Abstract

Humans have adapted well to diverse environments in part because of their ability to efficiently acquire information from their social environment. However, we still know very little as to how young children acquire cultural knowledge, and in particular the circumstances under which children prioritize social over asocial learning. In this study we ask whether children will selectively adopt either a majority-biased or a payoff-biased social learning strategy in the presence or absence of asocial learning. Three- to 5-year-old children (n = 117) were first shown a video in which four other children took turns in retrieving a capsule housing a reward from one of two boxes. Three of the children (the 'majority') retrieved a capsule from the same box and a single individual (the 'minority') retrieved a capsule from the alternative box. Across four conditions we manipulated both the value of the rewards available in each box (*equal* or *unequal payoff*), and whether children had knowledge of the payoff before making their own selection. Results show that children adopted a majority-biased learning strategy when they were unaware of the value of the rewards available but adopted a payoff-biased strategy when the payoff was known to be unequal. We conclude that children are strategic social learners who integrate both social and asocial learning to maximize personal gain.

Keywords: Selective learning; Cultural learning; Social learning; Majority bias; Payoff bias

The ontogeny of selective social learning: Young children flexibly adopt majority or payoff-based biases depending on task uncertainty

I. Introduction

The human capacity to respond adaptively to diverse environments, coupled with cultural transmission, has allowed our species to accumulate unprecedented forms of knowledge and skills that are often routinely maintained across successive generations (Boyd & Richerson, 1985; Henrich, 2015; Laland, 2017). The evolutionary success of this adaptive complex is in part a consequence of the existence of a variety of transmission biases, both direct and indirect, that allow learners to efficiently acquire relevant information from their cultural environment (Boyd & Richerson, 1985; Kendal et al., 2018). Indirect biases may influence the decision to copy based on characteristics of others rather than the behavior itself. For example, in 'model-based biases', observers show a preference for copying models displaying a specific characteristic (e.g., prestige (Chudek et al., 2012; McGuigan, 2013) or competence (Birch et al., 2008; Corriveau & Harris, 2009)). An example of alternative 'frequency-based biases' is where observers adopt the most common behavior on display, such as that shown by a majority of other individuals (Corriveau et al., 2009; Haun & Tomasello, 2011; Herrmann et al., 2013; Morgan et al., 2014). In contrast, direct biases are based on the content of the behavior itself, such as 'payoff-based biases' where observers adopt what they perceive to be the most beneficial behaviour among alternative options (Kendal et al., 2018; Rendell et al., 2011).

Despite the important role that such social learning biases likely play in early development (Price et al., 2017), a period when children are rapidly acquiring cultural knowledge, we are only beginning to understand the way in which such biases emerge and influence each other. We also know little as to how these social learning biases interact with information that children acquire asocially (through individual learning), a learning capacity that may be particularly important in diverse and changing environments (Laland, 2004). Here we aim to extend our understanding of the emergence of, and relationship between, majority-based and payoff-based transmission, and explore how the interplay between these transmission biases is influenced by the presence or absence of asocial learning.

In many contexts an individual faced with solving a novel problem may usefully look to solutions that already exist within their social group rather than (often inefficiently or even riskily) attempting to invent their own solution. The solution displayed by the majority of the group - which combines the prior individual learning efforts of multiple individuals - is often a productive and reliable solution for a naïve individual to adopt (Haun et al., 2012; Whiten, 2019). This bias toward adopting the majority behavior is already evident in the early stages of development across a variety of domains, including action copying (e.g., Burdett et al., 2016; Haun et al., 2012; Herrmann et al., 2013; Hu et al., 2013; McGuigan & Burgess, 2017; McGuigan & Robertson, 2015; Wilks et al., 2016), quantity judgements (Morgan et al., 2014), perceptual judgements (Corriveau & Harris, 2010; Haun & Tomasello, 2011; McGuigan & Stevenson, 2016), moral and prosocial decision making (House & Tomasello, 2018; Kim et al., 2016; McAuliffe et al., 2017) and verbal testimony (e.g., Chen et al., 2013; Corriveau et al., 2009; Fusaro & Harris, 2008; Harris, 2012; Schillaci & Kelemen, 2014). It would therefore seem that the pull of the majority is strong in the young of our species.

However, blindly copying the most common behavior witnessed, although oftentimes useful, has the potential to lead individuals to adopt maladaptive traits or to block rare, but-high quality variants. Children do not blindly copy; rather, studies have shown that children are not blanket conformists. Instead children adopt the approach of the majority selectively, for example by copying the majority more frequently when learning normative than instrumental skills (Clegg & Legare, 2016; Herrmann et al., 2013), when the majority is unanimous (Evans et al., 2018), when the peer majority is the same age or older (McGuigan & Burgess, 2017), and when the task solutions are more complex than an individual is likely to achieve by their own efforts (Morgan et al., 2014). Children also flexibly adjust their behavior in instances where following the majority comes at a cost, including a loss of efficiency (Morgan et al., 2014; Schillaci & Kelemen, 2014), accuracy (Wilks et al., 2014), privileged information (Einav, 2014), or a more valuable reward (Flynn et al., 2018). In addition, when a child's prior knowledge conflicts with that of the majority, they are less likely to rely on social learning (Chan & Tardif, 2013; Morgan et al., 2014). Thus, it appears as though children have evolved to be savvy social learners who show both selectivity and flexibility in the likelihood with which they copy a majority behavior (Evans et al., 2018).

