

The Development of Commitment: Attention for Intention

**Abstract**

Adhering to a partially defined plan requires an intentional commitment that curbs distracting desires conflicting with the planned course of action, enabling humans to act coherently over long horizons. Two studies ( $N = 50$ , 23 boys, ages 5-6, Chinese) explored the development of commitment to partial plans in a sequential decision-making task and the underlying cognitive capacity focusing on its correlation to capacity for attentional control. Results suggest that only 6-year-olds committed to partial plans, and children's commitment ratio was positively correlated with the use of proactive control. These findings indicate that intentional commitment does not develop simultaneously with the understanding of intention at infancy, but rather matures gradually in parallel with the development of attentional control.

*Keywords:* intention, commitment, partial plan, attentional control, proactive control

### The Development of Commitment: Attention for Intention

Picture a child building a block castle. She places a red cube on the ground as the castle's base, she then notices a gold sticker and decides she will later affix it to the castle's spire. As she continues building, she notices an alternative decoration that could be used; however, she ignores it, continuing with her current plan. In this sense, the girl determines the spire's decoration, even when many steps are missing between base and spire construction. Execution of this plan requires an intentional commitment that she will adhere to a course of action leading to the predetermined future plan, resisting distraction of conflicting designs along the way. This nature of committing to a future step, with undetermined preceding steps, is termed "partial planning" and is critical in human planning and problem solving (Bratman, 1987).

What is the developmental timeline of intentional commitment? 5-7 month old infants respond selectively to others' intentional actions in looking-time experiments (e.g., Csibra, 2008) and imitate the intentional actions of others (Gerson & Woodward, 2012; Hamlin et al., 2008). Thus, commitment, as an intrinsic property of intention, may develop together with the understanding of intention. Alternatively, commitment, which entails focusing on a planned course of action while shielding interference from alternative paths forward, may require mature executive control, which only develops at the end of early childhood (Unger et al., 2016; Troller-Renfree et al., 2020). Additionally, previous developmental studies on Theory of Mind (ToM) have explored intention, but not in the context of commitment (Poulin-Dubois & Yott, 2018; Wellman & Brandone, 2009). Furthermore, commitment itself has been studied primarily in the form of joint-commitment in collaboration (Kachel et al., 2018; Kachel & Tomasello, 2019), rather than self-commitment to individualized partial plans over time. Thus, the current research aims to explore the development of intentional commitment as well as its dependence on executive control.

**Intention: The Philosophical Perspective**

In philosophy, intention is most clearly formulated in the belief-desire-intention (BDI) model of the mind, in which “intention” is defined as the deliberating state that regulates conflicting desires to generate coherent actions with commitment (Bratman, 1987). However, in many psychological studies, the more parsimonious desire-belief model has often been accepted as the default, without explicitly representing intention (Baker et al., 2009; Jara-Ettinger et al., 2016; Liu et al., 2017). However, in philosophy, the importance of intention as a unique mental state has been demonstrated from a computational and functional perspective, where intention is critical for planning coherent actions into a distant future (Bratman, 1987; Searle & Willis, 1983). This can be understood through two assertions. First, unlike desires, which can be conflicting (e.g., one can simultaneously desire to eat a candy bar and lose weight), intentions cannot conflict with one another because they are tied to executable actions. Second, the committed nature of intention promises to bring about a singular fixed future. This stability of the future enables an agent to concatenate multiple intentions, with one intention stemming from the fixed future promised by the previously declared intention. Therefore, the agent can form a partial plan (Bratman, 1987), with a long horizon, by leaping forward from one promised future to the next, without concern for the gaps in between. This plays out in the aforementioned castle building example; while the child is still building the castle’s base, with many next steps uncertain, she has already committed to the design of the spire. Thus, intention necessitates a commitment to plans of actions under conflicting desires.

