Planning in young children: A review and synthesis

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Research on the development of planning is reviewed in the context of a framework that considers the role of three types of cognitive flexibility in planning development: event-independent temporal representation, executive function, and self-projection. It is argued that the emergence of planning abilities in the preschool period is dependent upon the development of event-independent temporal representation. Research on the development of executive function suggests that its sub-components, in particular inhibitory control, may be linked to developmental improvements on planning tasks. Recently, new paradigms have established that self-projection to the future appears to develop over the preschool period. We consider how these different forms of cognitive flexibility may themselves be related in development.

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Introduction

The emergence of planning abilities is widely regarded as an important developmental achievement. For example, planning is one of the core cognitive outcomes measured in the longitudinal NICHD study on child care (NICHD Early Child Care Research Network, 2005) and the importance of planning in a classroom context is widely recognized by educationalists (see various contributions to Meltzer, 2007). In addition, the past decade has seen a burst of research on the development of executive functions and how these skills relate to children’s planning ability. Researchers who work with children with various developmental disorders linked to executive dysfunction have also considered whether such populations have specific difficulties with planning and how this might relate to symptomatology (e.g., Geurts, Verté, Oosterlaan, Roeyers, & Sergeant, 2004; Mackinlay, Charman, & Karmiloff-Smith, 2006). Even more recently, there has been a growing interest in young children’s...
ability to think about the future, and how this ability might be linked to other aspects of cognitive development (Atance & Meltzoff, 2006; Suddendorf & Corballis, 2007), including planning.

As such, the time is ripe to review the research on children's planning – a goal that has not been undertaken since an edited book on the cognitive developmental research on planning by Friedman and Scholnick in 1997.

**Goals of this review**

In this review, we focus primarily on empirical research and theoretical advances that have occurred since the publication of Friedman and Scholnick's (1997) volume, a time that also coincides with the onset of increased work on the importance of executive functioning in young children's cognitive development, including the development of planning. There has been an extremely broad range of research on planning, and by necessity we are selective in our coverage of the topic, focusing primarily on planning in early and middle childhood rather than in adolescence, and on debates about cognitive factors rather than social and motivational issues.

The first goal of this review (Section 1) is to familiarize the reader with the various tasks that have been designed to measure young children's (and infants') planning ability. In doing so, we highlight that, although these tasks were designed to measure different aspects of children's planning, it is possible to conceive of their development as dependent on a particular type of cognitive ability that requires representing temporal locations in a flexible way (Hoerl & McCormack, in press; McCormack & Hoerl, 2008). Our second goal (Section 2) is to consider the role of another type of cognitive flexibility – executive functioning (or EF) – in children's planning. Again, we argue that developments in certain aspects of EF (most notably, inhibitory control) also underpin increases in children's planning ability.

In addition, we consider whether individuals who are characterized as having deficiencies in EF also show deficiencies in planning. Our third goal (Section 3) is to consider a third type of cognitive flexibility that has recently been termed “self-projection” (Buckner & Carroll, 2007). In particular we discuss how this type of flexibility may also be important for children's planning abilities, as well as their future thinking abilities, more generally.

These goals are not without their challenges, not least because there is no agreed-upon definition of what “planning” is, nor a consensus on tasks that provide a true measure of children's planning ability. As such, we begin our review by providing our working definition of planning which we derive from our theoretical perspective that increases in flexibility of thought (in the three ways that we characterized above) ultimately lead to increases in planning ability. This argument permeates each section of our review in that we view developments in temporal cognition, executive functioning, and self-projection as reflecting increases in the flexibility of children's thought that, in turn, are mirrored in developments in their planning abilities.

**Planning and flexibility of thought**

The idea that children's thinking becomes more flexible with development is a long-standing one, and has been expressed in a wide variety of ways, from the Piagetian notion of reversibility of thought (Piaget & Inhelder, 1966), to considering development as involving acquisition of and increasingly flexible use of strategies (Bjorklund, 1990), or assessing the impact of flexible thinking on children's use of categories and language, (Blaye & Jacques, 2009; Deak, 2003). The suggestion that cognition becomes more flexible with age plays a central role in approaches that focus on the development of executive functioning (Best & Miller, 2010; Diamond, 1991; Garon, Bryson, & Smith, 2008). For example, Diamond emphasizes the ability to flexibly adapt behavior to changing situations as a key component of cognitive control that shows a long developmental progression (e.g., Davidson, Amso, Anderson, & Diamond, 2006).

One of the basic features of planned behavior is that it is not simply stimulus-driven, and, because of this, planning results in behavior that is more flexible than non-planned behavior. Indeed it has long been argued that adult patient populations that have particular difficulties with flexible cognition struggle to plan their everyday lives (see Shallice, 1988). In this review, we want to explore to what extent it is useful to characterize developmental changes in planning in terms of changes in flexibility
of thought. However, because the term cognitive flexibility has been used in different ways, it is important to describe what we mean by flexibility in this context. Critically, planning is a key way in which flexibility of thought can be exploited to enable behavior to adapt not just to the current state of the world, but to anticipated states of the world in the immediate or distant future. Some of these anticipated states may in fact be states that are a result of one’s own actions: for example, they may be states that are a result of intermediate steps that form part of an action sequence leading towards an overall goal. In Section 1, we will see how in planning tasks, such as the Tower of Hanoi/London and errand-planning, successfully anticipating the consequences of one’s next actions are a critical part of an efficient planning process. Other anticipated states may be out of one’s control, and may be quite different from how things currently are. Indeed, as we will see in Section 3, tasks examining future thinking take as their aim to establish whether children (or animals) can prepare for a state that does not presently obtain (Atance & O’Neill, 2001; Russell, Alexis, & Clayton, 2010; Suddendorf & Busby, 2005) in order to meet a future, non-current, goal.

Not all behavior that adapts to future rather than current states of the world necessarily involves planning. For example, it would be misleading to describe a squirrel storing nuts for the winter as planning for the future (see Raby and Clayton (2009), for discussion). This suggests that planned behavior involves considering different sequences of action alternatives and choosing between them prior to action, given how non-actual states of the world are going to unfold (see also Haith, 1997). Consequently, we argue that planning involves certain temporal representational abilities. Specifically, an individual must represent particular points in a temporal series in such a way that she can consider which possible actions might be appropriate at which points in the series. This characterization of planning as involving anticipating non-actual states, and making choices, in advance of acting, about which actions to carry out, and in which order, given the nature of these non-actual states, already provides us with the basis for considering which types of behavior are planned and which are not. In Section 1, on planning in early childhood, we provide further analyses of whether particular behaviors should be taken as indicative of planning in this sense or not.

In characterizing planning in this way, we want to distinguish between three different ways in which flexibility of thought may be critical for ensuring that behavior successfully adapts to anticipated rather than merely current states of the world. These three aspects will provide a framework for considering the empirical work in this area, and a core aim of our review is to examine whether it is useful to think of the development of planning and future thinking in terms of the development of these three types of flexibility.

Flexible thought about time

That planning tasks require some ability to think about or represent time or temporal order is not a new idea (see most notably, Benson, 1997). We argue that it is important to consider the role of a particular fundamental temporal ability in planning, namely the ability to represent temporal locations in a flexible way, independently of the events that occur or may occur at those temporal locations, and that this is a representational ability that emerges developmentally. Note that this is not simply the ability to represent and reproduce a temporally ordered sequence of actions or events, an ability likely to be present from relatively early in development (Bauer & Mandler, 1992; Benson, 1997). Rather, it is the ability to represent points or steps in a sequence independently of the events that might occur at those points in time, termed event–independent temporal cognition or representation (McCormack & Hoerl, 2008). A number of different accounts of the development of temporal cognition (e.g., Nelson, 1996; Weist, 1989) feature the idea that it involves the emergence of flexible, event-independent ways of representing temporal locations, although the term itself has not been commonly employed (see Hoerl & McCormack, in press; McCormack & Hoerl, 2008). Our suggestion is that efficient performance on planning tasks may require a way of representing possible points in an action sequence in terms of, for example, before-and-after relationships, in such a way that would allow the child to consider which specific actions should be carried out at any specific point in the sequence. In other words, mentally planning a sequence of events in this type of task involves being able to consider that there are slots in a sequence of potential actions that could be filled in different ways.

Some research with preschoolers suggests that the ability to represent temporal sequences in this way develops between 3 and 5 years. In McCormack and Hoerl’s tasks (2005, 2007), short novel event
sequences involving two events A and B occurred out of sight of the child. In these sequences, the outcome depended on the order in which A and B occurred, but children were not told until after the events had happened which event (A or B) had occurred first and which had occurred second in the sequence. Children had to reason about the outcome of the event sequences by considering retrospectively how the order in which the two events occurred would have affected the outcome. One natural interpretation of the demands of this task is that it requires holding in mind an event-independent representation of the event sequence with appropriate open slots that are then filled when order information is provided retrospectively (McCormack & Hoerl, 2008). It is this sort of temporal representational ability that we think may be important in the development of planning, and in Section 1, we will develop this idea of planning as involving event-independent temporal representation further, and consider, for example, whether particular tasks used with young children require this ability.

Flexible thinking and executive functioning

There are a variety of accounts of the nature of EF and its development (e.g., Best & Miller, 2010; Garon et al., 2008; Zelazo, Muller, Frye, & Marcovitch, 2003), and it is beyond the scope of this review to adjudicate between these accounts. Although cognitive flexibility is sometimes described as just one sub-component of executive control (see Davidson et al., 2006), we are using the term here in a very general sense that could encompass the broad range of executive control processes. For the purposes of this review, we will highlight three critical sub-components that have emerged as important: inhibitory control, memory updating (usually referred to as working memory), and task switching (Best & Miller, 2010; Friedman et al., 2008; Garon et al., 2008; Miyake, Friedman, Emerson, Witzki, & Howerter, 2000). The suggestion that some planning tasks place substantial demands on inhibitory control has been elaborated within research with adults, particularly research with patients known to have difficulties in this domain (Goel & Grafman, 1995; Morris, Kotitsa, & Bramham, 2005). In Section 2, we will discuss how developmental research is relevant to assessing whether inhibitory control is important in certain types of planning tasks (e.g., Tower of London). Inhibitory control may also be important in planning tasks in determining whether participants take time to think rather than acting impulsively (Asato, Sweeney, & Luna, 2006).

Working memory has also been argued to be important in planning tasks because of the requirement to hold a series of actions or events in mind while considering their efficiency and order (Owen, 2005). Developmental studies, reviewed below, have specifically examined this issue. Finally, task switching might be thought to be particularly important with regard to complex tasks that involve a series of sub-goals (Rattermann, Spector, Grafman, Levin, & Harward, 2001), since such tasks may involve appropriately flexibly switching between these goals while keeping in mind the overall goal. In Section 2, we review developmental research that has examined whether there are relationships between children’s performance on planning tasks (primarily the Tower of London/Hanoi task) and aspects of their EF. This section also reviews relevant research on planning in children with developmental disorders such as autism and ADHD.

