The Development of Commitment: Attention for Intention

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Abstract

The ability to take action according to a partially defined plan allows humans to resolve a distant future, even when steps are missing between the present and that future. Adhering to this partial plan requires an intentional commitment that curbs distracting desires conflicting with the planned course of action, enabling humans to act coherently over long horizons. This research explored the largely unknown cognitive development of commitment to partial plans in a sequential decision making task among 5- and 6-year-olds, and its correlation to participant capacity for attentional control. Our results suggest that only 6-year-olds committed to partial plans, and moreover, that in both age groups, intentional commitment 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

Introduction

Picture a child building a block castle. She places a red cube on the ground as the castle's base. Then she notices a gold sticker that can be affixed to the castle's spire. Although she is building the castle's base, she has already decided what the top of the castle will look like. As she continues building, she notices an alternative decoration that could be used; however, she decides to ignore it and continue with her current plan. In this sense, the girl acts with a plan that is partially defined, allowing for determination of the castle spire's decoration, even when steps are missing between base construction and that future step. Execution of this plan requires an intentional commitment that she will adhere to a course of action that leads her to the predetermined future plan, without the attraction of conflicting desires 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 and tend to imitate the intentional actions of others (e.g., Csibra, 2008; Gerson & Woodward, 2012; Hamlin et al., 2008). Thus, commitment, as an intrinsic property of intention, may develop together with the understanding of intentional actions. Alternatively, commitment may be an ability that develops much later due to its goal of maintaining focus on a planned course of action, shielding interference from alternative paths forward. Thus, successful commitment may require advanced attentional control which only develops at the end of early childhood (Unger et al., 2016; Troller-Renfree et al., 2020). Intention as a key component of Theory of Mind has been previously explored in developmental psychology, however commitment has not been the focus in this line of work. While related research studies joint-commitment in collaboration (Kachel et al., 2018; Kachel & Tomasello, 2019), this does not directly speak to how the self commits over time to individualized partial plans.

The present study aimed to distinguish whether commitment to partial plans develops early or late in childhood, and how this cognitive ability connects to the development of attentional control.

Intention in a Theory of Mind: a Philosophical Perspective

In philosophy, intention is most clearly formulated in the belief-desire-intention (BDI) model of the mind. In this model "belief" is the informational state, "desire" is the motivational state, and "intention" is the deliberating state that regulates conflicting desires to generate coherent actions with commitment (Bratman, 1987). The more simplistic, desire model, claims that human behavior can always be reduced to complexes of beliefs and desires, with no need for intention as a distinctive mental state (Wellman, 2014). Yet BDI proposes that in order to act with commitment and determination, intention is necessary to regulate conflicting desires.

Although intention and desire are closely related, there is a clear difference between these two mental states. Unlike desire, for which its intensity can vary continuously and quantitatively—typically modeled as a utility function in decision theory, intention is a condition that is definitively met or dissatisfied (Brand, 1984). Additionally, unlike desires, which can be satisfied in a variety of ways, intention is only satisfied in one right way—the fulfillment of the intended plan of action (Searle & Willis, 1983). From a computational and functional perspective, intention is critically important for planning a sequence of coherent actions into a distant future (Bratman, 1987). This can be understood through two assertions. First, unlike desires which can be conflicting with each other (e.g., one can simultaneously want to eat the candy bar in front of them, and want to 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, 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 castle's spire. Thus, intention necessitates a commitment to plans of actions under conflicting desires.

The Development of Intention

Intention has also been studied extensively in psychology. Developmental research has found that infants can 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). Several research studies have also explored child understanding of intention as distinguished from desire, and specifically the linguistic distinction between intention and desire first appears during preschool age. At 4 years old, children begin to develop a differentiated conception of intention that is not confused with desire (Feinfield et al., 1999). By 5 years old, children can distinguish intentional from non-intentional actions (Colle et al., 2007; shultz1985judging) and semantically understand that desire only means "want to", while intention means "plan to" (Schult, 2002).