**Intention: The Developmental Perspective**

Intention has also been studied extensively in developmental psychology. Infants understand that an agent’s actions are structured by intentions even before their first birthday (e.g., Craighero et al., 2011; Myowa-Yamakoshi et al., 2012). In older children, studies

adopted verbal reports to explore semantic understanding of intention and desire. 4-year-olds develop a differentiated conception of intention that is not confused with desire (Feinfield et al., 1999). 5-year-olds can semantically understand that desire means “want to”, while intention means “plan to” (Schult, 2002).

There has also been work on behavioral measurements of goal persistence, in which infants persist in achieving their goals despite repeated failures (Leonard et al., 2017; Lucca et al., 2020). These studies demonstrated infants’ behavioral decisions when intentional behavior is disturbed. However, they do not specifically distinguish between intentions and desires, nor do they address conflicting desires and multiple goals. Thus, little is known about the computational function of intentional commitment for generating partial plans, as highlighted in the BDI model (Bratman, 1987). There are two computational studies that have emphasized the functional importance of intention for generating coherent actions in planning. One study (Jara-Ettinger et al., 2020), modeled intention as an ordered sequence of goals, determined by optimizing for expected utility. This enables an agent to reach multiple goals with coherent actions; however, it does not offer clear behavioral predictions that can distinguish intentional actions from those purely driven by expected utility defined by desires. Another study focused on revealing the behavioral signatures of intentional commitment, by comparing sequential actions between human adults and an optimal Markov Decision Process (MDP) model in a 2D navigation task (Cheng et al., 2021). The results showed that human actions qualitatively deviate from those of MDP with spontaneous commitment to intentions. One of the behavioral signatures revealed in this study is the “temporal leap” phenomenon, in which adults commit to a distant future even before finishing the current one. The “temporal leap” indicates that adult actions are indeed mediated by intentions instead of directly driven by a mixture of conflicting desires.

### **Intention and Proactive Control for Attention**

The concept of intentional commitment seems to be highly related to the cognitive capacity of proactive control. According to the Dual Mechanisms of Control theory (DMC; Braver, 2012) there are two types of attentional control: (a) reactive control, an “as-needed” control, which is typically in response to the detection of conflict, and (b) proactive control, a “planful” control, which maintains the early selected information and actively biases attention in a goal-driven manner (Troller-Renfree et al., 2020). Proactive control engages well before action and continuously regulates attention for goal attainment, while reactive control engages at the moment of taking action and works fleetingly (Braver, 2012).

As proactive control concerns “goal-relevant information” and “preventing distracting interference”, we suggest that this process is related to the intentional commitment for persistently pursuing a goal in the presence of alternative distracting goals. However, empirical research on proactive control mainly focuses on how attention is allocated to target objects (Chatham et al., 2009; Gratton et al., 2018), and not in the context of how proactive control coordinates belief, desire and intention for coherent actions. Therefore, we believe that joint research on proactive control and intentional commitment will prove valuable for exploring the cognitive capacities underlying intentional commitment. Previous developmental research has shown that children begin to transition from heavy reliance on reactive control to a more proactive strategy around 6 years old (Unger et al., 2016). If indeed this proactive control is underlying intentional commitment, we would also expect to see a rapid development of intentional commitment at this age. Thus, our study focused on 5- and 6-year-old children.

The present study explores the development of intentional commitment based on the “temporal leap” phenomena—a behavioral signature demonstrating how human adults spontaneously commit to a future goal (Cheng et al. 2021). This signature reflects the partial planning nature of human intentional actions, which lies at the core of the BDI model. In

addition to exploring the presence of this signature in children of different ages, we also wanted to explore the possible cognitive capacities it depends on. In particular, we investigated one candidate—proactive control of attention, also termed planful control (Troller-Renfree et al., 2020). Therefore, with the same group of children, we conducted a second experiment to measure their proactive control of attention. We hoped that a correlation between these two tasks would reveal a connection between the development of intentional commitment and proactive control. A pre-registration can be found here: <https://osf.io/4nzvf>. The materials and data for both studies are publicly accessible at <https://osf.io/mbnxe/files/>.

