DOI: 10.1111/cdev.13955

EMPIRICAL REPORTS

CHILD DEVELOPMENT

The development of commitment: Attention for intention

Shuyi Zhai[1] | Shaozhe Cheng[1] | Naomi Moskowitz[2] | Mowei Shen[1] | Tao Gao[2,3,4]

[1]Department of Psychology and Behavioral Sciences, Zhejiang University, Hangzhou, P.R. China

[2]Department of Psychology, UCLA, Los Angeles, California, USA

[3]Department of Statistics, UCLA, Los Angeles, California, USA

[4]Department of Communication, UCLA, Los Angeles, California, USA

Correspondence
Tao Gao, Department of Communication, UCLA, Los Angeles, CA 90095, USA.
Email: tao.gao@stat.ucla.edu

Mowei Shen, Department of Psychology and Behavioral Sciences, Zhejiang University, Zijingang Campus, 866 Yuhangtang Road, Hangzhou, ZJ 310058, P.R. China.
Email: mwshen@zju.edu.cn

Funding information
National Natural Science Foundation of China, Grant/Award Number: 32071044 and 32200869; UCLA Startup Funding

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 time. Two studies (N=50, 27 girls, ages 5–6, Han Chinese, in Hangzhou, China, 2022.02–2022.03) explored the development of commitment to partial plans in a sequential decision-making task and the underlying cognitive capacity focusing on its correlation to attentional control. Results suggest that only 6-year-olds committed to partial plans (d=.51), and children's commitment ratio was positively correlated with the use of proactive control (r=.40). These findings indicate that intentional commitment does not develop simultaneously with intention understanding, but rather matures gradually with the development of attentional control.

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- to 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 (Troller-Renfree et al., 2020; Unger et al., 2016). Additionally, previous developmental studies on theory of mind 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

Abbreviations: AX-CPT, AX-Continuous Performance Task; BDI, belief-desire-intention; MDP, Markov Decision Process.

Shuyi Zhai and Shaozhe Cheng contributed to the work equally and should be regarded as co-first authors.

to individualized partial plans over time. Thus, the current research aims to explore the development of intentional commitment as well as its dependence on execute control.

Intention: The philosophical perspective

The classic desire theory argues that any human behavior can be reduced to a complex of beliefs and desires (Audi, 1974; Davidson, 1963). However, recent philosophy of mind proposes an alternative view, suggesting that desires do not directly drive human actions. Instead, a gap exists between desire and action (Searle, 2003), which is bridged by a distinctive mental state—intention. 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. The 4-year-olds develop a differentiated conception of intention that is not confused with desire (Feinfield et al., 1999). The 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 belief-desire-intention (BDI) model of the mind (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., in press). The results showed that human actions qualitatively deviate from those of MDP with a 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 (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., in press). 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. This study was the first to investigate how intentional commitment to a partial plan develops, and thus we conducted exploratory analyses to arbitrate between two possible hypotheses. One hypothesis is that children's intentional commitment emerges early as they understand intentions; another is that children's intentional commitment develops with mature attentional control. A preregistration can be found here: https://osf.io/4nzvf. The materials and data for both studies are publicly accessible at https://osf.io/mbnxe/files/ . The analytic code is publicly accessible via request to the first author.

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.'s (in press) paradigm for testing the “temporal leap” signature. In a Pac-Man like task, participants continuously pursued goals that constantly appeared and disappeared (Figure 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. (in press).