Although previous developmental studies have explored children's understandings of intention, they focused centrally on the semantic difference between intention and desire using verbal reports. Thus, little is known about the computational function of intentional commitment for generating partial plans, as presented in the BDI model (Bratman, 1987). Yet, more recently, two computational studies modeling human planning emphasized the functional importance of intention for generating coherent actions. One study (Jara-Ettinger et al., 2020), modeled intention as an ordered sequence of goals that is determined by optimizing for expected utility. Results showed that this model of intention enables an agent to reach multiple goals with coherent actions. However, this model does not offer clear behavioral predictions that can distinguish intentional actions from those purely driven by expected utility without an intention. Another study focused on the psychophysics of intentional actions in adults, by comparing humans with an optimal Markov decision process model in a 2D navigation task (Cheng et al., 2021). The results showed that human actions qualitatively deviate from model actions with four behavioral signatures of intentional commitment: "disruption resistance" as sticking to a plan despite setbacks; "Ulysses-constraint of freedom" as avoiding paths lead to many possible futures; "Enhanced legibility" as choosing a path whose destination can be promptly inferred by a third-party observer; and "temporal leap" as committing to a distant future before finishing the current one. These behavioral results revealed the inflexibility of human actions, indicating that they are indeed mediated by intentions instead of merely optimizing the expected utility.

The Present Study

In the present study we used the "temporal leap" phenomena, reported in Cheng et al. (2021), as a behavioral signature for exploring the development of intentional commitment. 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. Therefore, with the same group of children, we conducted a second experiment to measure their strategy of cognitive control. We hoped that a correlation between these two tasks would reveal a connection between the development of intentional commitment and attentional control.

Based on the Dual Mechanisms of Control theory (DMC; Braver, 2012), we measured children's attentional control with AX-Continuous Performance Task (AX-CPT). This task measures which of the following two types of attentional control children use: (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. Both proactive and reactive control serve individuals in achieving goals, but they differ in implementation phase and extent. Proactive control engages well before actions and continuously regulates attention for goal attainment, while reactive control engages at the moment of taking actions and works fleetingly. Thus we believe proactive control is highly compatible with intentional commitment to a partial plan.

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 commitment at this age. Thus, this is the first of two reasons that our study focused on 5- and 6-year-old children. The second is that children at this age can understand that intention demands commitment (Schult, 2002), but are confused by conflicting desires (Choe et al., 2005; Rostad & Pexman, 2014).

To overview the present research, we measured the partial plan nature of a sequential decision making task (Study 1) and then adopted the decision task to measure attentional control in the same group of children with the AX-CPT task (Study 2). We then analyzed the correlation of task performance in the two studies.

Methods & Results

Study 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. 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 alloted 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. Additionally, we compared our child participant data with the results from adults performing the same task in Cheng et al. (2021).

Participants Participants in the study included 25 5-year-old children (13 boys, M_{age} = 5.39 years, SD = 0.19, range = 5.00–5.74), and 25 6-year-old children (10 boys, M_{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. Informed consent was obtained from the children's parents. This study and the following studies were approved by the Institutional Review Board at the Department of Psychology and Behavioral Sciences, ** University.

Materials and Procedure A continuous Pac-Man like task was presented on a 2D map with a 15×15 grid (created with Pygame, version 1.9.4, shown in Figure.1). At the beginning of the experiment, the map was created with an initial 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 updated 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.

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 percentage 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. Across all conditions, the averaged distance-difference was 0. We analyzed the commitment ratio across all conditions and uniquely in the equal-distance (0) condition.

The task was designed in blocks of 20 trials. Children were encouraged to complete as many blocks as possible, with a maximum of nine blocks. On average, 5-year-olds completed 7.7 blocks and 6-year-olds completed 8.7 blocks. Before the formal task, children were taught how to use arrow keys and completed 20 practice trials to ensure they understood the task and were familiar with the keys.

