**Study 3: Delay of gratification, delay discounting, future time perception and episodic future thinking in middle childhood.**

In this study we investigated whether individual differences in how far away the future feels (future time perception) and the detail with which future events are imagined (episodic future thinking) are related to children’s delay of gratification. We administered the following tasks to a sample of 7-to-11-year-olds:

* a standard delay of gratification that employs real rewards.
* a delay discounting task that employs hypothetical rewards.
* a novel measure of children’s subjective feeling of how far away future time points are (referred to below as future time perception).
* an episodic future thinking interview
* Verbal and visuo-spatial IQ measures

**Participants**

One hundredthirty-two children (64 male) aged 7-to-11-years were recruited for this study. One child did not provide data on the delay discounting task or future time perception task due to absenteeism on the second day of data collection. The sample was split into three age groups: 49 children aged 7-8 (*M*age = 8 years 2 months; SD = 5.2 months; range = 89 – 109 months); 42 children aged 9-10 (*M*age = 9 years 10 months; SD = 3.8 months; range = 112 – 126 months); 41 children aged 10-11 (*M*age = 11 years 1 months; SD = 3.7 months; range = 126 – 139 months).

**Measures**

**Delay Choice***.* This was a delay of gratification task which comprised 12 trials on which participants were offered a choice between a low value reward available immediately and a higher value reward available after a specified delay. Three delay periods were used, 1 day, 1 week and 1 month, with 4 trials at each delay. On each trial one of four reward pairs (once at each delay) were offered: trading cards (1 vs. 2), erasers (1 vs. 2), pens/pencils (1 vs. 2) and sweets (1 vs. 2).

Participants sat at a table across from the experimenter, with two trays, one labelled ‘now’ and one labelled ‘later’, placed in front of them. The experimenter showed children 3 types of trading card, each from a different theme (Football players, Star Wars characters and Despicable Me cards for the males; Disney Princess, Shopkins and Trolls cards for the females) and two types of novelty erasers (Lego shaped and emoji). Each child’s preferred trading card and eraser was used in the subsequent delay choice trials. On trials on which the trading card was the reward the cards were placed inside a small opaque envelope to hide the characters on the cards, ensuring that the specific cards used did not affect children’s choices.

On each trial children heard the following: “I have some [reward type] here. I’m going to give you a choice. You can have this one [reward type] right now, or you can have 2 [reward type] in a [delay length] time. If you take this 1 [reward type] here you can get it right now, but you won’t get the other 2 [reward type]. If you want to wait for the two [reward type] you won’t get any right now, but you will get these two [reward type] when I come back [delay length]”. Children were then asked two check questions: “If you choose this 1 [reward type], when will you get it?” and “If you choose these two [reward type], when will you get them?” If they answered either one of these questions incorrectly the choice and the delays were restated and the check questions repeated. They were then asked the test question: “What would you like to do? Point to the tray which shows me which you would like.” Participants were scored a 0 on a trial if they chose the immediate reward, and a 1 if they chose the delayed reward; scores ranged from 0-12.

**Episodic Future Thinking interview*.*** This task was based on the episodic thinking interview used by Coughlin et al. (2014). Children were asked to describe specific personal events located at one of three temporal periods (*tomorrow, next week* and *a few months*). All children completed the task in the same order (with cues in the order tomorrow, next week, a few months), and they were asked to generate two events for each temporal period. Children were prompted to give a specific rather than continuous event (“Can you tell me about something that is going to happen to you just one time tomorrow/next week/in a few months from now?”). Children were encouraged to give further details using the following prompts: (1) Can you tell me more about what will happen? (2) Can you tell me more about where this will happen? (3) Can you tell me more about who will be there? Each prompt was used once for any given temporal period.

We also asked children to make a series of judgments following their event descriptions. Participants judged the speed with which the event came to mind using the 3-point scale presented in Figure 1. The clarity with which the event was imagined using a 6-point clarity scale (Figure 2) and the emotional valence felt when imagining the event using a 7-point scale (Figure 3).