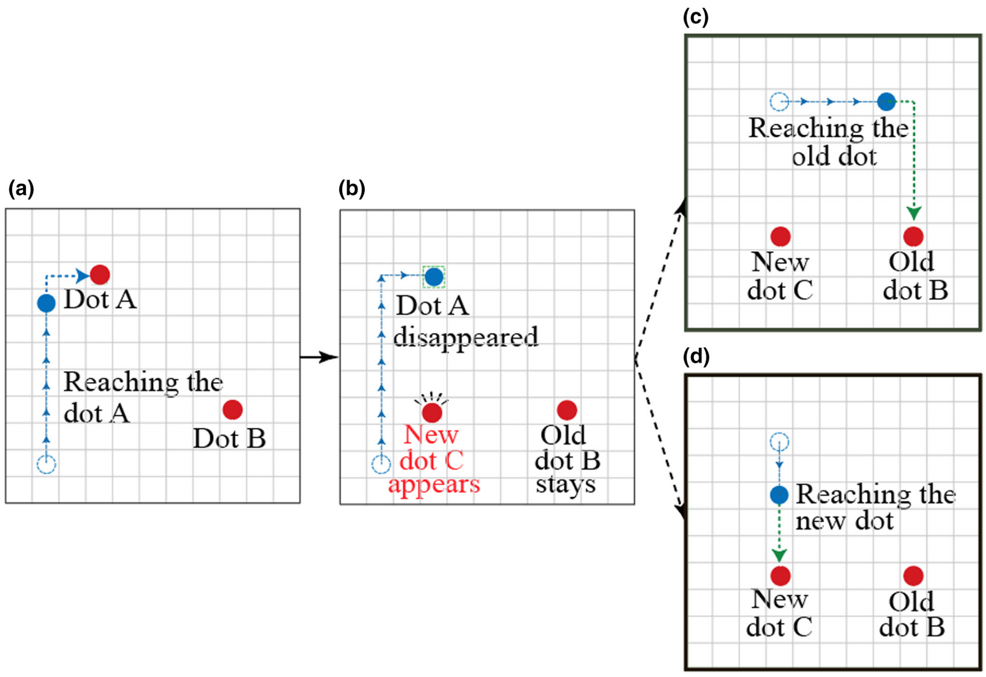

FIGURE 1 Navigating to a chain of two dots. (a) Task begins with a blue dot that represents the agent, and two red dots that represent the possible targets. (b) Once the agent reached a dot, the dot (A) disappeared, the other dot (B) remained (now becoming the old dot), and a new dot (C) appeared in a new location. The distance difference in this map is −5 (5(new) − 10(old)). The agent (c) chose to pursue the old dot B or (d) alternatively chose to pursue the new dot C.

Methods

Participants

An a priori power analysis was conducted using the program G*Power 3.1.9.2 with a conservative effect size Cohen's d=.8 (according to Experiment 3 of Cheng et al., in press) in which α=.05 and $1-\beta$=.80, indicating that 21 participants of each age group were sufficient. Consequently, we recruited 25 five-year-old children (12 girls, M_{age}=5.39 years, SD=.19, range=5.00–5.74), and 25 six-year-old children (15 girls, M_{age}=6.41 years, SD=.18, range=6.01–6.75). From February to March 2022, children were recruited from two kindergartens that served children from socioeconomically middle-class families 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. All participants reported a Han ethnic background. 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, Zhejiang 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°×11.84° from a distance of 60cm, and overlaid with a 15×15 grid (created with Pygame, version 1.9.4, shown in Figure 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° 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 Supporting Information.

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 with the distance-difference to the originally placed destination (old dot). Each trial was pseudorandomly 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 toward the old dots, and a commitment ratio lower than 50% indicates a bias toward 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., in press), 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 20min.

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, η^2=.16, see Figure 2a). Post hoc analysis (Bonferroni-corrected) showed that 6-year-olds had a commitment ratio (56.6%; 95% CI [0.51, 0.62]) that was significantly higher than 50% (t=2.57, p=.008, Cohen's d=.51) and did not significantly differ from adults (p=.999; see Experiment 3 in Cheng et al., in press, 56.5%; 95% CI [0.51, 0.62]). Five-year-olds showed an opposing pattern in commitment ratio (44.2%; 95% CI [0.37, 0.51]) to that of 6-year-olds and adults (p=.007, p=.013, respectively); one significantly lower than 50%, indicating a bias to reach new dots (t=−1.76, p=.046, Cohen's d=.35).

