		speech-act 2 I guess [actor] will slide [X].	Ich denke [actor] wird wohl [X] rutschen lassen.	*speaker-puppet (meanwhile)*	***speech-act 2*** [Actor] shall slide [X]!"	[Actor] soll [X] rutschen lassen!
time 2	*actor slides [Y]*			*actor slides [Y]*		

7.3 S3

S3. Original German script for the path and the carousel task.

	Path task	Carousel task
(Training) control question 1	*Guck mal, ein Hund. Er will auf dem Weg spazieren gehen. Jetzt geht er den Weg entlang! Er geht am Wald vorbei und über die Brücke in das Haus hier.* *Was war zuerst? Wald oder Brücke? Und was kam danach?* *Ok, also der Wald war vor der Brücke!*	*Siehst Du das Pferd? Und den Traktor? Das Karussell fährt immer genau eine Runde. Pass mal auf –* [carousel goes one round] *Das ist Sarah. Sie steigt in den Traktor ein, das Karussell fährt los: am Spielplatz – und am Bauernhof vorbei.* *Was kam zuerst? Was kam danach?*
(Training) control question 2	*Guck mal, eine Katze. Sie will auch auf dem Weg spazieren gehen. Jetzt geht sie den Weg entlang! Sie geht über die Brücke und am Wald vorbei in das Haus hier.* *Was war zuerst? Wald oder Brücke? Und was kam danach?* *Ok, also die Brücke war vor dem Wald!*	*Jetzt will Sarah auf dem Pferd reiten. Sarah steigt auf und los geht's!* *Am Bauernhof – und am Spielplatz vorbei.* *Was kam zuerst? Was kam danach?*
(Test) Q1	*Das sind Teo und Lucy. Die wollen auch auf dem Weg spazieren gehen.* [A cloud appears and occludes the whole scenario] *Oh, wo kommt denn die riesige Wolke her! Jetzt sehen wir ja gar nicht, wo die beiden langgehen! Aber hörst du die Fußstapfen?* [Cloud disappears] *Die Wolke ist weg und die beiden sind schon längst angekommen. Aber wo sind sie? Lucy sagt: Der Wald war vor der Brücke. Teo sagt: Die Brücke war vor dem Wald.* ***Also Teo sagt: Die Brücke war vor dem Wald. Wo ist Theo?***	*Aha. Pass auf, gleich kommt Tim dazu. Tim und Sarah wollen zusammen Karussell fahren. – Oh, eine Regenwolke!* [cloud appears on the left side of the screen, moves towards - and finally disappears- at the right side] *Aha, die beiden haben Regenschirme, schau, sie sitzen schon im Karussell. Los geht's.* [carousel goes one round] *Angekommen. Aber wer ist eigentlich wo mitgefahren?* ***Sarah sagt: „Der Spielplatz kam als erstes." Weißt Du wo Sarah ist?***
(Test) Q2	***Und Lucy sagt: Der Wald war vor der Brücke. Wo ist Lucy?***	*Aha* [the umbrellas disappear]. *Und Tim hat auf dem Pferd gesessen. Siehst Du?* ***Wenn wir Tim fragen: Was kam denn als erstes? Was sagt Tim?***

Curriculum Vitae

Karoline Lohse

geb. am 9. März 1983
in Kaltenkirchen

Studium

seit 04/2010	Promotionsstudentin im Grundprogramm Biologie der Georg-August University School of Science (GAUSS), Göttingen
2008-2009	Magisterarbeit: *Kooperation und Teilen bei Peer Partnern. Eine Studie mit 3-jährigen Kindern*. Max-Planck-Institut für evolutionäre Anthropologie, Leipzig, & Albert-Ludwigs-Universität Freiburg im Breisgau, Betreuer: Felix Warneken und Wolfgang Raible
08–11/2005	Auslandssemester Universidad Nacional de San Juan, Argentinien
09/2002–07/2009	Studium der Historischen Anthropologie & Romanischen Philologie, Albert-Ludwigs-Universität Freiburg im Breisgau
06/2002	Abitur, Dietrich-Bonhoeffer Gymnasium Quickborn