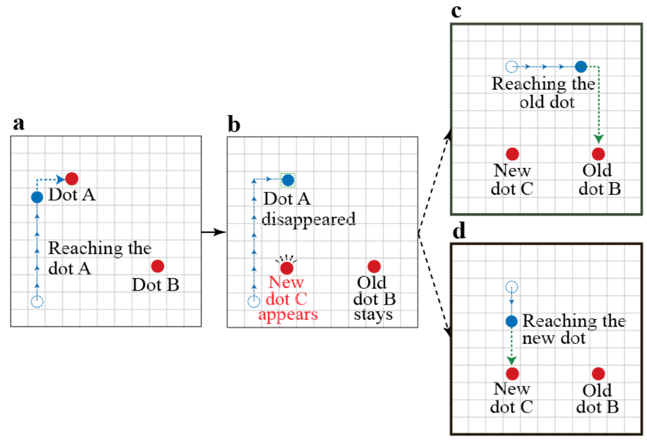

Figure. 1. Navigating to a chain of two dots.
a. The blue dot represents the agent, and the red dots represent the possible targets. At any moment there were always two red dots. b. Once the agent reached a dot, the dot (A) disappeared, the other dot (B) remained (now becoming the old dot), and a new dot (C) appeared in a new location. The distance difference in this map is -5 (5(new)-10(old)). c. The agent chose to pursue the old dot B. d. Alternatively, the agent chose to pursue the new dot C.

Results Across all conditions, the ANOVA on commitment ratio revealed a significant main effect of age group (F (2,68) = 6.37, p = 0.003, η^2 = 0.16, 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 is significantly higher than 50% (t = 9.02, $p < 0.001$, Cohen's d = 0.14) and did not significantly differ from adults (see Experiment 3 in Cheng et al., 2021, 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 ($ps < 0.05$); one significantly lower than 50%, indicating a bias to reach new dots (t = -4.80, $p < 0.001$, Cohen's d = 0.08).

Similar results were found when we focused on the equidistant (0 difference) condition. A significant main effect of age group (F (2,68) = 7.83, p = 0.001, η^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 is significantly higher than 50% (t = 4.55, $p < 0.001$, Cohen's d = 0.18) and did not significantly differ from adults (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; one significantly lower than 50%, indicating a bias to reach new dots (t = -3.25, p = 0.001, Cohen's d = 0.13).

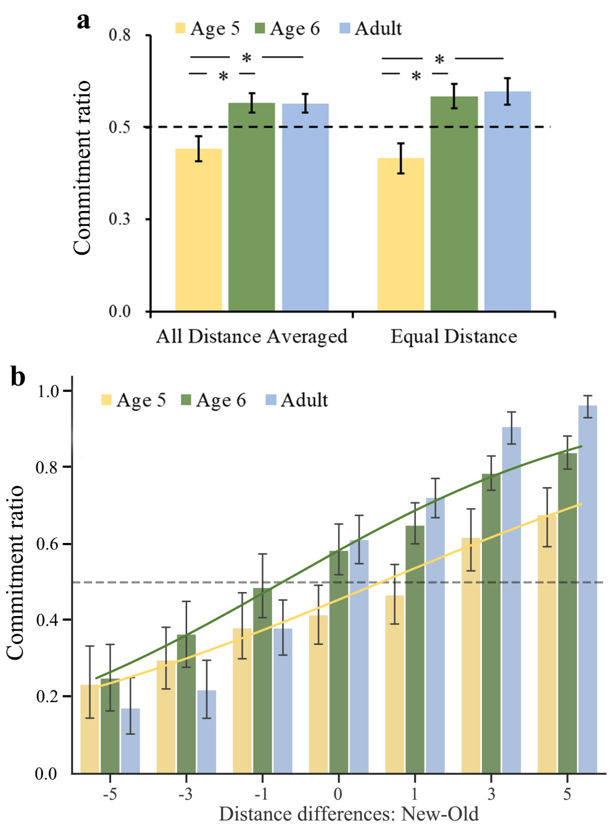

Figure. 2. a. Percentage of trials in which agents reached the old dot (commitment ratio) averaged across all distance conditions and in the equal-distances condition. b. Percentage of trials in which agents reached the old dot (commitment ratio) for each distance condition.