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, η^2=.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])

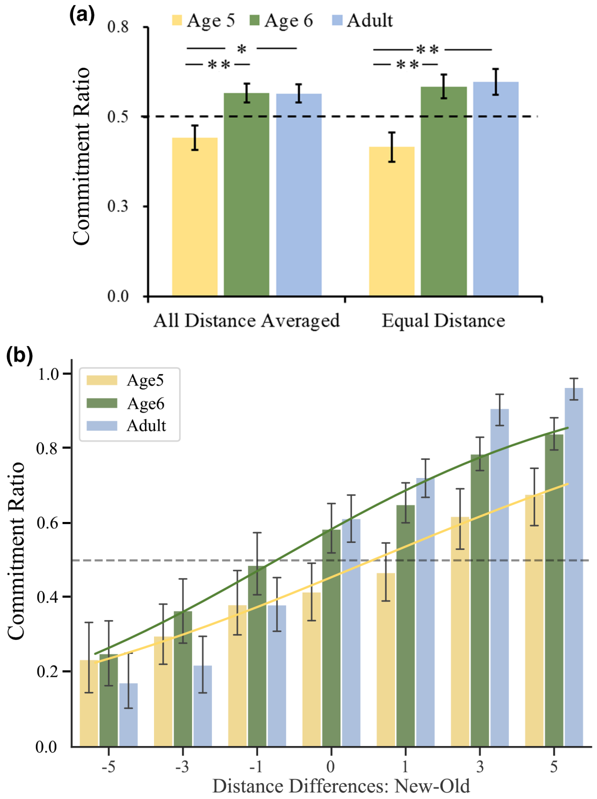

FIGURE 2 (a) Ratio of trials in which agents reached the old dot (commitment ratio) averaged across all distance conditions and in the equal-distance condition. (b) Commitment ratio for each distance condition with fitted logistic regression. The error bars indicate the standard errors. *, $p < .05$; **, $p < .01$.

significantly higher than 50% ($t=2.54$, $p=.009$, Cohen's $d=.51$) and 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); one significantly lower than 50%, indicating a bias to reach new dots ($t=-2.09$, $p=.009$, Cohen's $d=.42$).

Furthermore, we modeled commitment as a function of distance-differences with logistic regression (Figure 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 towards 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 toward 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.

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 the AX-Continuous Performance Task (AX-CPT; Chatham et al., 2009). 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 2 months of completing the first experiment (except one child absent during Experiment 2; $N=49$, 26 girls, $M_{age}=5.91$ years, SD = .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° × 6.68° 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 Figure 3. Each trial began with a fixation appearing for 1000 ms, followed by a cue stimulus (A or B) appearing for 500 ms. After a blank interval of 1000 ms, a probe stimulus (X or Y) was presented. At probe onset, children needed to press one of two response keys within 2000 ms. They were instructed to make a target response (press "1" on a

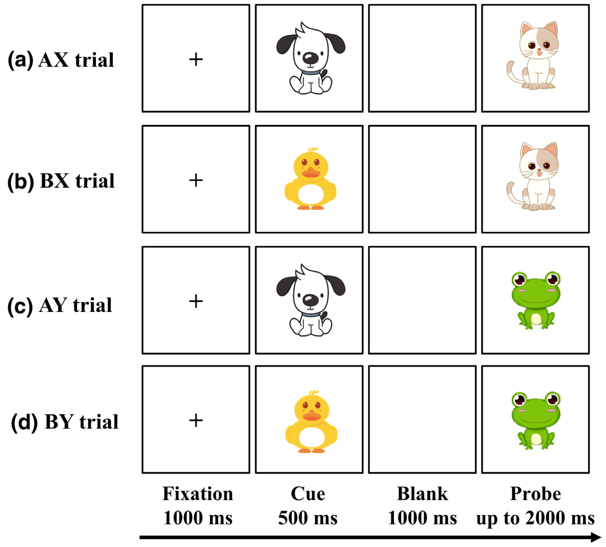

FIGURE 3 Child AX-Continuous Performance Task schematic. The task included 4 trial types: AX, BX, AY, and BY. Children were instructed to press the "1" button (target response) on AX trials (a), and press the "4" button (non-target response) on BX (b), AY (c), and BY (d) trials. Children who use proactive 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.