### **Experiment 1: The Development of Intentional Commitment**

In order to explore the development of intentional commitment among 5- and 6-year-old children, we adopted Cheng et al. (2021)’s paradigm for testing the “temporal leap” signature. In a Pac-Man like task, participants continuously pursued goals which constantly appeared and disappeared (Fig. 1). In this task, if children form a partial plan, they will commit to the next goal even before achieving the immediate one. This commitment will bias children against navigating along the optimal path to maximize the number of goals reached in the allotted time. This is because as children pursue an already committed goal, it may become a suboptimal pursuit due to the appearance of a new, more optimal, goal. This task will measure the automaticity and spontaneity of commitment because within the task there is no external pressure to commit. Additionally, we compared our child participant data with the results from adults performing the same task in Cheng et al. (2021).

## **Methods**

### ***Participants***

A priori power analysis was conducted using the program G\*Power 3.1.9.2 with a conservative effect size Cohen’s  $d = 0.8$  (according to Experiment 3 of Cheng et al., 2021) in

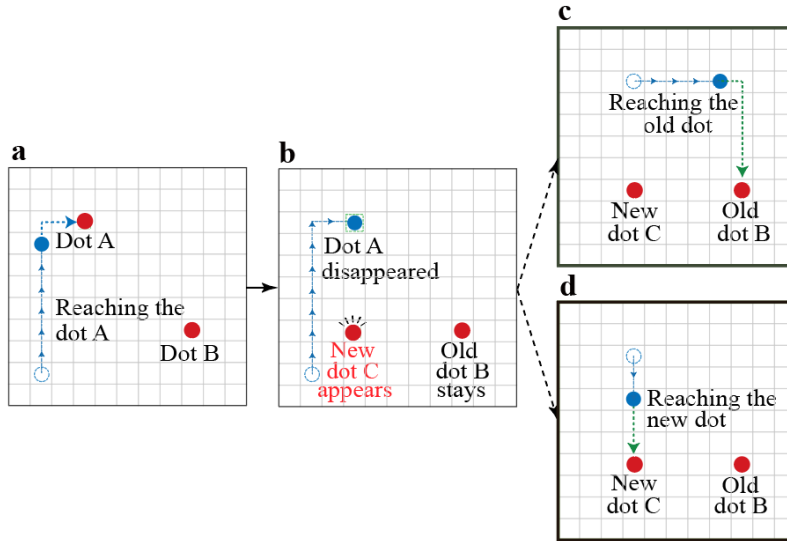
which  $\alpha = 0.05$  and  $1-\beta = 0.80$ , indicating that 21 participants of each age group were sufficient. Consequently, we recruited 25 5-year-old children (13 boys,  $M_{\text{age}} = 5.39$  years,  $SD = 0.19$ , range = 5.00–5.74), and 25 6-year-old children (10 boys,  $M_{\text{age}} = 6.41$  years,  $SD = 0.18$ , range = 6.01–6.75). Children were recruited from two kindergartens in Hangzhou—a large city located in southeast China. All participants reported normal or corrected-to-normal vision and had no history of neurological damage, psychiatric disorders, head trauma, or use of psychological medications. Informed consent was obtained from the children’s parents. This experiment and the following experiment were approved by the Institutional Review Board at the Department of Psychology and Behavioral Sciences, \*\* University.

### ***Materials and Procedure***

A child version of the continuous Pac-Man like task was presented on a light green (RGB: 205, 255, 204) background subtended a visual angle of approximately  $11.84^\circ \times 11.84^\circ$  from a distance of 60 cm, and overlaid with a  $15 \times 15$  grid (created with Pygame, version 1.9.4, shown in Fig.1). The agent was represented with a blue dot (RGB: 50, 50, 255), and the destinations were represented with red dots (RGB: 255, 50, 50). Each dot was of  $0.38^\circ$  visual angle and presented within one grid square. The stimulus was presented to all children on a 13.3-in. Dell XPS laptop with a 60-Hz refresh rate.

