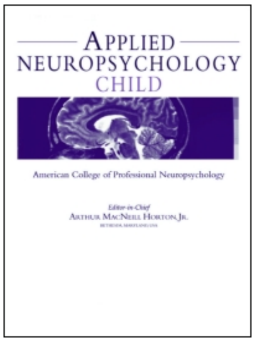

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ABSTRACT

A minimal amount of research has examined the cognitive predictors of children's performance in naturalistic, errand-type planning tasks such as the Zoo Map task of the Behavioral Assessment of the Dysexecutive Syndrome for Children (BADS-C). Thus, the current study examined prospection (i.e., the ability to remember to carry out a future intention), executive functioning, and intelligence markers as predictors of performance in this widely used naturalistic planning task in 56 children aged 7- to 12-years-old. Measures of planning, prospection, inhibition, crystallized intelligence, and fluid intelligence were collected in an individual differences study. Regression analyses showed that prospection (rather than traditional measures of intelligence or inhibition) predicted planning, suggesting that naturalistic planning tasks such as the Zoo Map task may rely on future-oriented cognitive processes rather than executive problem solving or general knowledge.

KEYWORDS

Children; planning; prospection; zoo map task

The ability to plan ahead is an important skill that is required for independent living. Planning involves making strategic decisions, executing the actions associated with these plans, and monitoring the goals (Craik & Bialystok, 2006; Gauvain & Rogoff, 1989). For example, when completing a project one must evaluate relative progress while still keeping the final goal in mind in order to assess which tasks have been accomplished and what is still yet to be done. Thus, planning has been defined as the predetermination of a course of action to achieve a goal (Hayes-Roth & Hayes-Roth, 1979). Conceptually, planning is related to a wide variety of cognitive constructs such as executive functions (EF; e.g., Welsh, Pennington, & Groisser, 1991). For instance, Zelazo, Carter, Reznick, and Frye (1997) consider planning one of four sub-phases of their problem-solving framework of EF. An essential component of planning is representing (sub-) goals, which requires thinking about the future. For that reason, planning has also been linked to episodic future thinking more recently (e.g., Atance, 2008; Atance & Jackson, 2009; Atance & O'Neill, 2001), Similarly, prospection, which refers to the ability to "pre-experience" what might happen in the future by simulating it in our minds (Gilbert & Wilson, 2007), is ascribed importance in everyday planning, indicating that planning may be a function of prospection (Buckner & Carroll, 2007; for a recent review see McCormack & Atance, 2011).

Despite decades of research on planning in adults (Hayes-Roth & Hayes-Roth, 1979; McCaskey, 1974; Sacerdoti, 1975), a minimal amount is known regarding children's planning. Several studies indicate that rudimentary planning skills exist by the age of three or four years in tasks that involve solving mazes or planning and executing trips to the store (e.g., Gardner & Rogoff, 1990; Hudson & Fivush, 1991; Miyata, Itakura, & Fujita, 2009). Clear age effects emerge between 4- and 5-year old children on these planning tasks. In comparison with younger children, 5-year olds seem to perform fairly well, showing the ability to reason about causal relations between temporally ordered future events (McColgan & McCormack, 2008). Similar age effects were observed by Hudson and Fivush, showing that five-year-olds plans are more complex and that they plan with increasing flexibility. Even beyond the fifth year of life, planning skills continue to improve; 9-year old children typically make better anticipatory plans when compared to 5-year olds (Gauvain & Rogoff, 1989). By the age of 12, children are able to plan effectively (as measured by the percentage of trials completed in the maximum number of moves allowed on a Tower of London task) and by the age of 15, children

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show the most efficient planning (assessed by the percentage of the minimum number of moves to find the solution; De Luca et al., 2003).

From a neuropsychological perspective, planning is examined using several different types of tasks. Some researchers use everyday-planning or naturalistic tasks that involve planning a grocery shopping trip (Gauvain & Rogoff, 1989; Hudson & Fivush, 1991). Others uses planning tasks that require problem-solving such as planning in order to find the way out of a maze (Gardner & Rogoff, 1990; Miyata et al., 2009) or the Tower of London paradigm (Luciana & Nelson, 1998) that involves moving a number of disks while following specific rules in order to accomplish a specific configuration of the disks.