**Future time perception.**In this task, which was broadly based on that used by Kim and Zauberman (2009), participants were asked to consider how far away eight future time points felt to them (1 day, 3 days, 1 week, 2 weeks, 3 weeks, 1 month, 2 months and 3 months). Kim and Zauberman used a procedure in which participants pulled a line along a computer screen; we made this task more concrete by getting children to pull a length of cord from a specially constructed dispenser (a wooden box of dimensions 160mm x 160mm x 150mm). The dispenser housed a large reel of cord. On one side of the box there was an aperture of diameter equivalent to the thickness of the cord, from which the cord could be pulled. A lever on the side of the box allowed dispensed cord to be wound back into the box.

Children were given the following instructions: “In this game I want you to think about how far away some times are in the future. I’m going to ask you to think about how far away tomorrow feels to you and how far away 3 months from now feels to you and how far away a number of times between tomorrow and 3 months from now feels to you. You are going to use this string to show me how far away times in the future feel to you. I’ll show you how it works”. The experimenter gave two demonstrations. For the first demonstration s/he informed participants that s/he was thinking about a ‘time very soon’, s/he then pulled out 90 mm of cord approximately (this corresponded to half a revolution of the winding handle on the side of the box). The cord was wound back after which s/he then informed the participants that s/he was now thinking about a ‘long time from now’, and pulled out 360 mm of cord approximately (2 revolutions of the winding handle). Participants then completed 8 trials in one of four counterbalanced orders (two of which began with the shortest judgment [1 day] and 2 of which began with the longest judgment [3 months]). The test question was as follows: “I want you to think about [tomorrow / 3 days from now / etc.]. How far away does that feel to you? Pull the string to show me how far away [tomorrow / 3 days from now / etc.] feels to you.” Once children had pulled out the string, the experimenter then cut off the length that had been pulled out for that trial and stored it before proceeding to the next trial. The length of each string was subsequently measured and recorded to the nearest 5 mm.

We first identified participants that failed to produce estimates that monotonically increased with actual distance of the time point in the future. Estimates at successive time points were compared: we classified as unsystematic responders those who produced two or more time estimates that decreased by greater than 20% over the estimate at the previous time point. Data from unsystematic responders was not included in the analyses that involved this task. For each participant we first transformed future time estimates into subjective units by setting the median string length for the shortest 1-day estimate equal one unit of subjective time. All time estimates were transformed into subjective units by dividing them by this number. We then used the least square method to fit power and linear functions to each participant’s data.

**Delay discounting.**This was a computerized delay-discounting task using hypothetical rewards. The delayed reward was £10 (UK pounds) and offered at one of four delays: 1 day, 1 week, 2 weeks and 3 months. The immediate reward ranged from 0 to £10 and varied in 50p increments. We employed an iterative optimizing procedure to hone in on indifference points at each delay (Richards, Zhang, Mitchell, & de Wit, 1999). On any given trial, the value of the immediate reward varies according to a random adjusting-amount procedure that is sensitive to the choice history of that subject at that delay. Each delay has four associated parameters (MaxTop, MinTop, MaxBot and MinBot) that at the outset are set to £10 (MaxTop and MinTop) or 0 (MaxBot and MinBot). These parameters are adjusted after each trial at that delay. The goal of the adjusting procedure (described below) is to allow the parameters to converge on an indifference point for that participant at that delay.

On each trial MaxTop and MaxBot represent the limits within which the immediate reward for that trial is randomly selected. So on the first trial at a given delay the immediate reward can take any value from 0 to £10 inclusive. After the participant makes their choice the values of the four parameters are updated according to the following rules:

*If the immediate reward is chosen and…*

* The immediate reward is > MinTop then MaxTop is made equal to the value of the immediate reward and all other parameter values remain the same.
* The immediate reward is <= MinTop but >= MinBot then Mintop is adjusted to the value of the immediate reward and MaxTop is adjusted to equal the previous value of MinTop prior to the participant’s choice and the value of MinBot and MaxBot remain the same.
* The immediate reward is < MinBot then MinBot is adjusted to equal the value of the immediate reward, MaxBot is set to equal 0, MinTop is adjusted to equal the value of the immediate reward and MaxTop is adjusted to equal the previous value of MinTop prior to the participant’s choice.

