\section{Experiment 1}

\hspace{1cm}Under both the ‘switching’ and the ‘non-maximizing’ definitions of exploration, children explored at a significantly higher rate than adults (proportion of switch choices, Figure 2A, 95\% CI [0.53, 0.79], d = 3.05, \textit{t}(26.47) = 10.55, \textit{p} < .001; proportion of non-maximizing choices, Figure 2B, 95\% CI [0.37, 0.61], d = 2.32, \textit{t}(44.02) = 8.03, \textit{p} < .001). Consequently, aggregated across both conditions and all trials, children earned fewer stars than adults (\textit{M\textsubscript{total stars}} = 332.0 vs. \textit{M\textsubscript{total stars}} = 450.13; Figure 2C, 95\% CI [-85.52, -150.73], d = -2.11, \textit{t}(39.97) = -7.32, \textit{p} < .001).

\hspace{1cm}Crucially, however, in the dynamic version of the task, children were much more likely to discover the change in reward structure (from a 1-star monster to an 8-star monster). By the end of 80 trials in the dynamic version, 93.3\% of children, but only 33.3\% of adults, correctly identified the monster that gave out 8 stars (Figure 2D, Chi-square test, $\chi$\textsuperscript{2}(1, N = 30) = 9.19, \textit{p} = .002 in favor of a relationship between age group and answers to this question). Of course, the only way to discover that one of the monsters had started giving out 8 stars was by exploring. Thus, while being a child was a good predictor of correctly identifying the 8-star monster (linear model, \textit{p} = .004), likelihood ratio test revealed evidence in favour of a model that also included switching ($\chi$\textsuperscript{2} = 22.46, \textit{p} < .001) or non-maximizing choices ($\chi$\textsuperscript{2} = 18.20, \textit{p} = .001). Within child participants, there was no evidence for a relationship between age and exploratory behavior (non-maximizing choices: \textit{p} = .088); switching: \textit{p} = .062).

\hspace{1cm}Importantly, children in both the static and dynamic conditions had a high overall accuracy across the five post-test questions about how many stars each monster gave out. Children’s responses were significantly above what chance would predict (\textit{M\textsubscript{correct}} = 100.0\% in the static condition; 84.0\% in the dynamic condition, \textit{t}-test against {mu} = .2, M = 0.84, 95\% CI [0.71, 0.97], \textit{t}(14) = 10.27, \textit{p} < .001). Adult post-test accuracy was also high (static: \textit{M\textsubscript{correct}} = 86.7\%; dynamic: 74.7\% when question about the 8-star monster was included; 85.0\% when question about the 8-star monster was excluded). Hence, children’s higher levels of exploration did {not} reflect greater difficulty learning or remembering the task structure. They knew the payoffs as well as or better than the adults did, but chose to continue exploring anyway.

\section{Experiment 2}

\hspace{1cm} Again, children switched between the monsters more often than adults did (Figure 2E, 95\% CI [0.53, 0.72], d = 3.04, \textit{t}(56.48) = 13.47, \textit{p} < .001), chose non-maximizing monsters more than adults did (Figure 2F, 95\% CI [0.42, 0.57], d = 3.08, \textit{t}(55.85) = 14.52, \textit{p} < .001), collected fewer stars than adults overall (336.64 vs. 453.57) Figure 2G, 95\% CI [-136.59, -97.28], d = 2.79, \textit{t}(54.2) = 11.93, \textit{p} < .001), and were more likely to detect the change in the dynamic condition than adults were (77.1\% vs. 34.9\% correctly identifying highest-payoff option, Chi-square test, $\chi$\textsuperscript{2}(1, N = 78) = 12.22, \textit{p} < .001; see Figure 2H).