Flexible thinking and self-projection

The last type of flexibility that we consider in this review has historically been described as either decentering or perspective-switching. In the Piagetian framework, the notion of decentering was meant to encompass the ability to adopt and coordinate perspectives that were not one’s own, and this could apply to mentalizing (thinking about another’s mental state, now commonly assessed using theory of mind tasks, Perner, 1991), spatial decentering (thinking about another spatial perspective on an array, traditionally assessed using tasks such as the Three Mountains task, Piaget & Inhelder, 1956), or temporal decentering (adopting a different temporal perspective on events, see e.g., Cromer, 1971; Harner, 1982). Although the idea that there are synchronous developmental changes in these different domains that reflect a domain-general cognitive shift fell out of favor some time ago (Flavell, 1977), analyses from the neuropsychological research literature provides a new impetus for considering what thinking in these different domains may have in common.

Most influentially, Buckner and Carroll (2007) have argued that spatial reasoning, mentalizing, and thinking about the past and the future involve a common ability they describe as “self projection”, and they argue that neuropsychological research suggests that these abilities rely on a common brain
system (see also Spreng, Mar, & Kim, 2008). Self-projection is defined as “the ability to shift perspective from the immediate present to alternative perspectives” (Buckner & Carroll, 2007, p. 49), and with respect to the future they introduce the term “prospection” to describe a type of self-projection to the future that requires “a shift of perspective from the immediate environment to the alternative, imagined, future environment, and that the imagined event is referenced to oneself” (p. 49). They argue that prospection plays an important role in everyday planning, and it may follow a similar developmental timetable to self-projection involved in mentalizing, spatial cognition, and thinking about the past (autobiographical memory).

We discuss the role of self-projection in planning and future thinking in Section 3, addressing two key issues. First, we describe the small number of developmental studies that have taken as their aim to examine self-projection to the future, assessing whether they have been successful in achieving this aim. Second, we examine whether there is any developmental evidence of a link between future thinking or planning and the other types of self-projection described by Buckner and Carroll (2007). Relatively little research has addressed this issue, although it seems likely that developmental researchers are particularly well placed to provide behavioral evidence addressing Buckner and Carroll’s “common system” claim.

Section 1: Planning in infancy and early childhood: towards event-independent temporal cognition

Although in the last decade a number of new non-verbal planning tasks have emerged, there exist few established paradigms to assess infants’ and very young children’s planning abilities. Unlike for older children and adults, there is no prototypical planning task for children younger than age 3. In fact, up until the last 10 years or so, much of what we knew about young children’s planning came from parental observations (Benson, 1997). In what follows, we review some of the recent research that can inform us about planning in early childhood and infancy.

Motor planning in infancy

The earliest indications of behavior that may require advance thought are in the domain of what is usually referred to as motor planning. The general aim of these tasks is to establish whether infants’ movements suggest that a future state of affairs is guiding their actions. Claxton, Keen, and McCarty (2003) examined whether, like adults, infants (10 ½-month-olds) changed their speed of approach towards an object (e.g., ball) if they subsequently intended to place the ball into a narrow tube, or throw it into a tub placed on the floor. Results indicated that infants did indeed reach for the ball faster in the latter context, compared to the former (as is the case with adults). The authors argue that this indicates that infants represented the future state of affairs and, moreover, one that was not perceptually available at the time of action. This last point is important because it distinguishes this paradigm from others in which the goal/future state of affairs is perceptually available (e.g., Clifton, Rochat, Robin, & Berthier, 1994; Lockman, Ashmead, & Bushnell, 1984).

Another clever motor planning task was developed by McCarty, Clifton, and Collard (1999). In one of their tasks, 9-, 14, and 19-month-olds were presented with a food-filled spoon, mounted horizontally on two vertical handles. The handle of the spoon was sometimes oriented to the child’s right and sometimes to the child’s left. Children could grasp the spoon how they wished, but the most effective strategy/plan was to reach for the handle using what is termed a “radial” grip (i.e., an overhand grip in which the thumb is oriented toward the bowl of the spoon). This type of grip brings food to the mouth quickly and without spilling. Because most infants are right-hand dominant, of interest is how they reach for the spoon when its handle is oriented to the left of their midline. It was only by 19 months of age that children began to resist reaching with their dominant (right) hand when the spoon was presented in this position, leading McCarty et al. to argue that the infants evidenced some capacity for advance planning.

A similar (but slightly more complex) task devised for use with children in the 2–3 year age range was developed by Cox and Smitsman (2006). An object (e.g., plastic sea animal) was placed at the center and far end (from the child’s perspective) of a circular table with an opening in the table situated either to the left or to the right of the child’s midline. A tool (e.g., a long wooden stick) was placed
perpendicular to the child’s midline, between the child and the object, with the goal being to use the tool to move the object into the opening. Of interest was how children’s behavior in the first phase of the task (grasping the tool) would be affected by the ultimate goal (transporting the object to the opening). Given that most children are right-hand dominant, when the opening is on their left side, this set-up poses little problem. That is, the tool can be grasped with the right hand and the object is easily swept into the opening. However, when the opening is on the child’s right side, grasping the tool with the right hand is a sub-optimal solution because it results in an awkward sweep of the object into the opening. Similar to McCarty et al.’s (1999) logic, these difficult trials are especially revealing of children’s motor planning. Results indicated that goal location (i.e., the side of the opening) had no effect on the 2-year-olds’ hand use, whereas it did affect the older children’s behavior. For the difficult trials, 3-year-olds used their right hand only about 50% of the time, whereas for the easier trials, this percentage was close to 100%.

Although we can agree with the general way of describing these tasks, namely as tasks that measure some type of motor planning, it is important to consider whether these tasks involve planning in the sense that we are conceiving of it. We characterized cognitive planning tasks as involving the ability to represent possible time steps in an action sequence in such a way that would allow the child to consider which specific actions should be carried out at any particular point in the sequence. By contrast, it is possible to describe children’s performance on the motor planning tasks just described without assuming that they are representing future temporal sequences in this way: Children simply have to make an appropriate choice for their first action (speed of approach or hand choice). One could argue that children’s behavior involves only adapting to the current state of the word (e.g., the current orientation of the spoon), given the child’s goal. Even though Cox and Smitsman’s (2006) task is more complex because it involves coordinating the relation between a tool, an external object (the sea animal), and a goal, children need not be representing the task in terms of a set of time steps that could be filled by different actions. Children simply have to make a binary choice (i.e., left/right hand) and in making that choice they do not need to represent the task as involving a series of subsequent steps that could be filled with different actions or events.

Nevertheless, we could conceive of both McCarty et al.’s (1999) and Cox and Smitsman’s (2006) tasks as requiring a rudimentary ability to inhibit a prepotent response (i.e., setting aside one’s usual grip/hand preference), thus evidencing that one of the key abilities for later planning skills, and hence one type of cognitive flexibility, is emerging (as discussed in Section 2).

Bauer, Schwade, Saeger Wewerka, and Delaney (1999) developed a task that might require representing action sequences. These researchers aimed to examine 21- and 27-month-olds’ ability to plan and execute a course of action to solve a novel problem. For example, one problem entailed making a rattle. Children were presented with two halves of a plastic barrel, and a small wooden block. The solution was to put the block into one of the barrel halves, snap them together and make a sound by shaking the barrel. Children were presented with varying amounts of information to help them in their plan generation. For example, in Experiment 1, children were shown the goal state (e.g., completed rattle), whereas in Experiment 2, they were shown the initial step (e.g., inserting the block into one of the barrel halves). Children completed the task most effectively when the goal state information was provided to them. Thus, children in Experiment 1 solved the problems more often than children in Experiment 2 (and, similarly, in a third experiment, children performed better when one of the actions that they were shown was the goal state). Nonetheless, even in Experiment 1, children only achieved the goal state on 40% of the problems. And, 27-month-olds showed more evidence of planning than 21-month-olds. One conclusion advanced by Bauer et al. is that children of this age may be successful planners only when the structure of the problem is well specified.

Success on this task involved carrying out not just a single action (e.g., choosing the correct hand), but carrying out a series of three actions in the correct order. Although Bauer et al. (1999) argue that the fact that children made relatively few ordering errors (e.g., snapping the two halves of the barrel together before trying to put the block in) suggests that children were indeed anticipating the consequences of their actions in advance of acting, this does not necessarily imply that children were conceiving of each step in the sequence as a point in time which could be filled by different actions. More specifically, unlike in tasks like the Tower of London/Hanoi task, the order in which actions must be carried out is determined solely by the physical enabling relationships between actions, and is not
a function of any rules or constraints that are imposed by the experimenter or the nature of the procedure. This suggests that there could be a way in which children could anticipate the action sequence in advance of acting in this task, but a way that still falls short of conceiving of each step in the sequence as a point in time which could be filled by different actions.

To make this argument, we introduce the notion of the simulation of action sequences in the sense most clearly articulated by Hesslow (2002). Hesslow argues for a very basic notion of simulation: “The idea that behavior can be simulated means that the activity in the motor structures, which prepare and initiate an action, can occur while its execution by the primary motor cortex is suppressed” (p. 243). His claim is that we can potentially prepare for an action sequence by using the same processes that would be involved in carrying out the action sequence, without actually completing the actions. He describes the simulation process proceeding as follows: “Perceptual activity generated by a simulated action can serve as a stimulus for a new response, and so on… thus enabling long chains of simulated responses and perceptions. By such simulated interaction with the environment, an organism could evaluate not only single responses but also whole courses of action before putting them to physical, potentially dangerous, tests… The anticipation mechanism will ensure that most actions are accompanied by probable perceptual consequences, so that during normal behavior we will always “in our thoughts” be a few steps ahead of the actual events. A simulation can thus be triggered by the same stimuli that elicit overt behavior” (p. 244).

Our suggestion is that this notion of action anticipation via some sort of motor simulation may be an adequate description of what underpins successful performance on Bauer et al.’s (1999) task. It may also be a way of explaining why it is that performance levels are relatively low. As it has been described here, in its most basic form motor simulation differs from how we might consider cognitive planning to proceed, in that a simulation “runs off” an action sequence, with each action automatically triggering the simulation of the next action. Thus, in its most basic form, this type of simulation would not involve weighing up or considering action alternatives at different time steps in a sequence. If this is the case, then simulation in this sense is more limited in its flexibility and depends crucially on the initial stimulus eliciting the simulation of the correct first action with subsequent simulated states similarly triggering the next simulated actions (for further discussion, see McCormack & Hoerl, in press). If this is what children are doing in Bauer et al.’s task, then they are not mentally trying out different alternative actions at different steps in the sequence, and this lack of flexibility may mean that if a simulation does not lead to the goal state, then children have few resources for altering their anticipated action sequence, limiting levels of performance.

To summarize, we have described various tasks that have recently been used to assess some sort of planning in infancy, but we have argued that these tasks may not require cognitive planning as we have described it. We can agree, though, that the tasks reviewed in this section may illustrate a basic capability to anticipate the consequences of actions or action sequences. This basic capacity is likely to be limited in flexibility because children are not mentally trying out which actions might be appropriate at different points in a temporal sequence. Nevertheless, some of the tasks do seem to require a type of behavioral flexibility that may be one of the building blocks of later planning abilities, namely the ability to inhibit a prepotent response. Both of these points suggest that an interesting question for future research is whether the behaviors measured in these tasks are continuous with those measured in older children. This question can only be addressed through careful longitudinal research.

Research with preschoolers

Early childhood planning tasks fall into three different categories: (1) Tower tasks, (2) route planning, and (3) “real-world.” Although, as we mention below, these tasks may measure different aspects of children’s planning, we argue in this sub-section that it is possible to view their development at least in part as due to the emergence of event-independent temporal cognition.