*If the delayed reward is chosen and…*

* The immediate reward is < MinBot then MaxBot is made equal to the value of the immediate reward and all other parameter values remain the same.
* The immediate reward is >= MinBot but <= MinTop then MinBot is adjusted to the value of the immediate reward and MaxBot is adjusted to equal the previous value of MinBot prior to the participant’s choice and the value of MinTop and MaxTop remain the same.
* The immediate reward is > MinTop then MinTop is adjusted to equal the value of the immediate reward, MaxTop is set to equal 10, MinBot is adjusted to equal the value of the immediate reward and MaxBot is adjusted to equal the previous value of MinBot prior to the participant’s choice.

This is an iterative process which runs until asymptote is reached i.e., there are no intervening values between the value of MaxTop and MaxBot. This procedure dispenses with the need to present every combination of delay and reward to the participant in the calculation of indifference points.

The task was programmed in E-prime Software (Psychology Software Tools, Pittsburgh, PA) and administered on a 15inch Dell laptop with touchscreen. Participants were told that they would be given a series of choices between two sums of money, one available immediately and one available after a delay. They were instructed to select the option that they preferred. Rewards and associated delays were presented serially each with an accompanying audio description of the value of the reward and the delay. Participants responded by tapping the picture of their preferred option.

The data were first subjected to a systematicity criterion (Johnson & Bickel, 2008). Unsystematic discounters were those that produced an indifference point for a given delay period that was £2 in value greater (i.e. 20% of the LLR) than the preceding delay period. The delay discounting data was then analyzed in a two-step process. First, a number of discount functions were fitted to each participant’s data. These discount functions were selected based on their normative (exponential discount function) or putative descriptive status (hyperbolic and quasi-hyperbolic discount functions). A fourth ‘noise’ model, a y-intercept model based on the mean indifference point that captures insensitivity to variations in delay was also fitted. The best fitting model for each participant was determined on the basis of Bayesian Information Criterion scores (BIC; Schwarz, 1978). In step two we derived model-based Area Under the Curve (model AUC), by applying integral calculus to the fitted function (Gilroy & Hantula, 2018). Model AUC scores are scaled to the interval 0-1 by dividing them through by the total area of the graph.

**WISC-IV subtests.** Due to the number of measures, children completed the study in two sessions, with the delay choice task and the EFT interview in the first session. The next session on the following day involved the delay discounting task, future time perception task and two WISC-IV subtests: the Block Design task followed by the Vocabulary task.

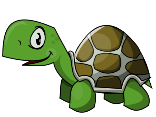


Figure 1. Scale used for speed judgements in the episodic future thinking interview.