At the beginning of the experiment, the map was created with the agent positioned on the grid and two destinations (dots) with equal Manhattan distances from the agent. The agent could then move, grid square by grid square, to reach a destination. Once the agent reached a dot, the map would update with the disappearance of the reached dot and the appearance of a new dot in a new location—indicating the beginning of a new trial. Children were told that the dots were inexhaustible and that they should “eat” the dots as quickly as possible. Children received no feedback for their choices. Two demos are included in the Supplemental Material associated with this article.





**Fig. 1.** *Navigating to a chain of two dots.*

(a) Task begins with a blue dot that represents the agent, and two red dots that represent the possible targets. (b) Once the agent reached a dot, the dot (A) disappeared, the other dot (B) remained (now becoming the old dot), and a new dot (C) appeared in a new location. The distance difference in this map is -5 ( $5(\text{new}) - 10(\text{old})$ ). The agent (c) chose to pursue the old dot B or (d) alternatively chose to pursue the new dot C.

The position of each newly presented destination was systematically manipulated by the distance-difference from the agent to the new destination (new dot) as compared to the distance-difference to the originally placed destination (old dot). Each trial was pseudo-randomly assigned to one of seven distance-difference conditions: [-5, -3, -1, 0, 1, 3, 5] (positive values indicating the new dot is placed further from the agent than the old dot). The commitment ratio was calculated by the ratio of trials children chose to pursue the old dot. A commitment ratio higher than 50% indicates a bias towards the old dots, and a commitment ratio lower than 50% indicates a bias towards the new dots. To ensure children's abilities to estimate distances was not a confounding variable, we analyzed the commitment ratio (a) across all conditions, where the averaged distance-difference was 0, and (b) focusing on the equal-distance (0) condition, where the old dot and new dot are equidistant from the agent.

Compared to the adult version (315 trials; Cheng et al. 2021), the child version of the task here had a reduced number of trials and was presented in blocks. Our task was designed in blocks of 21 trials, with the first trial excluded from analysis, as in this first trial the two destinations were presented simultaneously at trial onset. After each block, children took a break. Children were encouraged to complete as many blocks as possible, with a maximum of nine blocks, and they were given a sticker as a reward for each block they completed. The task ended if the child lost interest and refused to proceed to the next block, or after the ninth block. On average, 5-year-olds completed 7.7 blocks (range from 4 to 9) and 6-year-olds completed 8.7 blocks (range from 6 to 9). Before the formal task, children were taught how to use the arrow keys and completed 20 practice trials to ensure they understood the task and were familiar with the keys. The duration of the entire experiment was approximately 20 minutes.