Wissenschaftliche Tätigkeiten

12/2009-12/2013	Wissenschaftliche Mitarbeiterin, Georg-Elias-Müller-Institut für Psychologie, Abt. Biologische Entwicklungspsychologie, Georg-August-Universität Göttingen
11/2007–09/2008	Studentische Hilfskraft, Abt. Vergleichende und Entwicklungspsychologie, Max-Planck-Institut für evolutionäre Anthropologie, Leipzig
10/2004–07/2005	Studentische Hilfskraft, Abt. Empirische Kultur- und Sozialforschung, Institut für Grenzgebiete der Psychologie und Psychohygiene e.V., Freiburg im Breisgau

Lehrerfahrung

04/2010–09/2013	Seminarleitung *Diagnostizieren, Beurteilen und Fördern im schulischen Kontext*, Studiengang Master of Education, Georg-August-Universität Göttingen
2011-2013	Betreute Masterarbeiten, Projekt *Verständnis von Perspektivität im Alter von 3 bis 5 Jahren*: Nicole Böse, Anne-Kristin Rückert, Kira Sagolla, Kim Gärtner Betreute Bachelorarbeiten, Projekt *Temporal Cognition – Zeitlich-kausales Schlussfolgern bei 4- und 6-jährigen Kindern*: Theresa Kalitschke, Katja Ruthmann

Praktika, Hospitationen, Sommerschulen

09/2013	Bertelsmann Stiftung, Projekt *Wirksam in Bildung investieren – Familien und Institutionen stärken*, Gütersloh (dreiwöchige Hospitation)
04/2013	KiTa Bunte Welt, Studentenwerk Göttingen (zweitägige Hospitation), Vor- und Nachbereitung durch Prof. Dr. Kasüschke für die Robert Bosch Stiftung
09/2012	International Summer School: *The Research and Study Program on Education in Early Childhood*, 09.-13.09.2012, Robert Bosch Stiftung, Menaggio, Italien
11/2011	Leibniz Winter School: *Cognition and Communication*, 16.-21.11.2011, Leibniz Graduate School *Foundations of Primate Social Behavior* und Universität Wien, Österreich
02–04/2007	Max-Planck-Institut für evolutionäre Anthropologie, Abt. Vergleichende und Entwicklungspsychologie, Leipzig (Praktikum)
11/2005–01/2006	Goethe-Institut, Cinemathek, Santiago, Chile (Praktikum)

Ämter & Mitgliedschaften

seit 12/2011	Vertreterin der Promovierenden im Grundprogramm Biologie (inkl. Psychologie), Georg-August-University School of Science (GAUSS)
04/2011-12/2013	Stv. Mitglied in der *Studienkommission Lehrerbildung*, Zentrum für Lehrerbildung, Georg-August-Universität Göttingen
04/2010-10/2012	Modulkoordination *Diagnostizieren, Beurteilen und Fördern* (Bildungswissenschaften, Modul 3) im Studiengang Master of Education, Georg-August-Universität Göttingen

Stipendien

12/2011–12/2013	Robert Bosch Stiftung, Forschungskolleg Frühkindliche Bildung

Publikationen

Originalarbeiten im Zusammenhang mit der vorliegenden Dissertation

Lohse, K. & Rakoczy, H. (submitted). The development of reasoning about the temporal and causal relations between past, present and future events.

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Posterpräsentationen

Lohse, K., Rakoczy, H. (2012). Re-living the Past and Imagining the Future? Young Children's Temporal-Causal Reasoning in Analogous Memory, Updating and Planning Tasks. 20th Annual Meeting of the European Society for Philosophy and Psychology (ESPP), 28.-31. Aug., London, UK.

Lohse, K., Gräfenhain, M., Behne, T., & Rakoczy, H. (2012). Tell me What the Future Holds - Children Differentiate the Normative Structure of Predictions and Imperatives. 18th Biennial International Conference on Infant Studies (ICIS), 7.-9. Juni, Minneapolis, USA.

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Göttingen, 7. Januar 2014