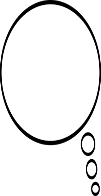
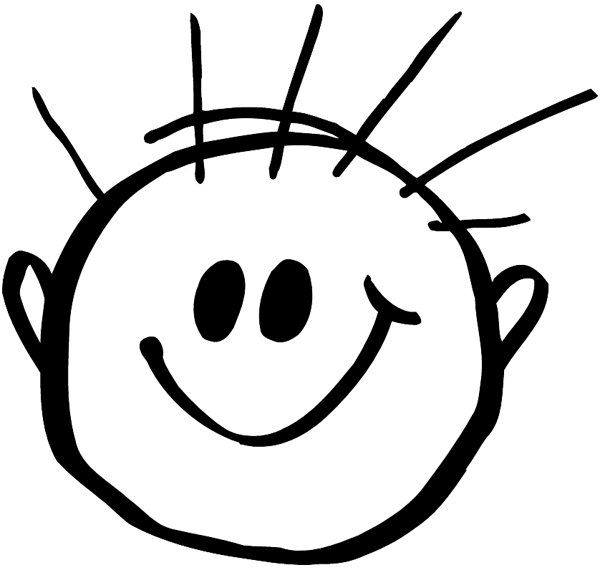
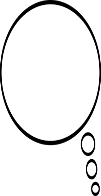
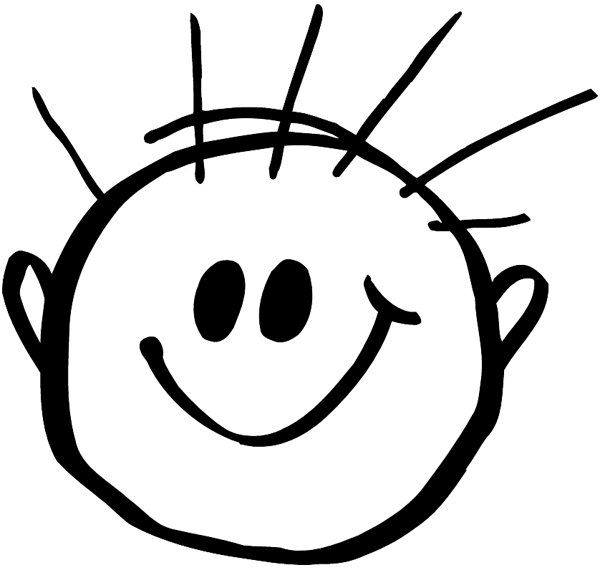
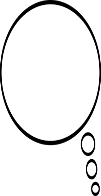
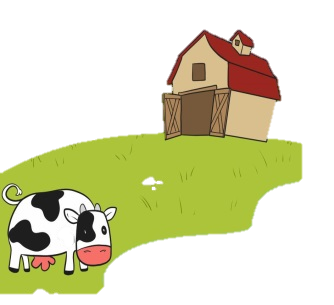
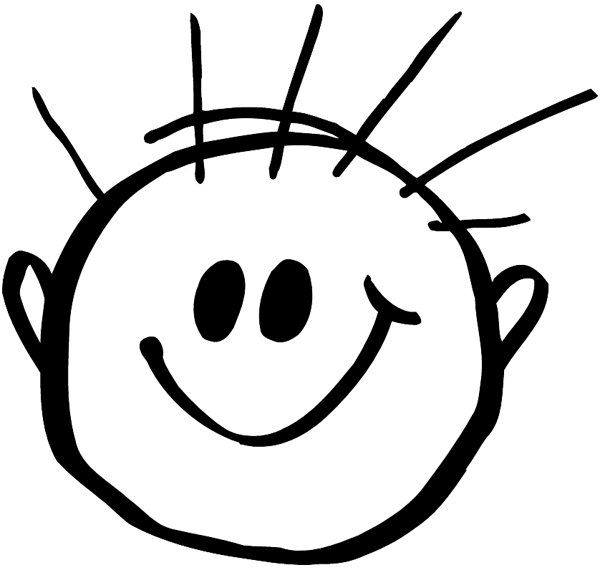
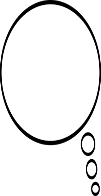
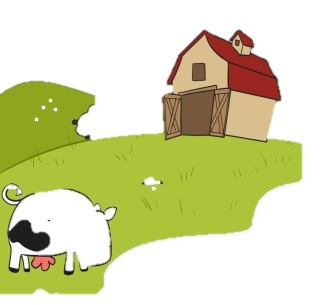
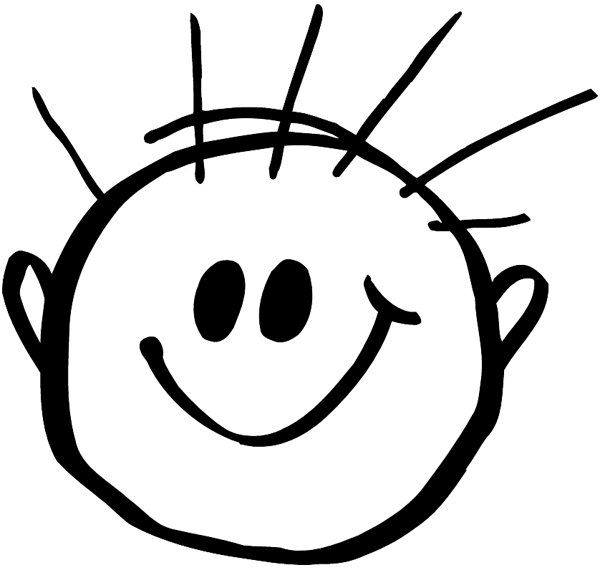