Within child participants, there was no evidence of a relationship between age and exploratory behavior (non-maximizing choices: \textit{p} = .378; switching: \textit{p} = .286). As in Experiment 1, some children maximized reward and some adults explored. While being a child was a good predictor of correctly identifying the 8-star monster, likelihood ratio tests showed evidence in favour of a model that also included switching ($\chi$\textsuperscript{2} = 11.43, \textit{p} < .001) or non-maximizing choices ($\chi$\textsuperscript{2} = 10.52, \textit{p} = .001).

\hspace{1cm}As in Experiment 1, children in both the static and dynamic conditions had high levels of accuracy on all of the post-test questions, not just on the question about the 8-star monster (86.4\% for children across both conditions, 93.33\% in static, 83.43\% in dynamic; compared to 77.57\% for adults across both conditions, 85.28\% in static, 64.65\% in dynamic overall, 72.09\% in dynamic excluding 8-star question). Children's responses were significantly above what chance would predict (t-test against {mu} = .2, static: \textit{M} = 0.93, 95\% CI [0.86, 1.00], \textit{t}(14) = 23.01, \textit{p} < .001; dynamic: \textit{M} = 0.83, 95\% CI [0.75, 0.92], \textit{t}(34), \textit{p} < .001).

\section{Combined Analyses}

\subsection{Children perform better in a covertly changed environment than adults.} In addition to helping children detect the change in one monster’s payoff, does exploration have any benefits? Specifically, do children make better choices than adults after the change?

\hspace{1cm}To answer this question, we looked at how often children and adults picked the best (i.e., highest-payoff) monster over time (Figure 2I), combining data from Experiments 1 and 2. For this analysis, we examined the proportion of ‘best’ choices during each half of the dynamic task (i.e. the 6-star monster in the first half; the 8-star monster in the second half). During Trials 1-40, adults chose the best monster more often (82.1\% of trials) than children (38.4\% of trials) (95\% CI [0.82, 0.38], d = 2.52, \textit{t}(85.83) = 12.72, \textit{p} < 0.001). During Trials 41-80, however, adults picked the best monster significantly {less} often (15.8\% of trials) than children (24.7\% of trials) (95\% CI [-0.158, -0.017], d = -0.45, \textit{t}(85.26) = -2.44, \textit{p} = .017).

\hspace{1cm}In the static version of the task, there was no drop in adults' performance during the second half of the task. During the first half of the static version, adults chose the best monster significantly more than children (85.0\% vs. 44.1\%; 95\% CI [0.30, 0.51], d = 2.62, \textit{t}(26.41) = 7.98, \textit{p} < .001). During the second half, adults still chose the best monster significantly more than children (95.5\% vs. 49.5\%; 95\% CI [0.34, 0.58], d = 2.78, \textit{t}(25.68) = 8.10, \textit{p} < .001).

\hspace{1cm}These results suggest that over time, high levels of exploration in a changing environment can lead to greater rewards. Adults' behavior may be close to optimal in the static version of the task, but the drawback of such behavior is shown by the dynamic version, where the same behavior becomes sub-optimal after a change in the environment. After this change, children were more likely to identify and choose the highest reward option. Overall, adults still won more stars than children, even in the dynamic version. However, if the difference in payoffs among the monsters in our game had been greater (e.g., if the one-star monster covertly started giving 30 stars), children would have earned more stars than adults after 32 trials. This illustrates the long-term benefits of exploration in dynamic or not-fully-known environments.

\subsection{Switching behavior across trials} We wanted to know how rates of exploratory behavior changed across the task. Specifically, we wanted to know whether children’s level of exploration remained high throughout the task or whether children at some point began to show adult-like patterns of maximizing reward by exploring less. We looked at the proportion of switch trials broken up into blocks of 20 trials. As Figure 2J shows, adults explored more during the first 20 trials than in later trials. Children however, remained highly exploratory for the duration of the task. A linear model predicting switch by block did not find evidence of change throughout blocks (\textit{p} = .075). For adults, however, block was predictive of the proportion of switch trials (\textit{p} < .001). This suggests that children stay highly explorative through the whole task while adults tend to explore more at the beginning of the task.