Tower tasks

Variations of the Tower of London (ToL) or Tower of Hanoi (ToH) have been the most widely employed tasks to study planning in children, in atypical populations, and in adults. The ToL task was developed by Shallice (1982), drawing on the pre-existing ToL, to specifically examine deficits in
planning in patients with frontal lobe pathology and the type of associated cognitive problems usually referred to as executive dysfunction. The ToL typically involves a set of colored discs or balls (often 3 or 5) that are placed on three pegs of differing heights (Shallice, 1982). Participants’ task is to convert an initial state of the balls to a goal state, with the latter state often illustrated using a picture. Movements of the balls are constrained by the fact that the pegs differ in terms of the maximum balls they can hold at any one time, and participants are not allowed to move more than one ball at a time. The ToH differs in that the pegs are all of the same height but the discs themselves are of different sizes, with the important constraint being that a disc cannot be placed on top of another disc that is smaller. In both tasks, participants’ challenge is to reach the goal state with the minimal number of moves without making any illegal moves.

Although Tower tasks have been used to measure children’s planning for decades, a distinctive feature of recent studies is that they have attempted to use such tasks with children as young as 3 or 4 years (e.g., Bull, Espy, & Senn, 2004; Carlson, Moses, & Claxton, 2004; Hughes, 1998; Luciana & Nelson, 1998; Wiebe, Esy, & Charak, 2008). One concern is whether such tasks are suitable for these young children. For example, in Carlson et al.’s study, group means suggest that most 3- and 4-year-olds did not progress beyond ToH problems that involved only two discs. Some researchers argue that these 2-disc problems do not require any planning in advance of action, with children simply guided perceptually to produce a match of the goal state (Kaller, Rahm, Spreer, Mader, & Unterrainer, 2008; and see Section 2). The high exclusion rate in Luciana and Nelson’s (1998) careful study (more than half of their sample of 4-year-olds) indicates that Tower tasks should only be used cautiously with children younger than 5, since a significant proportion of children of this age cannot follow the task instructions. It is also well-established that 3- to 4-year-olds are more likely than older children to break task rules and produce incomplete solutions (Klahr & Robinson, 1981; Baughman & Cooper, 2007). Indeed, we note that the NEPSY I test battery (Korkman, Kirk, & Kemp, 1998), which employs a ToL task, does not recommend use of this sub-test with children younger than 5, and does not provide norms for children below that age.

If a new form of event-independent temporal representation that supports cognitive planning emerges in the preschool years, we might expect to see qualitative shifts in children’s performance on such tasks. Indeed, the suggestion that 4-year-olds’ performance on the ToL is qualitatively different from older children’s has received strong support from a recent study carried out by Kaller et al. (2008). Kaller et al. noted that in Luciana and Nelson’s (1998) original study, 4-year-olds, unlike any other age group, showed a steep decline in performance (from around 85% correct to around 25% correct; see also Klahr & Robinson, 1981; Welsh, 1991) when problems increased in difficulty from 2 to 3 moves. Luciana and Nelson themselves concluded that this may be due to changes in spatial WM, since the 4-year-old group also showed a steep decline when the difficulty of a spatial WM task was increased from a 2-item search to the 3-item search. However, Kaller et al. pointed out that not only did the number of moves required for success increase between 2 and 3 item problems, but that all of Luciana and Nelson’s 3-move problems introduced a new requirement to generate an intermediate move. Problems involving intermediate moves require participants to generate a sub-goal of moving an item to a temporary position that is not its goal position, and can be contrasted with problems that can be solved through a series of immediate hits (compare Fig. 1a and b). As Kaller et al. note, “optimal solution of three-move ToL problems requiring an intermediate move can reliably be achieved only by mechanisms of strategic search ahead, whereas problems without an intermediate move may also be accomplished by simple perceptual matching-to-sample” (p. 362).

Kaller et al.’s (2008) study compared 3-move ToL problems that either did or did not require an intermediate move, and showed that 4-year-olds’ accuracy was highly affected by the need to generate such a move, whereas that of 5-year-olds was not. Kaller et al. concluded that the younger age group had real difficulties thinking ahead about the future consequences of an initial action. Accurate performance depends not only on achieving the sub-goal of moving the obstructing ball but, crucially, keeping in mind the consequences of how one achieves that sub-goal for achieving the overall goal. As they point out, the sub-goal of moving the obstructing white ball in problem 1(a) could be achieved by moving it to the second peg. However, resolving the sub-goal in this way would be detrimental to achieving the overall goal of reaching the final goal state. It is only if children anticipate the consequences of their initial move that they can solve the problem accurately, and it is integrating this anticipation of consequences with their action selection that appears to be difficult.
How should we interpret this qualitative developmental change in performance between 4 and 5 years? One way of interpreting young children's difficulties here may be in terms of a difficulty inhibiting a tempting initial move. We discuss the relationship between inhibition and ToL performance in more detail in Section 2, but it is worth pointing out that Kaller et al. carefully analyzed whether 4-year-olds' difficulty with ToL problems that require intermediate moves was related to inhibition, and found that only chronological age rather than performance on their inhibition task appeared to be related to difficulties in making such moves.

Another way of interpreting the developmental change observed by Kaller et al. (2008) may be in terms of a development towards event-independent temporal representation in this task. Solving problems without intermediate moves may not actually require children to consider the solution to the ToL problem in terms of a series of time steps that could be filled by different actions, since it does not involve managing sub-goals appropriately to yield the overall goal. In fact, children may completely fail to anticipate their action sequences in advance in these problems, and simply carry out each action in turn which then triggers the next action (i.e., their performance may be purely perceptually guided). Alternatively, they may indeed anticipate their actions, but use something like the sort of simulation of action sequences that was described above: the initial state of the apparatus could trigger a simulation of the first move, which might then trigger the simulation of the next moves in turn. Such a simulation would be successful when there are no intermediate moves required, because each new state of the apparatus straightforwardly enables the next appropriate move, given that the problem can be solved by a series of immediate hits. However, simple simulations of this sort would be less effective when there are alternative ways in which a sub-goal might be achieved, and when how it is achieved critically affects whether or not the problem can be subsequently solved. Under these circumstances, it may be necessary to consider steps of the problem as steps for which there is more than one action alternative, and hence select appropriately between these alternatives. The general point here is it may be possible to interpret Kaller et al.'s findings within the sort of developmental framework we have been outlining in this section.

**Route-planning tasks**

Route-planning tasks have been commonly used to study planning in both preschoolers and older children. In such tasks, children are asked to plan the most efficient route through a model grocery store, for example (e.g., Gauvain & Rogoff, 1989; Parent, Gosselin, & Moss, 2000), or through a maze (e.g., Gardner & Rogoff, 1990). In Gauvain and Rogoff's (1989) original route-planning task, children are presented with a model grocery store with a checkout counter and aisles of shelving. The size of the model allows children to view the layout of the store. A variety of pictures of grocery store items are placed on the store shelves, with items in a given category (e.g., fruits, meats, etc.) shelved.

![Fig. 1.](image-url)
together. Children are then presented with a “shopper” (a small plastic figurine), whom they must move through the store to gather items. Children are then given a list of items to retrieve and are asked to do so using the shortest route possible. Constraints are that the child cannot make the shopper “fly” through the store, and must plan the most efficient route possible.

Simplified versions of route-planning tasks have also been developed specifically for use with preschoolers, such as the Kitten Delivery task in which children have to plan an efficient route to collect and deliver toy kittens to their mother (e.g., Carlson et al., 2004; Fabricius, 1988; Wellman, Fabricius, & Sophian, 1985). A related task does not require children to plan a route, but to consider their route in advance so that they load up a delivery truck in the most efficient way: The Truck Loading task (adapted from Fagot & Gauvain, 1997) requires that children use a toy mail truck to deliver differently colored party invitations to their correspondingly colored houses, placed along a one-way street (i.e., children can only drive the truck in one direction along the street). It is a reverse sequencing task in which children must place the last invitation that they need to deliver into the truck first, and the first invitation that they need to deliver into the truck last. The task begins with two houses to which invitations need to be delivered, with one new house being added for each successive trial.

McColgan and McCormack (2008) have also developed a task that involves children considering the route that a character will take. In this task, children are told that a doll is going to visit a series of locations in turn, arranged in a semi-circle. At the mid-point of the semi-circle there is a toy kangaroo that the doll wants to photograph. Children have to judge where they should leave the doll’s camera so that she could pick it up and use it to take a photograph of the kangaroo. The correct answer is to choose a location to be visited before but not after the doll had visited the kangaroo. This is a single-trial task in which children get one opportunity to make a judgment, and McColgan and McCormack found that 5-year-olds but not 4-year-olds were able to judge correctly where the camera should be placed (see also McCormack & Hanley, in press).

Do these types of tasks involve reasoning in advance about which actions should occupy which locations in an event-independent representation of a sequence? In most versions of errand tasks, participants will only be able to plan the shortest route if they consider the before-and-after relationships between the collections of each type of object, and in doing so mentally arrange the order in which each collection is made. In that sense, participants do seem to need to be able to think of the action sequence they are to carry out in terms of different time steps in a sequence. Simply running off a simulation which begins with a particular action (in the way described in the previous sub-section) is unlikely to be successful, at least in the more complex versions of the task, because generating the next state does not necessarily trigger the next appropriate action – the relationships between the actions in this task are not the sort of enabling relations that might allow this to be the case. The Truck Loading task requires participants to carry out a sequence of actions that essentially involves reversing the sequence of location visitations to be subsequently carried out. This would seem to require participants to be able to think of the visiting of each location as steps or points in a temporal sequence and then mentally reverse these steps to guide the truck-loading. Finally, although McColgan and McCormack’s (2008) task does not require mental reversal of a sequence, children need to be able to consider the visiting of the locations in terms of their order relative to visiting the kangaroo, and select an appropriate point in the sequence. What these tasks all seem to have in common is that children be able to think of time steps or points in a temporal sequence in terms of before-and-after relationships, so that they can mentally arrange the order of events relative to other events. We note, though, that we are not aware of any studies that have examined the relationship between children’s comprehension or use of the linguistic terms “before” and “after” and their planning abilities (though see McCormack & Hanley, in press, for initial evidence of a link between comprehension of these terms and performance on a set of temporal tasks that include a planning task). This may be a fruitful direction in which to explore the role of temporal understanding and emerging planning abilities.

Interestingly, all three of these tasks also have a spatial component that maps onto the temporal component of the tasks. In route-planning tasks, such as Kitten Delivery, the optimal solution can be described not just in temporal terms as the quickest route but the spatially shortest route, and in the Truck Loading task, the temporal order in which the houses are to be visited maps onto their spatial location on the route. One interesting possibility is that the availability of spatial components makes it easier for young children to represent and reason about the temporal order of the
to-be-planned actions. This is not the case for all planning tasks: although the Tower of London task involves making spatial transformations (moving balls or discs), there is no spatial ordering that relates to the temporal order in which actions need to be carried out. The issue regarding the role of spatial representation in supporting emerging temporal representation and reasoning is a long-standing one in the developmental literature (Friedman & Brudos, 1988; see McColgan & McCormack, 2008), and another interesting direction for future research on planning may be to explore the extent to which early planning is supported by the availability of spatial information that maps onto temporal information.