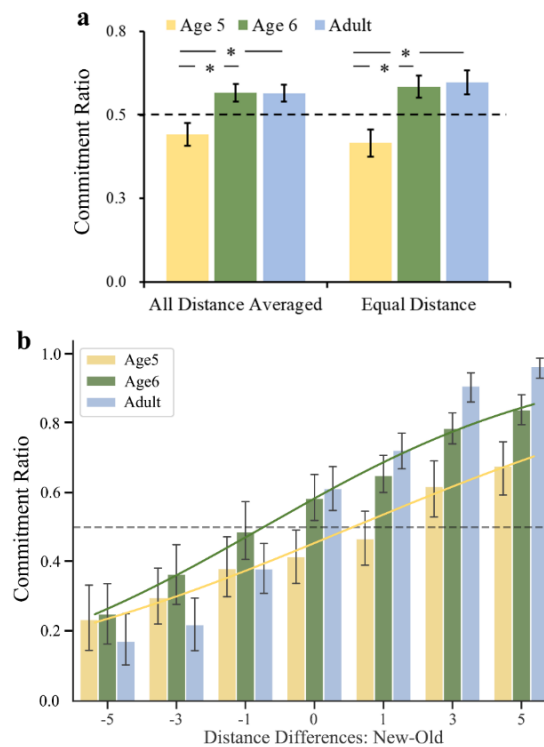
## Results

Across all conditions, the ANOVA with age group (5-year-olds, 6-year-olds and adults) as the between-subjects factor on commitment ratio revealed a significant main effect of age group ( $F(2, 67) = 6.37, p = .003, \eta^2 = 0.16$ , see Fig. 2a). Post hoc analysis (Bonferroni-corrected) showed that 6-year-olds had a commitment ratio (56.6%; 95% CI [0.51, 0.62]) that did not significantly differ from adults ( $p = .999$ ; see Experiment 3 in Cheng et al., 2021, 56.5%; 95% CI [0.51, 0.62]). The commitment ratio of 5-year-olds (44.2%; 95% CI [0.37, 0.51]) was significantly lower than that of 6-year-olds and adults ( $p = .007, p = .013$ , respectively).

Similar results were found when we focused on the equal-distance (0 difference) condition. A significant main effect of age group ( $F(2, 67) = 7.83, p = .001, \eta^2 = 0.19$ ) was found in commitment ratio. Post hoc analysis (Bonferroni-corrected) showed that 6-year-olds had a commitment ratio (58.4%; 95% CI [0.52, 0.65]) that did not significantly differ from

adults ( $p = .999$ ; 59.8%; 95% CI [0.52, 0.67]). Five-year-olds, again, showed an opposing pattern in commitment ratio (41.6%; 95% CI [0.33, 0.50]) to that of 6-year-olds and adults ( $p = .004$ ,  $p = .003$ , respectively).

Furthermore, we modeled commitment as a function of distance-differences with logistic regression (Fig. 2b). For adults (0.42; 95% CI [0.36, 0.49]) and 6-year-olds (0.34; 95% CI [0.27, 0.40]) the intercepts were significantly higher than 0 ( $ps < .001$ ), indicating biases toward old dots. For 5-year-olds, the intercept was significantly lower than 0 (-0.18; 95% CI [-0.25, -0.11],  $p < .001$ ), indicating a bias towards new dots. Note that this bias cannot be explained as any action cost associated with switching from the old goal to the new goal, as the new goal is presented *before* the execution of any action toward the old goal.



**Fig. 2.** (a) Ratio of trials in which agents reached the old dot (commitment ratio) averaged across all distance conditions and in the equal-distance condition. (b) Commitment ratio for each distance condition with fitted logistic regression. The error bars indicate the standard errors.

These results indicated that intentional commitment rapidly increases between 5 years

old and 6 years old, when commitment reaches adult levels. We speculate that this rapid increase is linked to the development of attentional control, which begins to transition from reactive to proactive during this same period. In Experiment 2, we tested this hypothesis by measuring attentional control in the same group of children, and how it correlates to their commitment ratio.

### **Experiment 2: The Relation to Attentional Control.**

Experiment 2 measured the same group of children's attentional control in a new task, different from the Pac-Man like navigation task. This allowed us to explore the correlation between intentional commitment and attentional control at the individual level. Children's attentional control was measured by a child version of AX-Continuous Performance Task (AX-CPT). Following convention, we calculated  $d'$  in terms of signal detection theory, which reflects children's sensitivity to a cue, and this varied sensitivity discriminates between the use of proactive versus reactive control. We hypothesized that children who utilize proactive control with higher frequency (high  $d'$ ), would display higher intentional commitment than children who utilize reactive control with higher frequency (low  $d'$ ).

## **Methods**

### ***Participants***

All children who participated in Experiment 1 completed the AX-CPT task within two months of completing the first experiment (except one child absent during Experiment 2) ( $N = 49$ , 23 boys,  $M_{\text{age}} = 5.91$  years,  $SD = 0.55$ , range = 5.00–6.75). Informed consent and ethics review were accounted for in the same manner as Experiment 1.

