ESM from “**Preparatory responses to socially determined, mutually exclusive possibilities in chimpanzees and children”**

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**Supplementary Information**

**Methods**

**Chimpanzee Participants.**

All five of the tested chimpanzees were born in captivity. Cassie and Holly have previously participated in experiments on mirror self-recognition, invisible displacement understanding, inferential reasoning, and metacognition. The chimpanzees live together in a large enclosure at Rockhampton Zoo where they have access to foliage and daily enrichment activities. Subjects had constant access to water throughout testing phases, and could leave the testing area at any time if they wished.

**Procedure.**

Prior to the demonstration and test phases with the parallel tube, participants were taught the basic action of catching a ball or grape with a simple straight tube that had only one opening and one exit. Participants had to catch three consecutive items in this practice phase before moving onto the demonstration phase. Across phases, children were told to place caught balls into a bucket beside them, and prior to the test phase they were told that if they caught lots of balls they would be rewarded with stickers (all children were rewarded with stickers at the conclusion of the experiment). Chimpanzees were rewarded by eating the grapes they caught, whereas missed grapes rolled out of their reach (though on a few instances the grape bounced into reach). Both the demonstration and test phases followed fixed pseudorandom orders. In the demonstration trials, the experimenter dropped the items into the tubes in the following order (from the experimenter’s perspective): *right, left, left, right, left, right*. In the test phases, the experimenter dropped the items in the following order (from the experimenter’s perspective): *right, left, left, right, left, right, right, left, right, left, left, right.* If the experimenter mistakenly deviated from this sequence, subsequent trials were adjusted to retain the overall distribution of the target emerging from each exit 50% of the time.

***Further chimpanzee trials.*** As described in the main text, two of the chimpanzee subjects (Alon and Leakey) tended to reach towards the location where the experimenter was holding the grape before the trial, and thus they frequently failed to cover either of the exits as the experimenter dropped it. We therefore decided to train these subjects in how to cover the bottom exits. During this training, the experimenter repeatedly held a grape directly above one of the tube openings and dropped it until the chimpanzee learned to cover the exit and catch the grape (first for the left tube, then for the right tube). Alon underwent this training phase after the first 12 trials (as he had covered a single exit on trial 1 only), whereas Leakey underwent training after 24 total trials (as she had covered a single exit on trials 10-12 of the initial testing phase). After training, test trials proceeded as normal.

**Results**

**GEE Analysis of Children’s Responses.**

The children’s responses across all 12 trials (see Figure 1) were analysed with a series of GEE models.

**Figure 1.** Percentages of children (by age group) and chimpanzees that covered two exits across all twelve trials.

The dependent variable was categorical (pass or fail), and the predictors (Age and Trial) were classified as continuous in order to check for linear effects. The repeated nature of the Trial variable was modelled with an autoregressive correlation matrix, such that trials closer in sequence were assumed to share more variance than trials further apart. Five GEE models were tested against each other, each containing a unique combination of predictors nested within the full factorial model (Age x Trial). These models included (i) Age, Trial, and the Age x Trial interaction, (ii) Age and Trial only, without the interaction, (iii) Age only, (iv) Trial only, and (v) a null model containing no predictors. Models were tested against each other on the basis of QIC value, with lower values representing a better fit to the data (Pan, 2001). A summary of the five models (best performing model highlighted in bold) is presented in Table S1 below.

**Table S1.** Summary of the five GEE models tested (selected model in bold).

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Model | Age effect | | Trial effect | | Age x Trial | | QIC |
| *χ2* | *P* | *χ2* | *p* | *χ2* | *p* |
| 1 | 4.41 | .036 | 1.97 | .161 | 1.73 | .189 | 464.44 |
| 2 | 7.77 | .005 | .03 | .617 | - | - | 465.13 |
| **3** | **7.74** | **.005** | **-** | **-** | **-** | **-** | **464.23** |
| 4 | - | - | .27 | .604 | - | - | 519.51 |
| 5 | - | - | - | - | - | - | 518.93 |

**Reward rates of participants when covering one of two exits.**

The trials on which children and chimpanzees covered only one of two exits (i.e., excluding trials where they covered both or no exits) were analysed in order to check whether reward levels were above chance. When covering one of two exits, children covered the correct exit (and so obtained the reward) on 132 out of 271 total trials (48.7%), which does not significantly differ from chance performance (50%), binomial test, two-tailed *p* = .716. Including only the first 12 trials, the chimpanzees covered the correct exit on 18 out of 32 total trials (56.2%) when covering a single exit, which also does not significantly differ from chance, binomial test, two-tailed *p* = .597. Thus, there can be no suggestion that participants were able to simply follow the experimenter’s movements and cover the correct exit to obtain the reward above chance.

Next, we separated the children who covered a single exit on trial 1 into two groups: those that covered the correct exit and obtained the reward (*n* =7) and those who covered the incorrect exit and did not obtain the reward (*n* = 12). A GEE analysis suggested that these two groups did not differ from each other in their likelihood of subsequently covering both exits, as including this Group variable did not improve the model fit (QIC increased from 123.37 to 135.16). Thus, there was no evidence that children were more or less likely to eventually use the optimal response as a function of the non-optimal response being rewarded on the first trial.

**Cross-study analysis of children’s performance (forked tube vs. social tube).**

We conducted an additional cross-study GEE analysis in order to compare children’s performance on the current task and the original forked tube task (7). First, data from the current study were combined with the data from the 2-, 3-, and 4-year-olds from the previous study (data from the previous study’s 2.5- and 3.5-year-olds were excluded, as there were no comparable age groups in the current study). Next, these combined data were entered into a series of GEE analyses nested within the full factorial Age x Trial model (as in the series of GEE analyses reported above). The best performing of these models (QIC = 1187.99) contained effects of Age and Trial, but no Age x Trial interaction. We then added the Study variable (forked tube vs. social tube) to the model, which greatly improved the model fit (QIC = 1058.02). The final model thus contained significant effects of Age, *χ*2­­(1) = 31.88, *p* < .001, Trial, *χ*2­­(1) = 11.92, *p* = .001, and Study, *χ*2­­(1) = 13.66, *p* < .001, with the Study effect suggesting that children of comparable ages performed better on the original forked tube task than the current social tube task.

**Additional Results from the Chimpanzees.**

Across the 12 trials Cassie switched between covering the right and the left exits four times, Holly switched once and Samantha consistently covered the left exit. The other two chimpanzees often failed to cover any exits, with Alon covering the left exit on trial one and Leakey the right exit on trials 10-12. Following additional training, Alon and Leakey registered 23 and 33 trials respectively before reaching 12 trials where they made a genuine attempt to catch the grape by covering at least one exit. Their 12 “genuine attempt trials” included two switches between sides for Leakey and two switches for Alon. Unlike any of the other chimpanzees in this study, Alon covered both exits on some later trials. In particular, he used both hands to cover the options on four trials (5, 7, 8 and 9), though returned to covering only one exit on trial 6 and on trials 10 to 12 (these final trials included another switch from covering the right to covering the left exit).

References

Pan, W. (2001). Akaike's information criterion in generalized estimating equations. *Biometrics*, *57*(1), 120-125.