Real-world planning tasks

Another type of planning task that has been used with preschool children is the type of “real-world” planning task used by Hudson and her colleagues (e.g., Hudson & Fivush, 1991; Hudson, Shapiro, & Sosa, 1995; see Hudson, Sosa, and Shapiro (1997), for review) to examine the extent to which children’s plans emerge from their script/general event knowledge. Their logic is that studying planning in these familiar contexts is important because it is where we might first see its emergence. For example, in Hudson et al.’s study (1995), 3- to 5-year-old children were simply asked to provide plans (as well as scripts) for going to the beach and going grocery-shopping (e.g., “can you tell me a plan for going to the beach/grocery-shopping?”). The number of planning “actions” that the children provided were then coded and analyzed. This type of task differs from those previously described in that it draws heavily on children’s long-term semantic memory rather than short-term memory. Because these tasks aim to examine the role of scripts in emerging planning, they involve contexts in which children will have pre-existing representations stored in long-term memory of “what usually happens”. Moreover, these representations will be already temporally ordered, reflecting the order in which the actions/events are usually carried out or encountered. Thus, it seems likely that children initially carry out such tasks simply by retrieving a temporally ordered representation from memory rather than considering how best to order a sequence of actions. Hudson et al. (1997; see also Hudson & Fivush, 1991) describe this as Level 0 planning, in which children are “simply ‘running off’ an event schema stored in memory” (p. 100).

Level 0 planning would not seem to involve event-independent thought about temporal sequences, although it would involve retrieving temporally ordered representations. Thus, we might expect young preschoolers to be successful on planning tasks at this level. Hudson et al. (1997) distinguish between further levels of planning in terms of whether they involve being able to consider alternatives for empty slots in a script (e.g., whether to order cola or orange juice in a restaurant; Level 1), whether they involve achieving more than one goal simultaneously (e.g., planning to buy foods both for a birthday party and also for breakfast when shopping; Level 2), and whether they require decomposing event sequences into different components related to different sub-goals and freely re-arranging them to form new action sequences (Levels 3 and 4).

One way of thinking about the increasing demands of these types of planning is in terms of the extent to which they involve a shift from event-dependent temporal representation to event-independent temporal representation. At Levels 3 and 4, which do not seem to be reached before 5 years, children are able to think of activities as arranged in a temporal framework that is hierarchically organized, and mentally re-arrange sub-sequences of events to different locations in the overall sequence as appropriate. Thus, children’s representations of temporal order are genuinely ‘freed up’ from the particular events that might occupy points in the sequence. The very beginnings of this freeing up can be seen in Level 1 planning, which 3-year-olds seem to be capable of under some circumstances, in which children are thought to represent an event in the sequence as a slot that could be filled in different ways. However, although at Level 1, for some scripts children may be operating with something like a placeholder that they can fill in specific ways as appropriate, they cannot yet think of this sequence of events as involving time steps that could be filled in multiple ways that would allow, for example, re-arranging events’ location in the sequence.

To summarize, a variety of tasks have been developed for use with preschoolers, in addition to versions of more traditional planning tasks such as the Tower of London/Hanoi. The most commonly used tasks appear to share a basic requirement that children be able to represent short temporal sequences in a flexible, event-independent way. In tasks that draw on script-like knowledge, developmental improvements can be seen as reflecting an increasing ability of children to operate with event-independent temporal
representations. We have argued that the qualitative shift in performance in the Tower of London task reported by Kaller et al. (2008) may also be interpreted in this way.

Section 2: Executive functions and planning

The relationship between EF and planning

In this section we explore whether increases in cognitive flexibility as captured by executive functioning can account for increases in children's planning. Before exploring this potential relation, however, it is important to distinguish between three developmental claims one could make about EF and planning. The first is that planning develops as part of a general, unfractionated, EF ability. Support for this claim comes from two recent Confirmatory Factor Analyses that have suggested that children's WM, inhibition, and performance on the ToL task may load on a single executive function factor (Hughes, Ensor, Wilson, & Graham, 2010; Wiebe et al., 2008). Although Wiebe et al. used an unusual measure of ToL performance (number of illegal moves), Hughes et al. used a more conventional measure of successful performance and broadly replicated their findings. If, as these analyses suggest, planning develops as part of a general unfractionated EF ability, then it would not make sense to try to explain its development in terms of EF sub-components. The second claim is that planning itself develops as a relatively separate sub-component of EF (see e.g., Levin & Hanten, 2005; Levin et al., 1991; Welsh, Pennington, & Grossier, 1991; see also Levin et al., 1996). Again, if this claim is correct then it suggests that we could not account for the development of planning in terms of developmental improvements in other sub-components of EF. The third claim is that children's performance on planning tasks improves due to developmental changes in sub-components of EF. This claim is compatible with recent conceptualizations that characterize EF in terms of a set of distinct, though interrelated, basic sub-components: working memory, inhibition, and task switching (see Best & Miller, 2010; Garon et al., 2008; Miyake et al., 2000; though see Wiebe et al., 2008). If the development of planning is underpinned by changes in these types of cognitive flexibility, then the task of developmental psychologists is to determine which sub-components contribute, and in what ways.

We argued in Section 1 that even some of the motor planning tasks used with relatively young children might involve some type of inhibitory control, insofar as they may involve setting aside a prepotent response. Furthermore, some of the tasks described in Section 1 may also require what is generally termed working memory (i.e., the ability to temporarily store and manipulate information simultaneously). This form of memory (which would potentially be required for manipulating or mentally reversing a sequence, as in the Truck Loading task) should be distinguished from short-term memory (which simply entails recalling a sequence in correct order, see Alloway, Gathercole, & Pickering, 2006). Although errand running or route-planning tasks do not necessarily require sequence reversal, they may task working memory insofar as they involve keeping in mind the ordered sequence of location visits one has planned while planning the next visits. However, we are only aware of two developmental studies that report a relationship between performance on these sort of tasks and the sub-components of EF – inhibitory control (Carlson et al., 2004) and task switching/WM (Mackinlay, Kliegel, & Mantyla, 2009) – and neither found this relationship to be significant. We do not know of any developmental studies that have examined the link between any of the proposed EF sub-components and what we have termed real-world planning tasks and thus we focus primarily in this section on whether children's performance on the Tower of London/Hanoi task (referred to as Tower tasks here) is related to components of executive control.

Working memory

Previous research has clearly established that developmental differences interact with the complexity of ToH problems, with the size of age effects typically increasing as the number of steps required for solution increases (Borys, Spitz, & Dorans, 1982; Klahr & Robinson, 1981; Luciana & Nelson, 1998; Spitz, Webster, & Borys, 1982; Welsh, 1991). Age effects have traditionally been accounted for by changes in the use of strategies that differ, at least in part, in terms of how many moves ahead in the problem children are able to think (so-called ‘search depth’; Borys et al., 1982; Klahr &
Robinson, 1981; though see Fireman, 1996). It might be tempting to conclude from this analysis of the nature of age effects that as children’s WM capacity increases, they become able to anticipate the future consequences of a longer series of imagined actions and thus become increasingly accurate on more complex problems. Indeed, research with older adults suggests that, at the other end of the lifespan, age differences on tasks such as the ToL are due to the WM demands of the task (Phillips & Forshaw, 1998; Phillips, Gilhooly, Logie, Della Sala, & Wynn, 2003; Phillips, MacLeod, & Kliegel, 2005). However, one of the most striking findings across recent developmental studies of the ToL is the lack of a strong or consistent relationship between children’s performance on WM tasks and performance on Tower tasks (Asato et al., 2006; Bull et al., 2004; Huizinga, Dolan, & van der Molen, 2006; Kaller et al., 2008; Lehto, Juujarvi, Kooistra, & Pulkkinen, 2003). In this respect, the findings with children mirror those with adults from Miyake et al.’s (2000) influential factor analysis of executive processes, which also reported that ToL performance loaded on a factor they labelled inhibition rather than on a memory factor (though see Robbins et al., 1998). The notable exception here is Senn, Espy, and Kaufmann’s study (2004) that used path analysis to demonstrate that WM performance predicted ToH performance (see also Sonuga-Barke, Dalen, Daley, & Remington, 2002). We note that their WM task – delayed alternation – involved children having to alternate their responses flexibly between trials, and it is not clear whether or not WM is the primary determinant of performance on their task (Espy, Kaufmann, McDiarmid, & Glisky, 1999; Levin et al., 1991).

This raises the issue of exactly what type of WM task one might predict to be related to Tower task performance (Bull et al., 2004). It has been argued that performance on such tasks should be specifically related to visuospatial WM rather than, for example, verbal short-term memory span, given that the task involves mentally anticipating the consequences of a number of object displacements in space while figuring out how to act (Gilhooly, 2005; Gilhooly, Wynn, Phillips, Logie, & Sala, 2002; Welsh, Satterlee-Cartmell, & Stine, 1999). Have developmental studies used WM tasks that are appropriate insofar as they (i) are specifically visuospatial and (ii) involve manipulating information during the retention period? While the tasks used in some studies do not appear to meet one or both of these criteria (e.g., Asato et al., 2006; Bull et al., 2004; Kaller et al., 2008), those studies using task batteries included at least one that required participants to process information while holding visuospatial information in mind (Huizinga et al., 2006; Lehto et al., 2003). We would tentatively conclude that, based on current findings, it has yet to be established that WM is the primary limitation on children’s performance on Tower tasks and thus that this specific component of cognitive flexibility underlies children’s improvements in planning.

Inhibition

Goel and Grafman (1995) have convincingly argued that a major limitation in performance on the ToH, at least in their adult brain-damaged patients, is not poor WM but the inability to deal with what they term counter-intuitive backward moves (see also Morris et al., 2005; Morris, Miotto, Feigenbaum, Bullock, & Polkey, 1997). Such moves are counterintuitive in that they require initially moving a ball away from its target position in order to facilitate an intermediate move necessary for a sub-goal. They argue that their patients do not have difficulty in planning per se but in inhibiting a tempting prepotent response. Baughman and Cooper (2007) have also formally modeled developmental changes on the ToL task by assuming that, with development, an inhibitory process prevents the automatic perceptual strategy of picking up one of the balls and, instead, triggers an inspection of the position of the other balls in the current state. Their model accurately predicts high levels of rule breaks and incomplete solutions in 3- and 4-year-olds due to the inefficient operation of supervisory processes.

Researchers have had some success finding a relationship between children’s performance on tasks measuring inhibition and Tower tasks (Asato et al., 2006; Bull et al., 2004; Hughes, 1998; Hughes et al., 2010; Kaller et al., 2008; Lehto et al., 2003; Senn et al., 2004). The findings resemble those of Miyake et al. (2000) with adults, who found that ToL performance also loaded on an inhibition factor. Moreover, analyses of how initial thinking time changes with age might suggest that as children get older they are less likely to impulsively try to solve the problem without pre-planning their actions. For example, Asato et al.’s (2006) study demonstrated that thinking time increased with age from 8 years to adulthood and was associated with better ToL performance (see also Huizinga et al., 2006;
Steinberg et al., 2008). Levin et al. (1996) also report that children’s initial planning time on the ToL was related to their performance on an inhibitory control task.