A naturalistic planning task that has received increased attention is the Zoo Map task from the Behavioural Assessment of the Dysexecutive Syndrome for Children (BADS-C; Emslie, Wilson, Burden, Nimmo-Smith, & Wilson, 2003). This task has been used widely in neuropsychology with typically-developing school-aged children (e.g., Engel-Yeger, Josman, & Rosenblum, 2009), as well as clinical populations such as children with autism spectrum disorder or attention deficit hyperactivity disorder (e.g., de Almeida, Macedo, Lopes, & Monteiro, 2014; Salcedo-Marin, Moreno-Granados, Ruiz-Veguilla, & Ferrin, 2013; Siu & Zhou, 2014; White, Burgess, & Hill, 2009). This task is structured such that children are asked to plan their route while visiting several animals and locations at a zoo. Children are instructed to avoid using the same route twice and points are subtracted from their performance score for redundant or ineffective steps.

In sum, there are a wide variety of tasks that all have been used to study "planning", but they all appear to tap into slightly different aspects of this multi-faceted construct. An assumption of the present study is that individual differences in performance (as well as differences reported in relation to age or clinical populations) will vary with the cognitive requirements of those tasks. Thus, we argue it is important from a conceptual, methodological, and developmental perspective to know more about the cognitive predictors of some of those core tasks. In this context, a substantial body of research has been published on planning performance in Tower-tasks that are highly correlated with working memory, inhibition, and shifting (Bull, Espy, & Senn, 2004; Lehto, Juujarvi, Kooistra, & Pulkkinen, 2003). These Tower-tasks require children to plan required moves in advance and to keep these steps in mind, thus performance has been associated with working memory capacities (St Clair-Thompson, 2011; Welsh et al., 1991). Planning up to three moves is present by middle childhood, but due to the limitations in working memory development the ability to generate more complex plans of 4 or 5 moves seems to develop in later childhood or adolescence (Best, Miller, & Jones, 2009). Bull et al. found that shifting (as measured in a verbal naming task where the naming criterion was switched) was the best executive predictor for 3- to 6-year-old children's Tower task performance. After controlling for baseline naming speed as the prepotent response bias in that task, however, the relation between planning and shifting disappeared. Conversely, Bishop, Aamodt-Leeper, Creswell, McGurk, and Skuse (2001) found no relation between verbal intelligence (based on the vocabulary and similarities subtests of the Wechsler Intelligence Scale for Children III, WISC-III) and performance in a Tower-type task in 7- to 15-year-old children. Considered jointly, these findings indicate that EF, but not general intelligence seem to be crucial for Tower-type task performance.

In contrast to Tower-type tasks, there has been very little investigation of the underlying cognitive and executive mechanisms that might explain age differences in errand-type tasks such as the Zoo Map task. Todd, Anderson, and Lawrence (1996) investigated the relation between planning performance in a naturalistic party planning task and general intelligence measured by the WISC-III. Results showed that general intelligence was a significant predictor of error rate in planning performance in 12- to 16-year-olds. These findings are in direct contrast with Bishop et al. (2001) who found no relation between verbal ability a planning on a Tower task. It is possible that intelligence plays a more important role in naturalistic planning tasks than in the Tower-type planning tasks, perhaps because knowledge of strategies may be more important in naturalistic tasks. Yet, a minimal amount of empirical work exists that studied predictors of naturalistic planning; thus the aim of the current study was to examine individual differences in school-aged children's performance on the Zoo Map task (naturalistic planning task) and to examine what cognitive abilities predict planning performance. This is particularly important, as no study has investigated the impact of both EF *and* intelligence on naturalistic planning tasks, which are suggested to be different in nature compared to Tower-type tasks.

Beyond EF and intelligence, it is conceptually important with regard to present study that we include an additional dimension that seems to be instrumentally for real world planning but has rarely been studied as a predictor of individual differences in planning: prospection. As planning requires an orientation to future states (Haith, 1997), according to Craik and Bialystok (2006), good planning requires (among others) prospection, "including the ability to look ahead and mentally envisage the relevant situation and the ability to anticipate potential problems and think of ways to overcome them" (p. 1236). Prospection is a complex integration process that requires a combination of self-monitoring and transformational thinking (in which one operation sets the foundation for the next) and therefore might rely on working memory and updating. The process of prospection is embedded in the representational space that working memory provides and its updating functions involve the episodic buffer that Baddeley's model of working memory proposes. Prospection is a multi-faceted construct and can be based on an event (when a specific event happens) or a time (at a certain time or after some specified time period has elapsed). Thus, we included a task tapping on prospection and examined whether prospection contributes to individual differences in planning performance over and above executive control and general cognitive functioning.