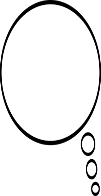
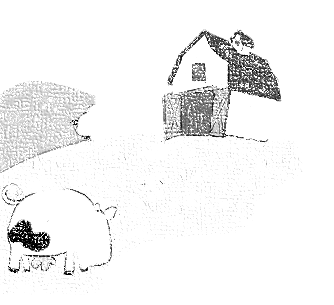
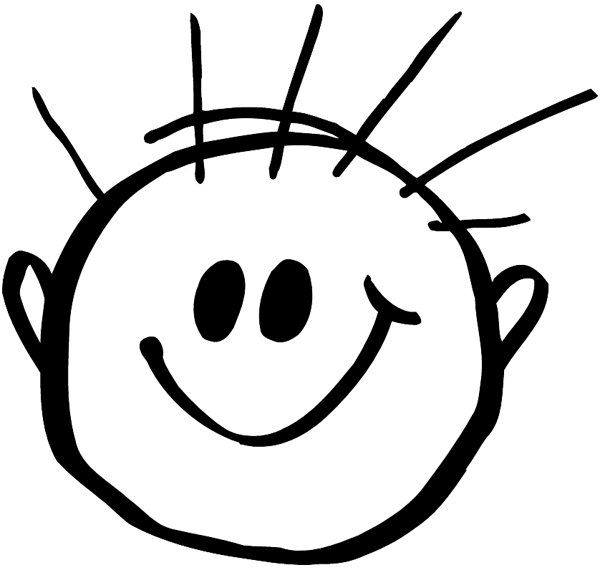
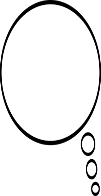
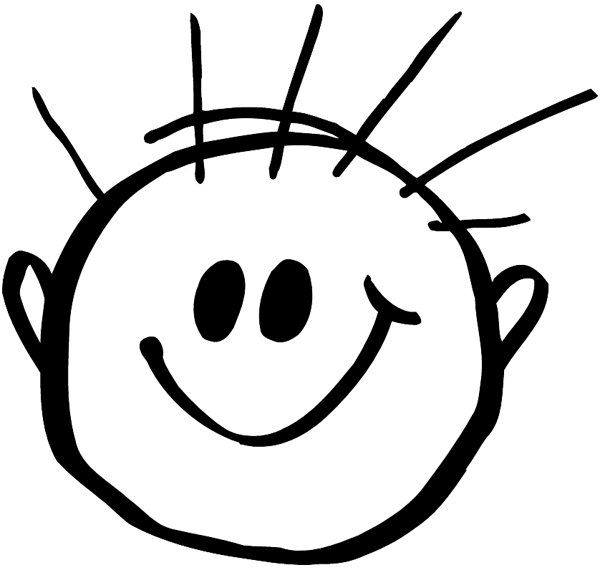


Figure 2. Scale used to elicit clarity judgements in the episodic future thinking interview.

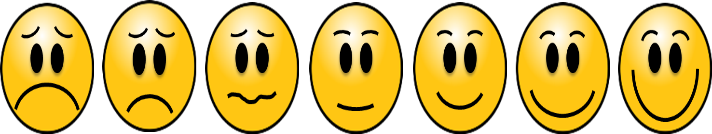


Figure 3. Scale used to elicit emotion valence judgements in the episodic future thinking interview.