Some developmental evidence for Goel and Grafman’s (1995) specific hypothesis that the difficulty lies in making counter-intuitive backward moves comes from Bull et al.’s (2004) study with preschoolers. A regression analysis showed that performance on an inhibition task accounted for ToL scores only for those problems that involved more than one of such moves. However, before concluding that inhibition and the development of inhibitory processes may play a role in individual and age group differences on Tower tasks, a number of contradictory findings need to be considered. First, some studies have found no relationship between children’s performance on Tower tasks and inhibition when general ability level was controlled for (Bishop, Aamodt-Leeper, Creswell, McGurk, & Skuse, 2001; Carlson et al., 2004; Huizinga et al., 2006; Klenberg, Korkman, & Lahti-Nuuttila, 2001; Pellicano, 2007; Sonuga-Barke et al., 2002). Moreover, some researchers who have found a relationship caution against assuming that inhibition is consistently the most important factor. Although Bull et al. found a relationship between inhibition and performance on more complex ToL tasks, no such relationship was found for ToH tasks (see also Humes, Welsh, Retzlaff, & Cookson, 1997; Welsh et al., 1999). Bull et al. argue that this differential relationship may have been due to the fact that in their ToL task there was a time limit for completion of each problem, and children were explicitly told the number of moves needed for each trial, whereas this was not the case for their ToH task. Bull et al. suggest that in the ToL task children may have been more likely to monitor the number of moves they were making and inhibit unnecessary moves appropriately, thus increasing the likelihood of finding a relationship between performance and inhibitory control. Taken as a whole, the findings suggest that the type of cognitive flexibility measured by inhibitory control tasks is likely to contribute to children’s performance on these planning tasks. However, this contribution seems to depend on features of the task such as its complexity and how it is implemented.

Task-switching

Task-switching is typically measured in young children using a child-friendly version of the Wisconsin Card Sorting Test, variations of which are sometimes referred to as the Dimensional Change Card Sort Task (DCCS, Zelazo, 2006). Typically, children have to sort cards on the basis of one dimension such as color, and then shift to sorting on the basis of a different dimension, such as shape. A link between performance on this type of task and planning is explicitly predicted by one influential theoretical account of EF development. According to Cognitive Complexity and Control Theory (CCCT), there are domain-general changes in children’s reasoning abilities in the preschool period (Frye, 2000). For present purposes, the most important claim is that around 4 years children become capable of reasoning using embedded conditional rules – i.e., if–if–then rules, which allow children to select the simpler if–then rule that is appropriate to the scenario about which they are making judgments, leading to important changes in behavioral control. This account predicts shifts in performance in the preschool years on planning tasks, such as Tower tasks, in which performance would be expected to be guided by embedded conditional rules (see Carlson et al. (2004) for discussion). Because of its domain-general nature, this account also predicts relationships between different tasks that are thought to involve embedded conditionals, such as the DCCS task.

However, there appears to be no reliable relationship between performance on this sort of task, and performance on the ToL, controlling for age and ability (Hughes, 1998; Hughes & Ensor, 2007; Pellicano, Maybery, & Durkin, 2005; Pellicano, 2007; Welsh et al., 1991; though see Brookshire, Levin, Song, & Zhang, 2004; Pellicano, 2010a). The findings of Bull et al.’s study (2004) with a preschool population are consistent with this, in that they found no relationship between their measure of task switching (which they label shifting) and overall ToL performance. However, they did find a relationship between task switching and performance on more complex ToL and ToH trials that involved at least two counter-intuitive backward moves. These more complex problems could involve up to seven moves in total. In the studies of Hughes and of Pellicano in which no relationship was found between task switching and planning (controlling for ability level), problem solution never required more than four moves. Thus, it may be that task switching only becomes critical in more complex Tower problems in which participants have to simultaneously manage (and thus switch between) a number of sub-goals.
Studies of EF in atypical populations of children provide another context in which to examine the relationship between EF and planning. In examining this literature, we can ask two questions. First, is it the case that planning impairments are found in populations associated with executive dysfunction? Second, what is the relationship between planning impairments and deficits in the components of EF that we have been discussing?

Are planning impairments found in populations associated with EF impairments?

Impairments in planning do not seem to be an inevitable consequence of childhood neurological disease or brain injury (Jacobs & Anderson, 2002; Schmitt & Wodrich, 2004), with only around half of Bonnier, Marique, Van Hout, and Potelle’s (2007) sample of children who had early severe brain injury showing impairments on the ToL. However, Jacobs and Anderson (2002) found that atypical patterns of performance on the ToL are most marked in those whose damage is specific to the frontal lobes (though see Anderson et al., 2010). This finding is consistent with other neuropsychological research on planning in adults and children (see Levin and Hanten (2005) and Morris et al. (2005), for review). Planning impairments have also been studied extensively in children with autism and children with ADHD, the developmental disorders most commonly associated with EF dysfunction.

Although studies have yielded mixed findings regarding planning impairments in autism, there are more studies that have found these impairments than those that have not (see Hill, 2004). Impairments have even been reported in close relatives of children with autism who do not themselves have a diagnosis of autism (Delorme et al., 2007; Hughes, Leboyer, & Bouvard, 1997; Hughes, Plumer, & Leboyer, 1999; Ozonoff, Rogers, Farnham, & Pennington, 1995). While a number of more recent studies have indeed replicated previous findings of an impairment in an autism group on at least some measures derived from planning tasks (see Barnard, Muldoon, Hasan, O’Brien, & Stewart, 2008; Geurts et al., 2004; Mackinlay et al., 2006; Pellicano, 2007, 2010a; Pellicano, Maybery, Durkin, & Maley, 2006; Verté, Geurts, Roeyers, Oosterlaan, & Sergeant, 2005; Zinke et al., 2010), others with both children and adults with autism have been less successful in identifying an autism-specific impairment, at least when verbal abilities or IQ are controlled for (Corbett, Constantine, Hendren, Rocke, & Ozonoff, 2009; Goldberg et al., 2005; Happé, Booth, Charlton, & Hughes, 2006; Lopez, Lincoln, Ozonoff, & Lai, 2005).

It may be that the disparity in findings is due to particular characteristics of the autism samples used in the studies, such as age or ability level. Indeed, Goldberg et al. (2005) and Ozonoff et al. (2004) suggest that whether or not planning deficits are found may depend on the age group tested, and that deficits may be notable only in later childhood or adolescence. However, this suggestion is not supported by the findings of Happé et al.’s study, in which deficits were found neither in an older nor a younger group with autism. Indeed, in a recent longitudinal study, Pellicano (2010a) found that although children with autism showed a planning impairment at both 5 and 8 years, the children with autism improved their performance more over this 3-year period than typically-developing children. Thus, contrary to previous claims (Ozonoff & McEvoy, 1994), Pellicano argues that EF problems such as planning become less marked with age in autism. Goldberg et al.’s (2005), Happé et al.’s (2006), and Corbett et al.’s (2009) studies that failed to find an impairment in children with autism tested high-functioning children with IQs well within the normal range, adding substance to Hill’s (2004) concern that, despite the fact that studies typically used a control group matched for ability level, learning disability per se may have contributed to group differences in planning in some previous studies (see also Happé et al., 2006, but see Pellicano, 2010a).

Willcutt, Doyle, Nigg, Faraone, and Pennington (2005) provide a meta-analytic review of 27 studies on planning in ADHD. Fifty-nine percent of these studies showed a deficit in planning in an ADHD group (as compared to a typical control group), and the meta-analysis showed a moderate effect size of group on performance on planning tasks. Studies that have been carried out since Willcutt et al.’s (2005) review also show this inconsistent pattern, with some showing impairments in either children or adults with ADHD across a variety of different tasks (Harrier & DeOrnellas, 2005; Kofman, Larson, & Mostofsky, 2008; Kopecky, Chang, Klorman, Thatcher, & Borgstedt, 2005; Marzocchi et al., 2008; Papadopoulos, Panayiotou, Spanoudis, & Natsopoulos, 2005; Young, Morris, Toone, & Tyson, 2007).
but others again failing to find group differences on versions of the ToL, at least when controlling for ability level (Corbett et al., 2009; Geurts et al., 2004; Goldberg et al., 2005; Happé et al., 2006; Mahone et al., 2002; Nyman et al., 2010; Riccio, Wolfe, Romine, Davis, & Sullivan, 2004; Solanto et al., 2007). As in studies of children with autism, it is difficult to know to what extent planning impairments that have been reported in ADHD might be linked to more general developmental delay.

Having said that, evidence from other atypical populations strongly suggests that learning disability or developmental delay are not inevitably associated with planning problems. In some populations (e.g., children with deafness, Figueras, Edwards, & Langdon, 2008; Tourette's syndrome, Verté et al., 2005; or Klinefelter's syndrome, Temple & Sanfilippo, 2003) planning abilities have not been found to be significantly impaired, and this has been sometimes found to be the case even when other types of cognitive impairments have been clearly demonstrated. Thus, impairments in planning do not inevitably accompany developmental delay or other cognitive difficulties.

What is the relationship between planning impairments and EF sub-components?

It is clear from looking across the studies just mentioned that although planning impairments have frequently been reported in populations that are known to have EF problems, there are numerous studies in which intact planning is reported in the presence of marked impairments in EF sub-components such as WM or inhibition (see Corbett et al., 2009, for a recent example). One could potentially argue that such dissociations reflect the fact that the tasks used in these studies vary in terms of their sensitivity and thus their ability to detect group differences. Another way of approaching the issue might be to examine whether, as in typically-developing children, there are relationships between performance on planning tasks and performance on other EF tasks. Unfortunately, although many of the relevant studies also measured WM, task switching, and inhibition, relationships between these measures and performance on Tower tasks are typically not reported. When such relationships are reported, findings regarding relationships with inhibition are mixed (Joseph & Tager-Flusberg, 2004; Pellicano, 2007, 2010a, 2010b). As with typically-developing children, there is relatively little evidence to support the idea that planning problems in these populations may be due to WM difficulties (though see Nyman et al., 2010). Some indirect evidence comes from Kopecky et al.'s (2005) Tower task study, which examined the effect of search depth on performance of children with ADHD. Search depth was defined as the number of moves a participant must mentally search ahead in order to carry out the sub-goal of moving the largest disc to its end position. Their prediction that children with ADHD would be particularly impaired on problems with a longer search depth was not supported, and they interpret this finding as suggesting that spatial WM problems do not underlie the group differences that they found (see also Marzocchi et al., 2008). However, a recent study of children with ASD suggested that when planning deficits are found in autism on the ToL, they may be a direct result of reduced efficiency in spatial WM. Zinke et al. (2010) distinguished between sub-groups of children with autism in terms of their spatial WM abilities, and found that only the sub-group with poorer spatial WM differed significantly from the control group in planning performance. However, these sub-groups were very small (seven children), and even the children in the sub-group with better WM performed more poorly on the ToL task than controls, if not significantly so.

EF and the development of planning: conclusions

One might argue that the most straightforward interpretation of the mixed patterns of intact and impaired abilities in atypical populations is that planning is itself a sub-component of EF that is at least partially separable from other components of EF. Such an interpretation would allow for planning to remain intact in the presence of other EF deficits, and for variability within a given population if it is accepted that (e.g.,) children with autism themselves vary in terms of severity and profile of EF problems (Hill, 2004; Pellicano, 2010a). It would also mean that it would not make sense to attempt to explain developmental changes in planning in terms of changes in the EF sub-components we have discussed, because it would suggest that planning develops relatively independently of these other components. However, it is not necessarily advisable to base claims about cognitive architecture in typically-developing children based on studying patterns of dissociations in atypical populations (Bishop, 1997; Karmiloff-Smith, 2009). If we look at typically-developing children, there seems to
be at least some evidence for selective relationships between performance on planning tasks and sub-components of EF, in particular inhibitory control, suggesting that it is useful to consider the role of the development of these aspects of cognitive flexibility in the development of planning.