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 min.

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 (Figure 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.

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 replanning. 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

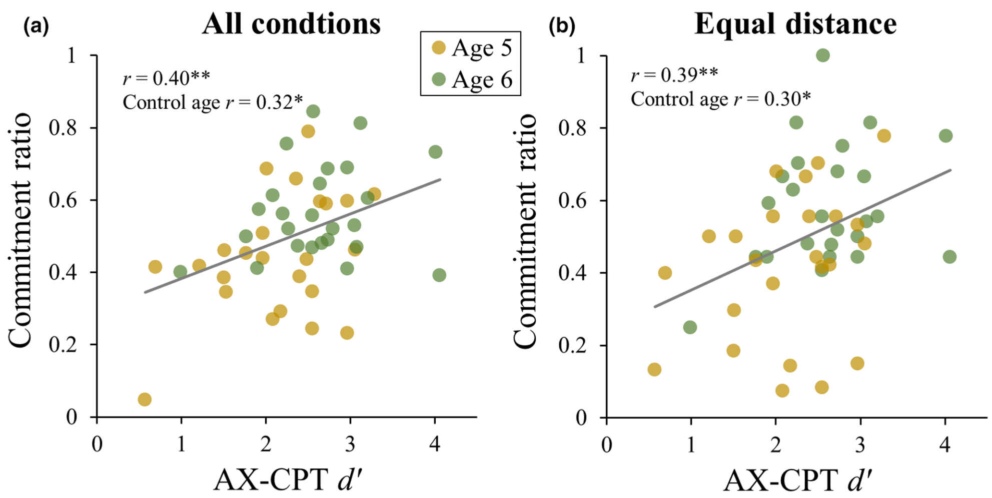

FIGURE 4 The correlation between proactive control (d') and bias toward the old dot (commitment ratio) (a) averaged across all distance conditions and (b) in the equal-distance condition, respectively. *, $p < .05$; **, $p < .01$.

by the results revealing that 6-year-olds have a bias toward old goals even when they become suboptimal. Compared with 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 5–6 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 et al., 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., 2022), also develop during this critical period of 5–6 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.

ACKNOWLEDGEMENTS

This work was supported by the National Natural Science Foundation of China (32071044) to Mowei Shen, National Natural Science Foundation of China (32200869) to Shuyi Zhai, and UCLA startup funding to Tao Gao. We are very grateful to the children who participated in this project.

CONFLICT OF INTEREST STATEMENT

There are no conflicts of interest to declare.

DATA AVAILABILITY STATEMENT

The data and code necessary to reproduce the analyses presented here are publicly accessible at https://osf.io/mbnxe/files/, and the analytic code is publicly accessible via request to the first author. The analyses presented here were preregistered. This manuscript has not been published or presented elsewhere in part or in entirety, and is not under consideration by another journal. All study participants provided informed consent, and the study design was approved by the appropriate ethics review boards. All the authors have approved the manuscript and agree with submission to your esteemed journal.

ORCID

Shuyi Zhai https://orcid.org/0000-0002-6560-0045

REFERENCES

Abrahamse, E., Braem, S., Notebaert, W., & Verguts, T. (2016). Grounding cognitive control in associative learning. *Psychological Bulletin*, *142*, 693–728. https://doi.org/10.1037/bul0000047

Audi, R. (1974). Intending. *The Journal of Philosophy*, *70*, 387–403. https://doi.org/10.2307/2024677

Bratman, M. (1987). *Intention, plans, and practical reason*. Harvard University Press.

Braver, T. S. (2012). The variable nature of cognitive control: A dual mechanisms framework. *Trends in Cognitive Sciences*, *16*, 106–113. https://doi.org/10.1016/j.tics.2011.12.010

Cheng, S., Zhao, M., Tang, N., Zhao, Y., Zhou, J., Shen, M., & Gao, T. (in press). Intention beyond desire: Spontaneous intentional commitment regulates conflicting desires. *Cognition*.