Furthermore, we modeled commitment ratio 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* < 0.001), demonstrating biases toward old dots. For 5-year-olds, the intercept was significantly lower than 0 (-0.18; 95% CI [-0.25, -0.11], $p < 0.001$), indicating a bias towards new dots.

These results indicated that intentional commitment increases rapidly between 5 years old and 6 years old, when the proportion of commitment is close to that of adults. 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 Study 2, we tested this hypothesis by measuring attentional control in the same group of children, and how it correlates to their commitment ratio.

Study 2: The Relation to Attentional Control.

Study 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-CPT, which allows for the discrimination of proactive and reactive control. Following convention, we calculated *d*' in terms of signal detection theory which reflects children's sensitivity to cue and the use of proactive strategy. 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*').

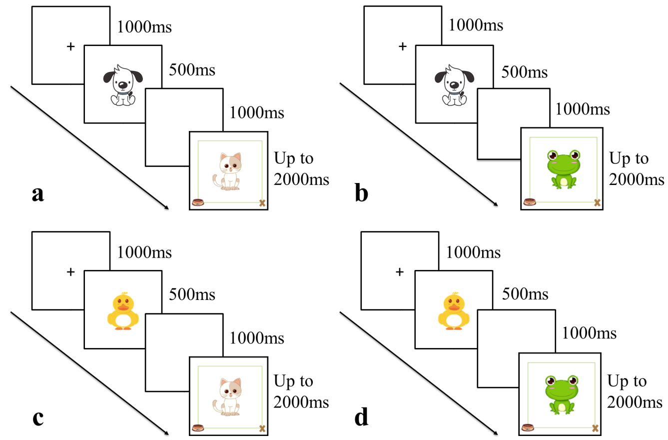

Figure. 3. Child AX-Continuous Performance Task schematic a. AX; b. AY; c. BX; d. BY.

Participants All children who had participated in Study 1 completed the AX-CPT task within two months of the first study (except one child absent during Study 2) (N = 49, 23 boys, M_{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 Study 1.

Materials and Procedure An illustration of a trial in AX-CPT is shown in Figure. 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. Consistent with previous studies in children, letter stimuli were replaced with cartoon figures: A-dog, B-duck, X-cat, and Y-frog. Children needed to make a response to the probe within 2000ms. They were instructed to make a target response (press "1" on a button box) to probe "X" if it followed cue "A" (AX), and make a non-target response (press "4" on a button box) for all other cue-probe sequences (i.e., AY, BX, BY). No feedback was given in the formal task.

AX trials were presented 55% of the time, while each other trial type (AY, BX, BY) was presented 15% of the time. 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. Children were encouraged to complete as many blocks as possible, with a maximum of four blocks. On average, participants completed 3.9 blocks. 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

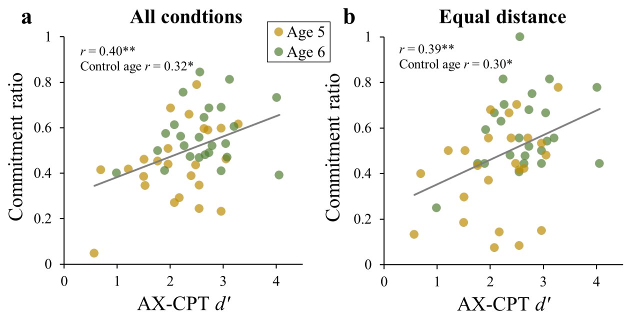

Figure. 4. The correlation between proactive control (d') and bias towards the old dot (commitment ratio) (a) averaged across all distance conditions and (b) in the equal-distances condition, respectively.

once the overall accuracy during practice reached higher than 80%, did the formal experiment began; otherwise, the child continued practicing.