This role, however, needs to be further explored. First, there is good evidence to suggest that the relationship between EF sub-components and performance on Tower tasks may vary substantially both with age and task complexity (Asato et al., 2006; Bull et al., 2004; Huizinga et al., 2006; Senn et al., 2004). Most strikingly, Senn et al. (2004) found that inhibition was the best predictor of performance in children younger than 4, whereas WM was the best predictor in older children (although, as we have said above, other aspects of cognitive flexibility may have determined performance on their WM task). Second, finding such relationships within a particular age group or sample does not immediately license the assumption that developmental changes on such tasks can be explained in terms of such basic processes. Trying to explain developmental change on the basis of existing findings is difficult, because almost all of the studies have been cross-sectional in design, and primarily have examined whether correlations exist within a given age group between performance on Tower tasks and tasks measuring WM, inhibition, and task switching.

Hughes’ work is the exception here, with her longitudinal studies having specifically looked at the predictive relationship between performance on WM and inhibitory control tasks at one age and ToL performance at a later age (Hughes, 1998; Hughes et al., 2010). Hughes (1998) found that ToL scores at 4–5 years were predicted by performance on both WM and inhibition tasks at age 3, with the predictive relationship with measures of inhibition being particularly strong (Hughes, 1998); similarly Hughes et al. (2010) report that performance on both these types of measures at age 4 is correlated with ToL performance at age 6. However, task-switching at age 3 was not predictive of later ToL scores when age and verbal ability were controlled for (Hughes, 1998). We note, though, that Hughes et al. found that not only do inhibitory control and WM at age 4 predict ToL performance at age 6, but that the relationship holds in the opposite direction as well: ToL performance at age 4 predicts inhibitory control and WM at age 6. Indeed, in line with this pattern of findings, Hughes’ (Hughes et al., 2010) position is not that planning improves developmentally as a result of improvements in inhibitory control and WM, but that the three abilities show significant common growth due to the development of a single EF factor. Additional studies using longitudinal designs looking at predictive relationships, or cross-sectional studies that include more careful statistical analyses of whether or not age effects or population differences can be accounted for in terms of differences in inhibition, for example, are necessary to resolve this issue.

Given the mixed pattern of findings from the large number of studies discussed in this section, it is difficult to draw firm conclusions. However, it would appear that, on balance, there is some evidence that aspects of cognitive flexibility (i.e., the EF sub-components we have focused on) may contribute to the development of planning, at least as measured by Tower tasks. Evidence is stronger for inhibitory control playing such a role than the other two sub-components. However, findings such as those of Senn et al. (2004) raise the possibility that different aspects of cognitive flexibility may be important for the development of planning at different developmental stages, and it would be useful for future research to specifically address this issue.

The use of tower tasks in developmental studies of planning: a note of caution

As this review has made clear, Tower tasks have been used extensively to examine planning development. However, in some studies, it is clear that, due to their novelty and complexity, Tower tasks themselves have also been conceived of as being “general purpose” measures of EF rather than of planning per se (e.g., Anderson, Anderson, & Lajoie, 1996; Senn et al., 2004). We have already suggested in Section 1 that such tasks might not be ideal measures of planning abilities in very young children. In fact, the use of Tower tasks as core measures of planning abilities has been considered controversial in the adult literature for some time (see Goel & Grafman, 1995; Lowe & Rabbitt, 1998; Miyake et al., 2000). Miyake et al. argue that even adult participants may spend relatively little time actually planning moves in advance of action, and instead use an online perceptual strategy of trying to progressively alter the state of the apparatus to be more perceptually similar to the goal state (see also Shallice’s, 1982, original paper). Despite their extensive use in the literature, we have found it difficult
to locate studies that have examined the predictive or ecological validity of Tower tasks in typically-developing children. The most extensive attempt to validate Tower tasks has taken place within the context of establishing the ToL as a sub-test of the NEPSY (see Korkman et al., 1998), primarily through examining correlations between performance on the task and established measures of cognitive ability (see also Anderson et al., 1996), and by demonstrating impairment in certain atypical populations. However, the ToL is one of a number of sub-tasks to be dropped from the revised version of the NEPSY (NEPSY II, Korkman, Kirk, & Kemp, 2007), due to what the authors describe as limited clinical sensitivity (see also Schmitt & Wodrich, 2004).

Other studies have found that ToL performance is not a good predictor of other cognitive abilities (Ward, Shum, McKinlay, Baker-Tweney, & Wallace, 2005), school achievement (Cohen, Bronson, & Casey, 1995), symptomatology or parental behavioral report measures in developmental disorders (Anderson, Anderson, Northam, Jacobs, & Mikiewicz, 2002; Lopez et al., 2005; Mahone et al., 2002; Pellicano et al., 2006; Sonuga-Barke et al., 2002; though see Campbell & Von Stauffenberg, 2009; Espy, Sheffield, Wiebe, Clark, & Moehr, 2011; Goulden & Silver, 2009; Joseph & Tager-Flusberg, 2004), or performance on other types of planning tasks (Carlson et al., 2004; Atance & Jackson, 2009). If Tower tasks are to maintain their privileged position within the developmental research literature as the planning measure of first choice, then it seems vital that more research is conducted on this issue. In particular, it would seem to be important to assess whether they are valid measures of planning for all age groups, particularly given the difficulties that preschool children appear to have with these tasks.

Last, recent studies have made it clear that it is necessary to report more extensive data from Tower tasks than simply an overall measure of task success (Anderson et al., 1996; Baker, Segalowitz, & Ferlisi, 2001). Indeed, Jacobs and Anderson (2002) argue that different measures taken from the ToL may tap different cognitive components of task performance. For example, they view time-to-first move as a measure of amount of time spent planning, the number of rule breaks as indicative of self-regulation, and perseverative errors as reflecting difficulties in switching. In recent detailed analyses of the ToL, Berg and colleagues have also argued convincingly that ToL performance in adults is multifaceted, that using the task effectively involves taking multiple measures of ToL performance and varying problem characteristics (Berg & Byrd, 2002; Berg, Byrd, McNamara, & Case, 2010), and that this is also likely to be true for developmental approaches. However, almost all of the studies with typically-developing children that have used factor analysis to explore the relationship between ToL performance and EF sub-components or the structure of EF have included just a single outcome measure from the ToL task (Brookshire et al., 2004; Hughes et al., 2010; Klenberg et al., 2001; Lehto et al., 2003; Senn et al., 2004; Sonuga-Barke et al., 2002; Welsh et al., 1991; Wiebe et al., 2008; though see Huizinga et al., 2006).

An notable exception to this is the study by Levin et al. (1996), which included measures of planning times, rule breaks, percentage of problems solved on the first trial, and percentage of problems solved within three trials. They found that these measures loaded differentially on different factors in their analysis, with planning time loading on a factor they labelled inhibitory control (with short planning times related to poor inhibitory control), and rule breaks and percentage of problems solved in three trials loading on a factor they identify as a distinct planning factor. Interestingly, the percentage of problems solved on the first trial loaded on a separate factor again, and they speculate that this factor may reflect the ability to hold a mental representation of the task (possibly a WM factor), although it is not clear why this factor should be particularly important with regard to solving the problem in a single trial as opposed to over three trials. The findings of their factor analysis raise the possibility that even measures from the task that seem quite similar (solving the problem over one versus three trials) may be an index of quite different cognitive abilities.

The importance of using multiple measures can be seen in some studies with atypical populations of children. A good example of this comes from Jacobs and Anderson’s (2002) study of ToL performance in children with brain injury. Children with damage to the frontal lobes obtained the same overall scores on the task as control groups and indeed took the same amount of initial planning time; atypical performance was only evident by examining more detailed aspects of performance. The particularly high rate of perseverative errors and rule breaks in the frontal group indicated that this group, despite good overall task performance, had notable problems with adjusting and regulating.
their behavior appropriately. A contrasting pattern of findings with children with ADHD suggests that, where they exist, planning impairments in this group may be a result of more impulsive behavior, with less time dedicated to initial planning (although this group is also likely to show more rule breaks on planning tasks as well; Kopecky et al., 2005; Marzocchi et al., 2008). Marzocchi et al. (2008) found that children with ADHD typically showed shorter initial planning times than controls, and their planning times did not increase appropriately with problem difficulty (see also Papadopoulos et al., 2005; Verté et al., 2005; Young et al., 2007). These effects on planning time suggest that group differences with respect to ADHD may be due to an impulsive approach to the task (Young et al., 2007) and also fit well with theories that describe some cognitive problems in ADHD as a result of delay aversion (see Sonuga-Barke, Sergeant, Nigg, & Willcutt, 2008).

Section 3: Self-projection, future thinking, and planning

We now turn to considering a different type of cognitive flexibility – self projection – described by Buckner and Carroll (2007) as “the ability to shift perspective from the immediate present to alternative perspectives” (p. 49). In this section, we discuss two types of self projection: self projection in the form of mentalizing, and self projection to the future. So far, the planning tasks that we have considered involve making plans to meet immediate goals (e.g., matching a structure, completing a “grocery list”). This can be contrasted with research on what has been termed future thinking, which is typically measured using tasks that require considering how to meet one’s future rather than present goals. We have discussed Buckner and Carroll’s (2007) notion of prospection, or self-projection into the future in our introductory section, but their account is just one of several to focus on future thinking. Other theorists have used the terms episodic future thinking (Atance & O’Neill, 2001, 2005), mental time travel to the future (Suddendorf & Busby, 2005; Suddendorf & Corballis, 2007), or constructive simulation of the future (Schacter & Addis, 2007) to capture a distinctive type of future thinking. These approaches have in common with Buckner and Carroll’s the idea that there is a type of self-projection into the future that has a close relationship to thinking about the past (in the form of autobiographical memory), and that this type of thinking about the future is distinctive in that it involves a type of detachment or disengagement from the current state of the world. It is because of this that this type of future thinking can be considered to involve a specific type of cognitive flexibility that is quite different from the notion of flexibility used in discussion of EF.

Anticipating future states of the self: disengaging from present concerns

One of the distinctive features of these theories of future thinking is that they place an emphasis on the ability to anticipate future states of the self that differ from current ones. Thus, the type of planning that is targeted in this context is very different from that measured in most standard planning tasks. The type of planning tasks we have reviewed so far have examined children’s ability to plan and then immediately carry out a series of actions in order to achieve a currently-active goal, that is, a goal that is generated in response to a problem that is manifest here and now. Insofar as such tasks involve anticipating the future at all, it is anticipating how the future consequences of actions will meet one’s current needs. Suddendorf and Corballis (2007) argue that the hallmark of what they term mental time travel to the future is behavior that (i) is aimed at solving a problem that is not currently manifest and (ii) is guided by anticipating a future rather than a present need (see also Suddendorf & Busby, 2005; Tulving, 2005).