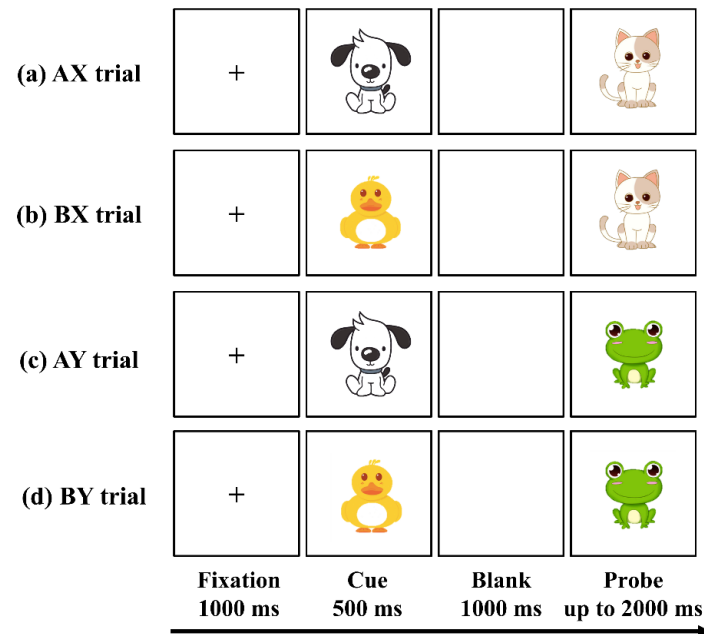
### ***Materials and Procedure***

Stimuli for the child version of the AX-CPT were cartoon figures, including pairs of cues (target cue "A" = dog or non-target cue "B" = duck) and probes (target probe "X" = cat or non-target probe "Y" = frog). Each cartoon figure subtended a visual angle of

approximately  $6.68^\circ \times 6.68^\circ$  from a viewing distance of 60 cm. The stimuli were presented to children on a white background on a 13.3-in. Dell XPS laptop with a 60-Hz refresh rate.

An illustration of a trial in AX-CPT is shown in Fig. 3. Each trial began with a fixation appearing for 1000ms, followed by a cue stimulus (A or B) appearing for 500ms. After a blank interval of 1000ms, a probe stimulus (X or Y) was presented. At probe onset, children needed to press one of two response keys within 2000ms. They were instructed to make a target response (press “1” on a button box) if probe “X” followed cue “A” (i.e., AX), and make a non-target response (press “4” on a button box) for all other cue-probe sequences (i.e., AY, BX, BY). By choosing the correct target response within the time frame children present proactive control because maintenance of the cue supports the anticipation of the correct response. No feedback was given in the formal task. Similar to prior research, AX trials were presented 55% of the time, while each other trial type (AY, BX, BY) was presented 15% of the time. Proactive control is indexed by a preparatory response pattern influenced by the cue (e.g., rule out the possibility of a target response following a non-target cue, such as high accuracy on BX trials).

Trials were presented in blocks of 40 trials each (22 AX, 6 AY, 6 BX and 6 BY). In each block, trials were presented in a random order. After each block, children took a break. Children were encouraged to complete as many blocks as possible, with a maximum of four blocks, and they were given a sticker as a reward for each block they completed. On average, participants completed 3.9 blocks (range from 3 to 4). Before the formal task, children practiced at least 12 trials to ensure they understood the task and were highly familiar with the keys to be pressed. For each practice trial, feedback was given to inform the child of whether they had responded correctly. Only once the overall accuracy during practice reached higher than 80%, did the formal experiment begin; otherwise, the child continued practicing. The duration of the entire experiment was approximately 20 minutes.