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 (Cohen et al., 1999; Swets & Sewall, 1963): $d' = H - F$, where H is the proportion of hits on AX trials and F is the proportion of false alarms on BX trials.

Results Analysis revealed that *d*' increased with age ($r(49) = 0.33$, $p = 0.020$); yet our main interest was in how a participant's *d*' correlates with their commitment ratio in Study 1. Results showed that *d*' was significantly correlated with commitment ratio in both the averaged distance difference condition ($r(49) = 0.40$, $p = 0.004$) and the equal-distances condition ($r(49) = 0.38$, $p = 0.006$) of Study 1(Figure.4). Even after controlling for age, these relations were still significant (all conditions: $r(46) = 0.32$, $p = 0.028$; equal-distances condition: $r(49) = 0.30$, $p = 0.042$).

Thus, as predicted, we observed a positive correlation between commitment ratio and *d*', indicating a connection between intentional commitment and attentional control.

Discussion

Adopting the sequential decision making task, the current research explored the development of commitment to a partial plan and its relation to children's attentional control. In our first study we observed a transition in intentional commitment between 5 and 6 years old. Specifically, 5-year-old children were unable to demonstrate a commitment to an existing goal; they seemed to be attracted by new goals rather than adhering to old ones. Yet 6-year-old children demonstrated an opposite pattern, with a commitment similar to that of adults, they preferred to reach the old goals and resist re-planning. Furthermore, we found a significant positive correlation between high levels of intentional commitment and more frequent use of a proactive control strategy, suggesting that attentional control may play a significant role in the development of commitment (Study 2).

There are three possible explanations for the correlation we found between intentional commitment and attentional control. The first explanation is that the development of intentional commitment leads to a transition in attentional control strategy. However, such an explanation is implausible because the attentional control task used in this study involves neither intention nor sequential decision-making. 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 attentional control and intentional commitment. Yet, there is no clear candidate mental state that causally influences both intentional commitment and attentional control. This is because attentional control is commonly treated as a basic executive function which explains other forms of cognitive performance and social functioning (e.g., 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 the most likely explanation is that the presence of intentional commitment relies on the development of attentional control. We hypothesize that in a visual environment, pursuing a goal persistently depends on the capacity of focusing attention toward that goal. It requires humans to resist distractions, such as the abrupt onsets of new objects which instantly 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 the previously committed goals. However, children who rely on reactive control are easily distracted by the abrupt onset of new goals, demonstrating a bias towards these new goals. This causal explanation can be examined in future studies with a direct manipulation of attention in a sequential decision task requiring intentional commitment.

The current study found that children first commit to their own intention at 6 years old, much later than the emergence of joint-commitment in interpersonal cooperation at 3 years old. Intuitively, we think that intention follows the trend of emerging across the individual level to the interpersonal level, yet for commitment, it may be the opposite. Commitment emerges with extensive social experience as children begin to understand the normative force of joint-commitments on both their own actions and the actions of their cooperative partners. The commitment to cooperative partners may be gradually internalized during development, and then used to discipline one's own behavior. Joint-commitment develops early because the presence of others emphasizes the importance of regulating one's own actions (Kachel et al., 2018; Kachel & Tomasello, 2019), while individual commitment appears later because there's no such external constraint—one must rely only on their own control ability. This may be a developmental pathway of human commitment from normative obligation to self regulation. This implication could be examined in future studies with similar tasks. For example, a possible study could task two children with reaching a destination together without using communication, and looking for varying commitment to a partial plan across participant age.

Conclusion

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 does not emerge with intention understanding at infancy, but matures gradually with the development of attentional control.

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