Studies with children have started to examine when they become capable of the sort of planning that may be underpinned by mental time travel. Following up work by Atance and O’Neill (2005), in Atance and Meltzoff’s (2005) study, 3–5-year-old children were shown photographs and asked to imagine being in a location in which their hypothetical future state would not match their current physiological state (e.g., being in a cold snowy place) and to select an object they might want to take with them (e.g., a warm coat). In this study, the majority of children as young as 3 years were likely to plan to take an object that would meet a future need. However, when the competing item choices were semantically related to the future situation, this age group frequently chose the semantic
associate that would not actually be useful for their hypothetical future state (e.g., some 3-year-olds chose to take ice-cubes to the snowy place). The authors suggest that below 5 years, children's ability to consider future needs is fragile. In Atance and Meltzoff's (2006) study, 3–5-year-olds' physiological state was experimentally manipulated so that they felt thirsty at the time of testing, and children were then asked whether they would prefer pretzels or water at a future point in time (tomorrow). Despite pretzels being children's preferred option at baseline (as assessed in a separate group), the majority of children judged that they would want a drink of water tomorrow. This suggests that even 5-year-olds find it difficult to disengage from their current state and imagine a future need.

It is important to point out a key feature of these experiments, which is that the choices that children made in the present had no actual impact for future events. In the Atance and Meltzoff (2005) study, the ‘future’ events were entirely hypothetical (and thus, arguably, not located in the future at all), and in their (2006) study, children were told merely to pretend that they would be coming back tomorrow. In this sense, these studies differ from related studies that have attempted to demonstrate future thinking in animals (Mulcahy & Call, 2006; Osvath & Osvath, 2008; Raby, Alexis, Dickinson, & Clayton, 2007; for review see Raby and Clayton (2009)), in which the animals' behavioral choices had a genuine impact on the future. It may be that children are more likely to reason carefully and choose an appropriate object for a future state if that choice were really to make a difference. As far as we are aware, only two studies have used a scenario in which young children's object choices in the present could have a genuine impact on a future state.

In Suddendorf and Busby's (2005) “two-rooms” task, children visited one room that was empty, save for a puzzle board. After a brief stay in this room, children visited another room that had various objects, including puzzle pieces, in it. Children were then told that they would be returning to the original room. When given a choice of objects to take back to the room with them, only 4- and 5-year-olds, but not 3-year-olds, were likely to select the puzzle pieces. The authors argue that choosing the puzzle pieces requires children to anticipate that these will be needed in the future, even if they are not needed right now. One possible criticism of this study is that children may have succeeded by making a semantic association between “puzzle pieces” and “puzzle board.” An interesting manipulation would have been to include distractors that were semantically associated with the future location or the puzzle board, rather than necessary for the task, given that Atance and Meltzoff's (2005) results suggest that inclusion of such distracters may influence children's performance. However, Suddendorf, Nielsen, and von Gehlen (2011) recently reported similar findings across a broader range of scenarios to which this semantic association argument does not as readily apply. Moreover, they showed that when children were presented with the choices immediately after they had encountered the problem (i.e., with no delay), even the 3-year-olds selected the correct solutions to two novel problems (to access desirable items and feed a character). This latter finding is important, because it rules out an explanation of younger children's task failure in delay conditions in terms of any kind of problem-solving difficulty, and suggests that their difficulties lay with anticipating their future need.

In a more recent study by Russell et al. (2010), children played a game of blow football on a special table. On the child's side, it was possible to reach the top of the table to play the game without the need for a step, whereas it was demonstrated to them that, on the experimenter's side, the step was necessary in order to be able to play the game. After playing the game on the side for which the step was not necessary, 3–5-year-olds were told that they were going to return the next day, and they had to choose two objects necessary to play the game from the other side. The correct choices were the step and a straw needed to blow the football; incorrect choices were semantically related attractive distracters (e.g., a stuffed animal wearing a football shirt) that were not actually necessary for the game. Only 5-year-olds chose the correct two items significantly more often than chance. A critical feature of this study is that, because they were going to play the game from the other side of the table next time (the side needing the step), what children would need in the future was different from what they had needed in the recent past, with the authors arguing that children had to imagine not only a future perspective of the self, but a perspective that differed spatially from the one that they had previously occupied.

Taken together, the results of these experiments support the general view that there are improvements between 3 and 5 years in children's ability to act in the present in such a way as to anticipate
their future needs. In addition, these improvements have been reported irrespective of the different ways that researchers have asked children about the future, including a “hypothetical” future, “tomorrow,” or a more “immediate” timeframe (e.g., 10 min). Nevertheless, it would be important to explore this issue more systematically by, for example, using the same paradigm, while varying the temporal distance of the future location that children are required to consider. We now turn to briefly discussing the relationships between future thinking, planning, and the form of self-projection known as mentalizing.

**Future thinking, planning, and self-consciousness**

We note that theorists in this area tend to assume that there is a qualitative shift in ability at this age range that reflects the emergence of a distinctive, entirely new, cognitive system. For example, it has been suggested that the ability to set aside one’s current goals and context and flexibly consider a future point in time is a type of decentering that may require a new type of self-consciousness (e.g., Suddendorf & Corballis, 2007; see also Atance & O’Neill, 2005). Specifically, some theorists have linked this type of flexibility of thought with the development of theory of mind (ToM) abilities (Buckner & Carroll, 2007; Suddendorf & Corballis, 2007). For example, Suddendorf and Corballis (2007) argue that a representational theory of mind is a precondition for mental time travel because “this level of folk psychology [is required to] be able to identify with one’s future self, understand that this future self may have mental states that differ from one’s current state, and care about them’ (p. 308). However, convincing evidence for a link between ToM abilities and episodic past or future thinking is sparse. Although it is often claimed that ToM is a prerequisite for self-projection to the past, in the form of autobiographical/episodic memory (Perner & Ruffman, 1995; Naito, 2003), the best currently available evidence from longitudinal research suggests that this relationship does not hold (Reese & Cleveland, 2006). As far as we are aware no developmental studies have as yet examined whether there is an empirical link between children’s future thinking and ToM. However, some empirical research has examined whether there is a link between ToM and the flexibility of thought required in more traditional planning tasks, and we now briefly summarize these findings.

Perner and Lang (2000) have made a specific claim about the role of ToM abilities in facilitating the development of planning, although the sort of planning tasks were not episodic future thinking tasks but the more traditional planning tasks discussed in the last section. Their claim centers on the idea that ToM facilitates EF development and thus performance on planning tasks that recruit EF. Perner’s original suggestion was that executive control typically requires inhibiting a conflicting, and often maladaptive, action schema, and doing this efficiently involves the child realizing that mental states are causally efficacious and, crucially, that in some cases they can lead to actions that are undesirable and thus must be suppressed. He argues that only when children are alert to the causal effects of mental states, through understanding the properties of the representations underpinning their own and others’ actions, are they able to flexibly control their actions that result from such states and make accurate predictions about those of others. Interpreted in this way, his theory explicitly claims that ToM is important for planning insofar as it involves reflectively pre-selecting appropriate action schemas by inhibiting prepotent but undesirable ones (Perner & Lang, 2000; though see Perner, Lang, & Kloo, 2002). As we have discussed in Section 2, such an ability might be thought to be important in planning tasks such as Tower tasks that seem to place demands on inhibitory control.

Hughes (1998) has found that at ages 4–5, performance on a ToL task was significantly correlated with an aggregate ToM score even when age and verbal ability were partialled out. Such a relationship has since been replicated in separate samples of typically-developing children of similar ages by Pellicano (2007), Hughes and Ensor (2007),1 and Pellicano et al. (2005).2 Thus, based on this set of findings,

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1 The relationship between ToM and ToL performance is not reported in Hughes and Ensor’s paper, but a re-analysis of these data found a significant correlation between performance on these tasks ($r = .21, p < .01$) when controlling for verbal ability and performance on the Day–Night task (Hughes, personal communication, 2009).

2 Re-analysis of the Pellicano et al. (2005) data (Pellicano, personal communication, 2009) found a significant correlation ($r = .36, p < .05$) between these tasks in 4-year-olds even when controlling for both verbal and non-verbal ability. This correlation was not however significant in 5-year-olds, perhaps because this older group performed at a much higher level on the ToM tasks.
there appears to be good reasons to believe that a robust relationship exists between ToM and planning (at least as measured by ToL). However, Hughes has re-analyzed the data from Hughes and Ensor’s paper, showing that the relationship between ToM and ToL at aged four remains significant even when levels of inhibitory control are partialled out (based on scores from the Day–Night task; Hughes, personal communication, 2009), suggesting that there is a robust relationship between planning and ToM that is not mediated by inhibitory control. This analysis casts doubt on Perner’s original construal of the relationship between planning and ToM, as we have interpreted it.

Moreover, although the findings we have mentioned suggest a relationship between ToM and planning, there are two reasons to remain cautious about the conclusions one draws from them. First, although the issue is controversial, the general conclusion of recent longitudinal studies (Hughes & Ensor, 2007; Pellicano, 2010b) seems to be that performance on tasks associated with EF is predictive of later ToM performance rather than vice versa. Thus, the concurrent correlational findings we have mentioned may not reflect a contribution of ToM to planning abilities. Second, Hughes’ (1998) findings were not replicated in the most systematic study of the relationship between planning and ToM, that of Carlson et al. (2004). Carlson et al.’s (2004) study used three separate planning tasks (ToH, Truck Loading, and Kitten Delivery), and found that once verbal ability was controlled for there was no relationship between any of the planning tasks and ToM. However, participants were around a year younger than those in Hughes’ (1998) study, and performance levels on all three planning tasks were notably low in 3-year-olds. These low levels of performance may have masked a relationship between planning and ToM.

To summarize, theoretical approaches to both future thinking and to the sort of planning discussed in previous sections, along with initial experimental findings, justify additional research focusing specifically on the relationship between ToM and these abilities. More generally, developmental research provides an important context in which claims about the relationship between different types of self-projection, made in the context of the adult neuropsychological literature, could be examined. The ability to examine such relationships will hinge on establishing an agreed-upon paradigm or set of paradigms to measure children’s self-projection to the future, and recent empirical advances on this issue that we have discussed are very promising.

Conclusions and future directions

We have reviewed research on planning in typical and atypical populations in the light of the general idea that the development of planning can be conceived of in terms of the development of three types of cognitive flexibility: event-independent representations of time, executive functions, and self-projection. This has provided a framework in which some of the various strands of research on the development of planning can be summarized. In Section 1, we argued that it is possible to conceive of the development of planning in the early years as a shift towards the use of event-independent representations of temporal sequences that allow children to make decisions about which acts to carry out and in which order to successfully anticipate future states of the world. In Section 2, evidence from both typical and atypical populations suggested that it makes sense to consider the pattern of relationships between the development of planning and separate components of executive control, rather than considering EF as a unitary function. In doing so, the data suggest that inhibitory control is the EF component that may play the most important role in the development of planning. However, even this finding must be interpreted cautiously due to the fact that most studies showing this link have focused on planning as measured by the Tower of Hanoi/London. The extent to which inhibitory control, for example, is related to performance on other measures of planning is an important issue for future research. Thus, whereas it is possible to conceive of developments in various types of planning tasks (e.g., Tower of Hanoi/London, route-planning) as involving the cognitive flexibility provided by the emergence of event-independent representations of time, it is as yet unclear exactly how we should conceive of the relationship between cognitive flexibility associated with EF and the various types of planning tasks that we have outlined in this paper.

In Section 3, we considered two types of self-projection: future thinking and Theory of Mind. Research using quite different types of planning tasks was reviewed: future thinking tasks that involve anticipating a future rather than current goal. Studies with children are beginning to tackle the signif-
icant empirical challenge of examining whether young children are capable of the type of future thinking highlighted in recent theorizing, and we anticipate that this issue will generate a considerable amount of new research. Furthermore, there is theoretical justification, and at least some empirical evidence, that points to the importance of additional research examining the relationship between self projection in the form of Theory of Mind and planning or future thinking. We have reviewed the role of the three types of cognitive flexibility in separate sections, and we want to finish with a consideration of how these different constructs may be related, because this may suggest important directions for future research.