Chatham, C. H., Frank, M. J., & Munakata, Y. (2009). Pupillometric and behavioral markers of a developmental shift in the temporal dynamics of cognitive control. *Proceedings of the National Academy of Sciences of the United States of America*, *106*, 5529–5533. https://doi.org/10.1073/pnas.0810002106

Chevalier, N., James, T. D., Wiebe, S. A., Nelson, J. M., & Espy, K. A. (2014). Contribution of reactive and proactive control to children's working memory performance: Insight from item recall durations in response sequence planning. *Developmental Psychology*, *50*, 1999–2008. https://doi.org/10.1037/a0036644

Chun, M. M., Golomb, J. D., & Turke-Browne, N. B. (2011). A taxonomy of external and internal attention. *Annual Review of Psychology*, *62*, 73–101. https://doi.org/10.1146/annurev.psych.093008.100427

Cohen, J. D., Barch, D. M., Carter, C., & Servan-Schreiber, D. (1999). Context-processing deficits in schizophrenia: Converging evidence from three theoretically motivated cognitive tasks. *Journal of Abnormal Psychology*, *108*, 120–133. https://doi.org/10.1037/0021-843X.108.1.120

Craighero, L., Leo, I., Umiltà, C., & Simion, F. (2011). Newborns' preference for goal-directed actions. *Cognition*, *120*, 26–32. https://doi.org/10.1016/j.cognition.2011.02.011

Csibra, G. (2008). Goal attribution to inanimate agents by 6.5-month-old infants. *Cognition*, *107*, 705–717. https://doi.org/10.1016/j.cognition.2007.08.001

Davidson, D. (1963). Actions, reasons, and causes. *The Journal of Philosophy*, *60*, 685–700. https://doi.org/10.2307/2023177

Deng, W. S., & Sloutsky, V. M. (2016). Selective attention, diffused attention, and the development of categorization. *Cognitive Psychology*, *91*, 24–62. https://doi.org/10.1016/j.cogpsych.2016.09.002

Feinfield, K. A., Lee, P. P., Flavell, E. R., Green, F. L., & Flavell, J. H. (1999). Young children's understanding of intention. *Cognitive Development*, *14*, 463–486. https://doi.org/10.1016/S0885-2014(99)00015-5

Gerson, S. A., & Woodward, A. L. (2012). A claw is like my hand: Comparison supports goal analysis in infants. *Cognition*, *122*, 181–192. https://doi.org/10.1016/j.cognition.2011.10.014

Gratton, G., Cooper, P., Fabiani, M., Carter, C. S., & Karayanidis, F. (2018). Dynamics of cognitive control: Theoretical bases, paradigms, and a view for the future. *Psychophysiology*, *55*, e13016. https://doi.org/10.1111/psyp.13016

Hamlin, J. K., Hallinan, E. V., & Woodward, A. L. (2008). Do as I do: 7-month-old infants selectively reproduce others' goals. *Developmental Science*, *11*, 487–494. https://doi.org/10.1111/j.1467-7687.2008.00694.x

Herwig, U., Baumgartner, T., Kaffenberger, T., Bruhl, A., Kottlow, M., Schreiter-Gasser, U., Abler, B., Jäncke, L., & Rufer, M. (2007). Modulation of anticipatory emotion and perception processing by cognitive control. *NeuroImage*, *37*, 652–662. https://doi.org/10.1016/j.neuroimage.2007.05.023

Jara-Ettinger, J., Schulz, L. E., & Tenenbaum, J. B. (2020). The naïve utility calculus as a unified, quantitative framework for action understanding. *Cognitive Psychology*, *123*, 101334. https://doi.org/10.1016/j.cogpsych.2020.101334

Kachel, U., Svetlova, M., & Tomasello, M. (2018). Three-year-olds' reactions to a partner's failure to perform her role in a joint commitment. *Child Development*, *89*, 1691–1703. https://doi.org/10.1111/cdev.12816