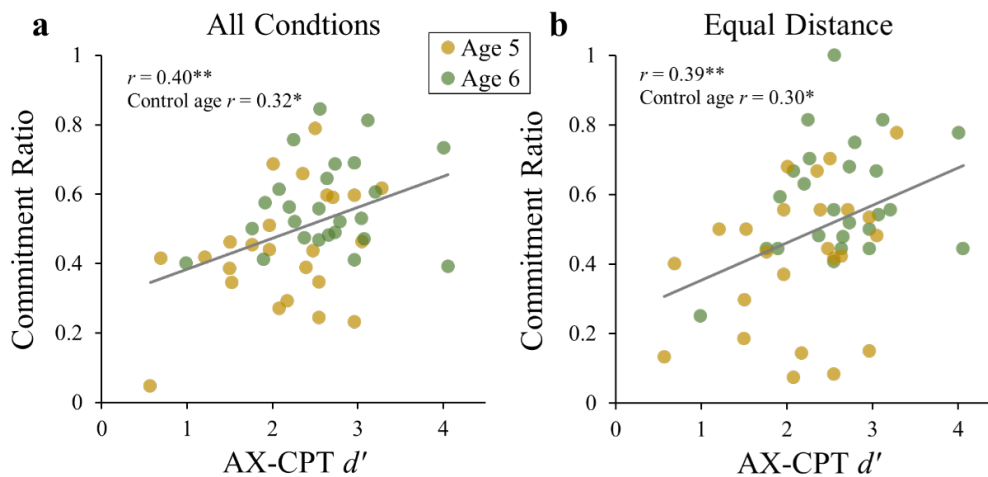
**Fig. 3.** *Child AX-Continuous Performance Task schematic. The task included 4 trial types: AX, BX, AY, and BY. Children were instructed to press the “1” button (target response) on AX trials(a), and press the “4” button (non-target response) on BX(b), AY(c) and BY(d) trials. Children who use proactive control make an anticipation when they see the cue, which leads to high hit rates in AX and low false alarm rates in BX. Children who use reactive control make a response only when they see the probe, which results in high false alarm rates in BX.*

### **Data Analysis**

Consistent with previous studies, trials with response times faster than 100 ms were removed from all analyses. To assess the attentional control strategy children use,  $d'$  was computed in terms of signal detection theory to control for response biases (Cohen et al., 1999; Swets & Sewall, 1963):  $d' = H - F$ , where  $H$  is the z transform of proportion of hits on AX trials and  $F$  is the z transform of proportion of false alarms on BX trials. Higher  $d'$  indicates increased use of proactive control and lower  $d'$  indicates increased use of reactive control.

### **Results**

Pearson's correlation revealed that  $d'$  increased with children's age (a continuous variable accurate to the day,  $r(49) = .33, p = .020$ ); yet, our main interest was how a participant's  $d'$  correlated with their commitment ratio in Experiment 1. Results showed that  $d'$  was significantly correlated with commitment ratio in both the averaged distance difference condition ( $r(49) = .40, p = .004$ ) and the equal-distance condition ( $r(49) = .38, p = .006$ ) of Experiment 1 (Fig. 4). Even after controlling for age, these correlations were still significant (all conditions:  $r(46) = .32, p = .028$ ; equal-distance condition:  $r(49) = .30, p = .042$ ). Thus, as predicted, we observed a positive correlation between commitment ratio and  $d'$ , indicating a connection between intentional commitment and proactive control.



**Fig. 4.** The correlation between proactive control ( $d'$ ) and bias towards the old dot (commitment ratio) (a) averaged across all distance conditions and (b) in the equal-distance condition, respectively.

### General Discussion

In a task with sequential goals, the current research explored the development of commitment to a partial plan and its relation to children's proactive control of attention. Our first experiment revealed a transition in intentional commitment between 5 and 6 years old. Specifically, 5-year-olds were unable to commit to an existing goal, demonstrating attraction to new goals rather than adherence to old ones. Yet 6-year-olds demonstrated an opposite

pattern; similar to adults, they preferred reaching old goals and resisting re-planning.

Furthermore, we found a significant positive correlation between high levels of intentional commitment and high levels of proactive control, suggesting the significance of proactive control in the development of commitment.