**EF and event-independent temporal cognition**

In Section 2, we distinguished between considering planning as recruiting sub-components of EF, and considering planning itself to be a distinct EF sub-component. It is possible that both of these suggestions are correct: that on complex planning tasks such as Tower tasks, not only are the EF sub-components we have discussed important, such as inhibition, but performance also depends on a potentially separate component of EF that itself makes a distinctive contribution to performance on planning tasks. Indeed, this latter suggestion is in line with the findings of the original factor analyses carried out on children’s performance on EF tasks (Levin et al., 1991; Welsh et al., 1991). How should we best characterize such an ability? In Section 1, we described planning tasks as involving event-independent temporal cognition, and, in line with other analyses of the development of temporal cognition (Nelson, 1996; Weist, 1989), conceived of this as a new representational ability that is likely to emerge over the preschool period. Once this basic ability is intact, however, performing well on planning tasks beyond the preschool period may depend on the ability to construct and skillfully manipulate such temporal representations. We note that the three basic sub-components of EF (WM, task switching, and inhibition) that are standardly identified in recent conceptualizations by developmentalists of the structure of EF (Best & Miller, 2010; Garon et al., 2008) do not readily map onto this ability. It is true that WM tasks typically involve remembering temporal-sequential information. However, most standard WM tasks do not actually involve manipulating such sequences; either the tasks simply involve retrieving and recalling a sequence (e.g., as in the Corsi blocks task) or doing so while simultaneously processing other, non-temporal, information (e.g., simultaneously judging the verticality of sentences in a verbal serial recall task). Backward serial recall, in which participants recall a sequence in reverse order, is potentially the exception here, because participants have to flexibly manipulate specifically temporal information.

Thus, one theoretical issue that we think deserves consideration by developmentalists is whether the type of processing of temporal-sequential information we have in mind here should be itself considered to be an important component of EF. Historically, accounts of the function of the frontal lobes have consistently emphasized the importance these brain regions in flexibly generating temporally structured sequences of behavior and various accounts of EF have at their heart the idea that the role of such functions is in producing appropriately temporally sequenced actions (e.g., Damasio, 1985; Fuster, 1980, 2001; Jouandet & Gazzaniga, 1979; Shallice, 1988). However, tasks standardly used to measure the EF sub-components of inhibition or task switching in children (e.g., the Day/Night task, or the DCCS) do not involve measuring sequences of behavior (scores are calculated based on discrete responses given over multiple trials). Neuropsychological research with patients with frontal lobe lesions has examined whether such patients have general problems dealing with and manipulating temporal sequence information by, for example, asking patients to correctly re-order a variety of different types of sequences (see Zanini, 2008; Zanini, Rumiati, & Shallice, 2002). These considerations suggest that it might be useful for developmental psychologists to examine whether the ability to construct sequences and, critically, manipulate specifically temporal information is related to children’s planning abilities. More generally, it might be useful to think about how to locate this type of temporal ability in accounts of the development of EF.

**Self-projection and EF**

How might EF and self projection to the future be related? As touched upon in Section 3, psychologists have already tried to link EF with self-projection in the form of mentalizing, as measured by
ToM tasks; there is a very extensive literature discussing the relationship between these cognitive abilities, both in children and in adults (e.g., Carlson & Moses, 2001; Hughes, 1998; Moses, 2001; Perner & Lang, 2000; Rakoczy, 2010). More pertinently, some research, particularly with clinical populations, has also attempted to link EF and self-projection to the past or future (Dalgleish et al., 2007; de Oliveira, Cuervo-Lombard, Salame, & Danion, 2009; Raes, Verstraeten, Bijeibeier, Vasey, & Dalgleish, 2010; Stuss & Levine, 2002). Empirical studies have yet to establish whether EF may play a role in determining children’s levels of performance on future thinking tasks (as opposed to more traditional planning tasks reviewed in Section 2), and, given the requirement of such tasks to disengage from the current state of the world, such a role seems very plausible. Moreover, it seems likely that developmental studies could be particularly useful in examining the nature of the relationship between EF and self-projection to the future, both because of the possibility of finding sufficient variability in both these abilities in young children and because of the possibility of identifying the causal direction of this link. However, by definition, self-projection to the future requires not just disengaging from the current state of the world, but imagining and reasoning about a future state of the self, in which one’s environment and goals may be quite different. This can be contrasted with many EF tasks, which typically involve participants remaining focused on completing immediate goals – for example, Stroop-like tasks measuring inhibitory control that involve participants ignoring task-irrelevant stimulus features that may distract from the task at hand. It is notable that current discussions of the nature of inhibition within the developmental literature suggest that the ability to delay a response may be a distinct type of inhibitory control (e.g., Carlson & Meltzoff, 2008; Carlson & Moses, 2001); it may be that future thinking is likely to be related to this type of inhibition.

While there may be an interesting developmental story to be told about the relationship between EF and self projection to the future, it is important to emphasize that any complete account of the emergence of future thinking needs also to consider the conceptual resources required for future thinking that themselves require a developmental explanation. There is a clear parallel here with the debate regarding the relationship between self-projection in the form of mentalizing (ToM) and EF, thus it is worth briefly considering the issues arising from that debate. Although researchers may argue that EF is critical in determining children’s performance levels on standard ToM tasks (e.g., Carlson & Moses, 2001; Ensor & Hughes, 2008; Russell, 1996), it is also accepted that passing such tasks involves possessing and using the appropriate mental state concepts, and that an account of some sort (even if it is nativist) needs to be provided of how children come to be in possession of such concepts. Indeed, research on the relationship between EF and ToM suggests that any developmental account of the relationship between EF and possessing and using mental state concepts might need to be richer than the simple hypothesis that EF is necessary for performing well on ToM tasks (for a good example of a richer account, see Russell, 1996). For example, Sabbagh, Xu, Carlson, Moses, and Lee (2006) have argued that the role of EF may be complex, in that EF may facilitate children’s ability to use the sort of social experiences that are important in the acquisition of mentalistic concepts. Similarly, characterizing the relationship between EF and future thinking may also require considering the particular ways in which EF contributes not just to performance on future thinking tasks but to the development of the necessary conceptual resources.

Event-independent temporal cognition, planning, and self projection

We have suggested that a discussion of the relationship between EF and self projection to the future could be informed by considering the parallel debate in the area of ToM. However, although the conceptual abilities required for self-projection in the sense of mentalizing have been extensively debated by developmental psychologists for some time (e.g., Astington, Harris, & Olson, 1988; Frye & Moore, 1991; Perner, 1991), there has been less analysis of the conceptual resources required for self-projection to the future. Indeed, as mentioned in Section 3, much of the debate surrounding such conceptual resources has been concerned with whether ToM abilities themselves are necessary for future thinking (see Suddendorf & Corballis, 2007). There is a further important issue, which is how to best characterize the type of temporal concepts required for self projection to the future. Indeed a central aim of the related animal studies has been to explore whether animals are capable of conceiving of and representing the future at all (Raby & Clayton, 2009; Roberts & Feeney, 2009). What is meant to be
distinctive about future thinking tasks is that the future context and future goals are not the same as those in the present, and, arguably, planning for the future in these tasks requires appreciating just such a fact. This would suggest that these tasks require having a conception of time and sufficiently extended temporal horizon such that events can be considered as belonging to either past, present, and future.

It is beyond the scope of the current review to discuss in detail what is involved in representing time in this way (see McCormack & Hoen, 1999, 2001, 2005, in press, for extensive discussion), but it is clear that there is a basic contrast to be drawn between being able to represent time steps in a particular serial order, as required in traditional planning tasks such as the Tower of London task, and being able to represent time itself as a framework in which there are categories of events belonging to the past, present, and future (see McCormack & Hoen, 1999). Nevertheless, we would argue that traditional planning tasks and future thinking tasks have in common the demand to be able to think of either time steps in a sequence or temporal locations in the future independently of the events or actions at a given temporal location – i.e., what we have described as event-independent temporal thought. In future thinking tasks, such as that of Russell et al. (2010), children need to be able to consider a temporal location in the future at which events have not yet been determined, and reason about how they can best influence the future outcome. What such tasks should require if they are to be genuine tests of future thinking, which is not required in traditional planning tasks, is that children need to be able to think of such temporal locations as being at specific points in the future (McCormack & Hoen, in press). This requires being able to conceive of time as a linear dimension that stretches into the past and future, with each point on this dimension represented as an unrepeatable location that is uniquely specified on this dimension. Being able to think of temporal locations in this way is part of what is captured by the term “episodic” when applied to thinking about both the past and the future, i.e., that one can think of the events in question as episodes, as having occurred or that will occur at unique points in time. As yet, we know relatively little about exactly when and how such a conception of time develops (though see Friedman (2003), for a review of research on children’s temporal cognition).

The origins of cognitive flexibility

Although we have argued that the development of planning can be considered in terms of the development of three sorts of cognitive flexibility, we have not discussed what sorts of experiences, if any, underpin the development of these sorts of flexibility or that may explain individual differences in such abilities. This is an important direction for future research. Gauvain’s research, which we have not covered in this review, has suggested that the development of planning abilities may be facilitated through shared planning activities with adults (e.g., Gauvain, 1999; Gauvain & Huard, 1999; Gauvain & Rogoff, 1989). An interesting way of connecting that work with the research that we have addressed is to consider how social experiences may be important in the development of the three types of cognitive flexibility that we have focused on. With regard to EF, although it has been recently claimed that individual differences are primarily genetically determined (Friedman et al., 2008), there is an emerging body of findings that seems to indicate that EF components such as inhibitory control may be influenced by children’s social and cultural experiences (e.g., Hewage, Bohlin, Wijewardena, & Lindmark, 2011; Oh & Lewis, 2008; Sabbagh et al., 2006; see special issue of New Directions in Child and Adolescent Development, 2009). Insofar as such components contribute to the development of planning abilities, this suggests that it may be useful to consider the impact of such experiences on planning development (though see NICHD Early Child Care Research Network, 2005). Turning to self-projection to the future, it is by now well-established that the development of self-projection in the form of ToM is influenced by children’s social and cultural experiences (e.g., Cutting & Dunn, 1999; Hughes & Leekam, 2004; Liu, Wellman, Tardiff, & Sabbagh, 2008) in particular by early differences in maternal talk about the mind (Ensor & Hughes, 2008; de Rosnay & Hughes, 2006; Laranjo, Bernier, Meins, & Carlson, 2010; Ruffman, Slade, Devitt, & Crowe, 2006; Taumoepeau & Ruffman, 2008) and it is likely that the same is true of the developmental emergence of self-projection to the future (Benson, 1997; Hudson, 2002; Hudson, 2006). We know relatively little about how temporal cognition may be affected by social experiences, although Nelson (1996) has argued convincingly that it is only through
discussion of non-actual events with adults and acquisition of temporal language that children begin to grasp important temporal concepts, and indeed become capable of what we have described as event-independent temporal cognition. Taken together, these considerations point to the importance of examining in more detail exactly how social experiences affect the development of planning through their impact on cognitive flexibility.

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References