In the present study, we set out to address two separate questions related to performance on the Zoo map task: First, as there is little literature on the development of naturalistic planning in children, we intended to explore the development of planning in children between 7- and 12-years using the Zoo map task. The second aim of the study was to investigate the cognitive constructs that predict performance in that naturalistic planning task, considering general cognitive abilities, EF, and prospection.

Method

Participants

Participants were 56 children (30 girls) between 7- and 12-years-old ($M = 9.57$, $SD = 1.73$) who were enrolled in a large-scale cognitive development study in schoolchildren (see Mackinlay, Kliegel, & Mäntylä, 2009). All participants were from German-speaking middle-class families and mostly Caucasian. Participants were recruited through local primary and secondary schools and all parents gave informed consent before testing. Participants were screened for major developmental disorders such as attention deficit and hyperactivity disorder, autism spectrum disorder, anxiety, and depression via parent report; no child included had any history of a developmental disorder.

Measures

Planning

To assess planning ability, the subtest 'Zoo Map 1' of the Behavioural Assessment of the Dysexecutive Syndrome for Children (BADS-C; Emslie et al., 2003) was used. A key strength of this test is its high ecologic validity (Engel-Yeger et al., 2009) and its child-friendliness (Baron, 2007). The children received a general map of a zoo with different stations (e.g., animal enclosures, cafe, toilets). They were asked to plan their route from a starting point to a specific end point, visiting eight stations along the way. In addition, children had to follow rules including: visiting only certain animals and places in the zoo, keeping to the paths, and walking along each path only once. Performance was scored based on visiting the animals in an optimal sequence (maximum 8 points assigned) and points were subtracted for breaking any of the rules. Afterwards, this final score was standardized into z-scores, resulting in scores ranging from -2.76 to 1.12 (maximum performance) in that sample.

Fluid intelligence

To assess fluid intelligence as an indicator of problem solving the subtest 'block design' from the *Hamburg-Wechsler Intelligenztest für Kinder* (HAWIK-R; Tewes, Schallberger, & Rossmann, 1999) was used. The children were presented with a model bi-colored mosaic and had to reproduce it with several bi-colored cubes. The models consisted of two, four, or nine cubes. The score was calculated by summing up all points given for correct rebuilding of the pattern according to the HAWIK-R manual.

Crystallized intelligence

The 'general knowledge' subtest of the HAWIK-R (Tewes et al., 1999) was used to measure crystallized intelligence. The children were asked different questions representing a wide range of general knowledge. The questions were read to children by the experimenter and children responded orally. Correct answers were summed up.

Executive function

An inhibition task was used as an indicator of EF. This ability was measured by the subtest 'Go/No-Go' of the *Testbatterie zur Aufmerksamkeitsprüfung* (Zimmermann & Fimm, 2002). In this task, children were presented with one of two stimuli on the computer screen: 'X' or '+'. Children were told to respond to the 'X' by pressing a button but to not respond to the '+'. Forty stimuli were presented, half of which were 'X's. The dependent variable used was the mean standard deviation of the RT according to the test manual (Zimmermann & Fimm, 2002; see Dreisörner & Georgiadis, 2011, for similar approach)[1].

[1]Note that using other outcome scores from the TAP such as the mean of the correctly inhibited responses or the median of the reaction times did not change the obtained results.

Prospection

A time-based prospective memory task was used to assess prospection. Child appropriateness of the task as well as comparability to other tasks in that field was ensured. Therefore, we followed methodological suggestions for prospective memory research with children by Kvavilashvili, Messer, and Ebdon (2001). During this task, children were asked to perform a one-back picture task continuously. Children had to decide whether each picture was the same or different as the picture directly before by pressing a key labeled with either "yes" (in case the picture was the same) or "no" (in case the picture was different). One hundred and twenty-two black-and-white drawing pictures were presented, each picture was displayed for 4 sec and 40 of these trials were one-back hits. Additionally, they had to remember to press a yellow key on the keyboard every two minutes. Children could monitor the time that passed since the task had started by pressing another key, and after 3 s it disappeared. There were five target times and all responses 2.5 s prior or after the target time were scored as correct.

Results

There was a highly significant correlation between children's age and Zoo Map task performance, $r(54) = .448$, $p < .001$, showing that older children performed better than younger children on the planning task (see Figure 1).