Kachel, U., & Tomasello, M. (2019). 3- and 5-year-old children's adherence to explicit and implicit joint commitments. *Developmental Psychology*, *55*, 80–88. https://doi.org/10.1037/dev0000632

Leonard, J. A., Lee, Y., & Schulz, L. E. (2017). Infants make more attempts to achieve a goal when they see adults persist. *Science*, *357*, 1290–1294. https://doi.org/10.1126/science.aan2317

Lucca, K., Horton, R., & Sommerville, J. A. (2020). Infants rationally decide when and how to deploy effort. *Nature Human Behaviour*, *4*, 372–379. https://doi.org/10.1038/s41562-019-0814-0

Myowa-Yamakoshi, M., Scola, C., & Hirata, S. (2012). Humans and chimpanzees attend differently to goal-directed actions. *Nature Communications*, *3*, 693. https://doi.org/10.1038/ncomms1695

Plebanek, D. J., & Sloutsky, V. M. (2017). Costs of selective attention: When children notice what adults miss. *Psychological Science*, *28*, 723–732. https://doi.org/10.1177/095679761769300

Poulin-Dubois, D., & Yott, J. (2018). Probing the depth of infants' theory of mind: Disunity in performance across paradigms. *Developmental Science*, *21*, e12600. https://doi.org/10.1111/desc.12600

Schult, C. A. (2002). Children's understanding of the distinction between intentions and desires. *Child Development*, *73*, 1727–1747. https://doi.org/10.1111/1467-8624.t01-1-00502

Searle, J. R. (2003). *Rationality in action*. MIT press.

Searle, J. R., & Willis, S. (1983). *Intentionality: An essay in the philosophy of mind*. Cambridge University Press.

Swets, J. A., & Sewall, S. T. (1963). Invariance of signal detectability over stages of practice and levels of motivation. *Journal of Experimental Psychology*, *66*, 120–126. https://doi.org/10.1037/h0049098

Troller-Renfree, S. V., Buzzell, G. A., Bowers, M. E., Salo, V. C., Forman-Alberti, A., Smith, E., Papp, L. J., McDermott, J. M., Pine, D. S., Henderson, H. A., & Fox, N. A. (2019). Development of inhibitory control during childhood and its relations to early temperament and later social anxiety: Unique insights provided by latent growth modeling and signal detection theory. *Journal of Child Psychology and Psychiatry*, *60*, 622–629. https://doi.org/10.1111/jcpp.13025

Troller-Renfree, S. V., Buzzell, G. A., & Fox, N. A. (2020). Changes in working memory influence the transition from reactive to proactive cognitive control during childhood. *Developmental Science*, *23*, e12959. https://doi.org/10.1111/desc.12959

Unger, K., Ackerman, L., Chatham, C. H., Amso, D., & Badre, D. (2016). Working memory gating mechanisms explain developmental change in rule-guided behavior. *Cognition*, *155*, 8–22. https://doi.org/10.1016/j.cognition.2016.05.020

Volkmer, S., Wetzel, N., Widmann, A., & Scharf, F. (2022). Attentional control in middle childhood is highly dynamic—Strong initial distraction is followed by advanced attention control. *Developmental Science*, *25*, e13275. https://doi.org/10.1111/desc.13275

Wellman, H. M., & Brandone, A. C. (2009). Early intention understandings that are common to primates predict children's later theory of mind. *Current Opinion in Neurobiology*, *19*, 57–62. https://doi.org/10.1016/j.conb.2009.02.004

Yantis, S., & Jonides, J. (1984). Abrupt visual onsets and selective attention: Evidence from visual search. *Journal of Experimental Psychology: Human Perception and Performance*, *10*, 601–621. https://doi.org/10.1037/0096-1523.10.5.601

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Zhai, S., Cheng, S., Moskowitz, N., Shen, M., & Gao, T. (2023). The development of commitment: Attention for intention. *Child Development*, *00*, 1–9. https://doi.org/10.1111/cdev.13955