Our developmental findings support the BDI model, suggesting that intention is a distinctive mental state regulating conflicting desires (Bratman, 1987; Searle & Willis, 1983). More specifically, we tested one important function of intention: the formation of partial plans, which is the capacity to commit to a distant future even before reaching the proximal one. This is demonstrated by the results revealing that 6-year-olds have a bias towards old goals even when they become suboptimal. Compared to adults, the unique contribution of our developmental approach here is that we discovered the developmental trajectory of intentional commitment as it transitions from a bias toward new goals to old goals between 5 and 6 years-old. The rapidly developing commitment during this period provides a window to inspect the cognitive mechanisms. It implies a maturation of certain cognitive mechanisms during 5 to 6 years of age that could be the prerequisite for the emergence of intentional commitment. Thus, in the current study, we focused on the connection between commitment and proactive control, which also emerges during this period.

We found stable correlations between intentional commitment and proactive control, for which there are three possible explanations. The first is that the development of intentional commitment leads to a transition in attentional control. However, such an explanation is implausible because the AX-CPT task involves neither intention nor sequential decision-making (Chatham, 2009). In addition, no theory has yet proposed that the use of proactive control is influenced by intention. The second explanation is that an additional factor exists that affects both proactive control and intentional commitment. Yet, no clear candidate mental state exists that causally influences both. This is due to attentional control



commonly being treated as a basic executive function which explains other forms of cognitive performance and social functioning (e.g., Abrahamse et al., 2016; Chevalier et al., 2014; Herwig et al., 2007; Troller-Renfree et al., 2019). The most obvious confounding factor in our study, age, has also been controlled. Thus, the last and most likely explanation is that the presence of intentional commitment relies on the development of proactive control. We hypothesize that in a visual environment, persistently pursuing a goal depends on the capacity to focus attention toward that goal. It requires humans to resist distractions, such as the abrupt onsets of new objects which automatically grab human attention (e.g., Yantis & Jonides, 1984). When attention fails to resist those distractions, commitment to the intention dissipates. Children who can use proactive control, can actively maintain their attention to previously committed goals. However, children who rely on reactive control are easily distracted by the onset of a new goal, causing an opposite pattern of results with a bias towards the new goal. This causal explanation can be examined in future studies with a direct manipulation of attention in a sequential decision-making task requiring intentional commitment.

Although attention is one of the major themes in cognitive sciences and has been extensively studied (Chun et al., 2011), it is rarely mentioned in models of agency such as the BDI model. Our results indicate that attention plays a key role in intentional commitment, which suggests possible connections between the current study and other recent developmental research on attention. For example, research has shown that other types of top-down attention, such as the capacity to sustain attention selectively to task-relevant information (Deng & Sloutsky, 2016; Plebanek & Sloutsky, 2017) and inhibit onset distractions (Volkmer et al., 2021), also develop during this critical period of 5 to 6 years old. It is reasonable to assume that there is a close connection between proactive control and these other top-down attentional control mechanisms (Chun et al., 2011), although the exact

relation between these mechanisms has not been extensively researched. Thus, future studies would benefit from the further exploration of intentional commitment in a broader context of attention.

Our results offer a direct test of the two alternative hypotheses we articulated in the introduction. The early development hypothesis assumed that commitment is a default component of intention and the late development hypothesis suggested that commitment requires the maturity of executive control. Our results corroborate the late development hypothesis, demonstrating that commitment is not a free process effortlessly maintained with the emergence of intention; but rather, commitment demands effortful proactive control of attention. Interestingly, once a child matures enough to proactively control their attention, this commitment arises spontaneously with intention, despite (a) the presence of salient attention grabbing distractors and (b) that commitment can hurt task performance as the committed goal is often suboptimal. Therefore, our results show that with mature executive control, children spontaneously spend effort to commit.

Our results revealed that 6-year-olds, but not 5-year-olds, matched the adult pattern of intentional commitment to partial plans and furthermore that the presence of intentional commitment is positively correlated with the use of proactive control. These findings demonstrated that intentional commitment to partial plans does not emerge with intention understanding at infancy, but matures gradually with the development of proactive attentional control.

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