To investigate the influence of different factors contributing to planning performance, a regression analysis was conducted. As suggested, performance in general cognitive abilities, EF and prospection were used as predictors in a hierarchical regression analysis. No other control variables were included in the analysis. Measurements of general cognitive abilities, i.e., both fluid and crystallized intelligence as indicators of knowledge and problem solving were entered in the first step

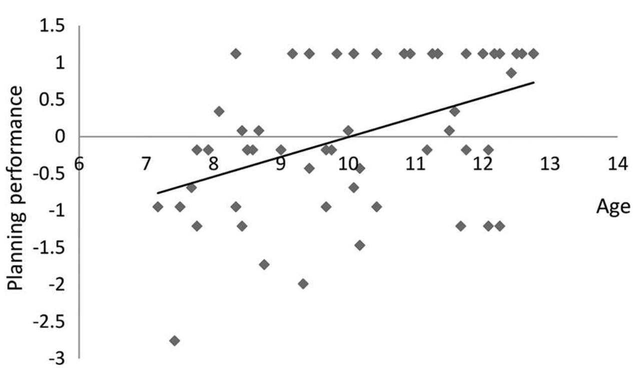

Figure 1. Planning performance (z-standardized scores ranging from −2.76 to 1.12) as a function of age.

Table 1. Hierarchical regression predicting planning performance.

Predictor	β	T	p	ΔR^2
Step 1				.131*
Crystalized intelligence	.115	.704	.485	
Fluid intelligence	.070	.478	.635	
Step 2				.003
Inhibition	.064	.484	.631	
Step 3				.079*
Prospection	.356	2.168	.035	

Note. β, t, and p values are taken from the final regression considering all predictors simultaneously.
*$p < .05$.

as previous studies suggested that general cognitive abilities influence performance in naturalistic planning tasks. Inhibition as a measure of EF was included as a predictor in the second step of the regression. The third step included prospection as a predictor that not has been investigated thus far. The increase in explained variance by consecutively entering an additional set of predictors was of special interest for the present results as it indicates factors that contributed to planning performance over and above the predictors entered in the previous steps. Table 1 shows the results of the hierarchical regression analysis. General cognitive abilities contributed significantly to planning performance in children ($R^2 = .131$, $F\ (2,\ 49) = 3.70$, $p = .032$). This was not true for inhibition ($\Delta R^2 = .003$, $F\ (1,\ 48) = 0.18$, $p = .673$), entered in the second step, as it did not increase the explained variance significantly. However, prospection as entered in the third step was a significant predictor of planning performance ($\Delta R^2 = .079$, $F\ (1,\ 47) = 4.70$, $p = .035$) suggesting that prospection as opposed to EF could account for additional variance in planning performance in the Zoo Map task beyond measures of general cognitive abilities. Additionally, when conducting the same hierarchical regression analysis with age entered in the fourth step did not further increase the amount of explained variance ($\Delta R^2 = .034$, $F\ (1,\ 46) = 2.08$, $p = .156$), suggesting that the cognitive resources entered before were able to explain the initially observed age effect.

Discussion

Children between 7 and 12 years old showed age-related improvement on the Zoo Map task of the BADS-C. In line with Craik and Bialystok (2006), we found prospection significantly predicting naturalistic planning performance over and above general cognitive abilities and EF. Together general cognitive abilities, EF, and prospection explained the initially observed age effect. These findings are consistent with the idea that children rely on future-oriented intentional abilities when engaging in the Zoo Map test. Somewhat surprisingly, inhibition as a traditional marker of EF did not predict planning performance. These data support several important developmental, conceptual, and methodological conclusions.

With regard to our first aim, age effects were clearly revealed in the Zoo Map task confirming findings of Engel-Yeger et al. (2009) using the same task as well as being similar to findings of age effects in children's performance on other naturalistic planning tasks (see Gauvain & Rogoff, 1989). While studies comparing older and young adults in naturalistic planning tasks repeatedly did not show any age effects (Kliegel, Martin, McDaniel, & Phillips, 2007; Phillips, Kliegel, & Martin, 2006), children's planning performance shows age-related improvement. This provides further evidence that children seem to develop their planning efficiency at least into adolescence.

The second aim of our study was to investigate predictors of planning performance in the Zoo map task. In line with Todd et al. (1996), general cognitive abilities contributed to planning performance. This suggests that intelligence is of importance in naturalistic planning tasks for the reason that children can profit from applying their knowledge and strategies. Interestingly, even though crystallized and fluid intelligence combined was a significant predictor of Zoo Map performance, the individual variables were not significantly related to performance on this task. It might be the case that each single factor did not predict planning performance on its own, but a combination of those variables provided more information that were relevant for planning. Alternatively, this might be a power-related phenomenon with more variance for two scores combined than for a single score. This finding requires further investigation.

Inhibition, however, did not predict naturalistic planning performance over and above general cognitive abilities. This is in contrast to past studies documenting positive relations between EF and planning on tower type tasks (e.g., Bull et al., 2004; Lehto et al., 2003). If this finding holds up to replication, it seems to suggest an important methodological conclusion. Distinct underlying cognitive factors of different task types would affirm the importance of distinguishing more problem-solving type tasks from naturalistic planning tasks. Alternatively, planning as measured in the Zoo Map taps into aspects of executive control that are not captured by standard controlled attention tasks such as the Go/No-Go task. Therefore, it might be important to analyze single subtask scores in more detail when using batteries such as the BADS-C. This might yield more insight than relying on global indicators. Perhaps planning as measured in the Zoo map task might be better predicted by other EF measures like shifting or working memory. Indeed, when analyzing the task structure, the Zoo map task requires keeping the current (sub-) goals in mind, updating working memory after each single sub-goal that is reached, and finally switching between the rules and mapping them rather than inhibiting overlearned response tendencies. In fact, other EF measures such as reasoning or multi-tasking might be stronger related to the Zoo Map planning task and have not yet been considered in past research. Thus, future studies should further examine the role of working memory updating, reasoning, and multi-tasking as EF facets possibly related to Zoo map planning.

The most interesting conclusion rests on the conceptual extension that prospection seems to be an important facet of – at least – this type of naturalistic planning measure. This is consistent with Craik and Bialystok (2006) as well as Buckner and Carroll (2007) and suggests that school-aged children rely on abilities to solve future-oriented intentional tasks during naturalistic route planning tasks, which has not been demonstrated so far. Importantly, childhood seems to be a crucial period for the development of future-oriented abilities (e.g., Mahy, Moses, & Kliegel, 2014, for conceptual framework). Findings on the development of mental time travel (Atance & Meltzoff, 2005; Busby & Suddendorf, 2005), although not the same construct as prospection (see Atance & Jackson, 2009), are in line with that interpretation. It will be an important task for future research to disentangle, both conceptually and empirically, the different layers by which planning, prospection, intentional behavior, mental time travel, or episodic future thinking are connected. It is possible that the ability to create temporal representations and to reason about a sequence independently of emerging events or ongoing activities (McCormack & Atance, 2011) could be a common link explaining the relation between prospection and planning, as it is inherent in those processes. An important next step in future research is to investigate the relationship between different executive function measures (working memory and shifting with different executive loads) and prospection (both time-based and event-based) that would help to better understand their effect on planning abilities.

Our current findings bring to light that we still do not fully understand the complex process of planning. It might be the case other factors than the ones considered in the literature so far may contribute to the process of planning. In addition to inhibition (as measured by go/no-go) planning might additionally require working memory (as assessed by for instance complex span tasks) to compare current and final goals, shifting (as measured by, for example, the Wisconsin Card Sorting Test) between current and final goals, and monitoring one's progress. Beyond that, variables as meta-cognition or time perception might be related to the process of planning and it might be worth considering them in future studies. Furthermore, some of the currently considered factors might interact and therefore have a differential effect on planning. Thus, one general limitation is the lack of knowledge of the number and nature of factors contributing to planning. Further research investigating variables contributing to planning as well as the interaction of those variables is required.

Another potential limitation of the study (and a general problem for all studies using one cognitive task as a predictor for different constructs), is the question how process-specific each of the tasks were and to what extent they were capturing a single pure process. This issue should be considered in future research by using multiple measures for each construct allowing for the modeling of the relations between planning and its cognitive predictors on a latent level.

In conclusion, planning abilities as measured in the Zoo Map task increase between 7- and 12-years-old children. The current study further suggests that individual differences of performance in this type of naturalistic planning task are best predicted by future-oriented cognitive processes rather than EF as measured by a Go/NoGo inhibition task or general cognitive functioning; thus, the Zoo Map task of the BADS-C, in addition to capturing general cognitive abilities, measures the future-oriented aspect of planning.

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