The studies described above provide tentative evidence that the existence of a cost (a negative payoff) for copying the majority behavior reduces the likelihood that majority-biased transmission will occur. However, studies that have directly examined payoff-biased transmission in childhood are rare and have to date employed only a single model (Vale et al., 2017). This neglect is somewhat surprising, since the introduction of differently valued behaviors into a social group allows for a direct assessment of the benefit of a particular behavior. This is not possible when an individual is provided with frequency information alone. In Vale et al.'s (2017) recent exploration of payoff-based transmission, 4- and 5-year-old children were initially allowed to exchange tokens for either a lower or higher value reward (personal experience) before being exposed to the preference of a female model (social experience). Children's choice of reward was influenced both by personal and social information, with children being most likely to adopt the modeled solution if the value of the personal reward was low and the value of the modeled reward was high. Thus, young children appeared to be able to gauge the potential benefit of each option and display payoff-biased transmission to maximize personal gain in response to the behavior displayed by a solitary model. What remains unknown is whether children make similar judgements when exposed to differing payoffs within the more complex context of a group majority. In line with predictions from theoretical models individuals should ignore social information when they have prior knowledge but rely on social learning when they are uncertain of the payoff involved (Kendal et al., 2005).

To address this gap the current study systematically varied the presence of majority and payoff information within the context of varying task uncertainty. Specifically, we explored the interplay between majority-based and payoff-based transmission biases by adapting a paradigm used to examine majority-biased transmission in previous studies (Haun et al., 2012, 2014). Haun and colleagues presented children (and great apes) with a reward retrieval task in which rewards of equal value could be obtained from one of three differently colored boxes. In the 2012 study naïve participants selected a box after observing the choice made by four peer models, three of whom (the majority) selected one box, whilst the remaining model (the minority) selected an alternative box (Haun et al., 2012). Despite all models receiving an identical reward, rendering the choice of box somewhat arbitrary, the observing children most often opted for the box chosen by the majority. In a follow-up study this preference for the majority selection was witnessed even at the expense of an individually acquired strategy. Participants who were allowed to acquire a preference for one of the boxes before observing the peer models frequently abandoned their own selection in favor of that of the majority (Haun et al., 2014).

Here we extend the Haun et al. (2012; 2014) paradigm to explore the influence of a peer majority on the reward retrieval behavior of 3- to 5-year-old children across two pairs of conditions in which: 1) the payoffs available to the majority and the minority were either the same or differently valued (*equal* versus *unequal payoff*), and 2) the value of the payoffs was either known or unknown to the observer prior to the demonstration (*value known* versus *value unknown*). In each condition children were presented with multiple trials, providing scope for strategy switching and the discovery of the respective payoffs in those conditions in which the value of the reward was initially unknown. In this way we could examine whether children use flexible strategies for social versus asocial learning initially and then adapt other strategies in subsequent trials (Kendal et al., 2005). Relevant work has suggested that children and adults may use opportunities to explore before converging on the most optimal solution or choice (Gopnik, 2020; Kirkpatrick et al., 1983). Under *equal payoff* conditions (both *value known* and *value unknown*) we predicted that children would show a majority-based bias across trials that would be particularly strong in the early trials of the *value unknown* condition (as children had only the information provided by the majority to act upon). In contrast under *unequal payoff* conditions (both *value known* and *value unknown*), where the majority obtained a reward of lower value than the minority, we predicted that a payoff-based bias would take precedence over a majority-based bias as children sought to maximize personal gain. This payoff-based bias was predicted to be evident from the first trial of the *value known* condition (where children knew the unequal value of the rewards from the outset), and from the point at which the children discovered the payoff imbalance in the *value unknown* condition (with a majority-based bias predominating up to that point); see Table 1.

Table 1.

Predicted outcomes in a 2 x 2 experimental design exploring children's choices according to reward payoff and whether the reward value was known or unknown

		Prior knowledge of reward value	
		Value known	**Value unknown initially**
Payoff	**Equal payoffs**	Children likely to show weak majority bias from 1st trial	Children likely to show strong majority bias in 1st trial that reduces across trials
	Unequal payoffs (majority lower value, minority higher value)	Children likely to show payoff bias from 1st trial	Children likely to show strong majority bias in 1st trial then switch to payoff bias across trials

2. Methods

2.1 Participants

One hundred and seventeen 3- to 5-year-old children (60 females, 57 males; *mean age* = 60.49 months, *SD* = 6.89 months, range = 45-72 months) took part in the study. Eleven of the children were excluded as they either indicated a preference for the lower value reward (N = 2), witnessed another child participate (N = 1), mentioned a preference for a particular color of reward housing (N = 5), or through experimenter error (N = 3). From the remaining 106 participants, 25 children (12 female, *mean age* = 59.32 months, *SD* = 8.97 months) were allocated to a '*Value Unknown - Unequal payoff*' condition, 28 children (13 female, *mean age* = 60.71 months, *SD* = 6.87 months) to a '*Value Unknown - Equal payoff*' condition, 27 children (13 female, *mean age* = 61.30 months, *SD* = 7.47 months) to a '*Value Known - Unequal payoff*' condition, and 26 children (16 female, *mean age* = 60.81 months, *SD* live= 6.61 months) to a '*Value Known - Equal payoff*' condition.

Ethical approval for the study was granted by [retracted for submission] University. Informed consent was obtained from both the parents (written consent), and the children (verbal assent) prior to their participation. Due to the opportunistic nature of our data collection within the environment of a science museum no specific demographic data was collected, however the vast majority of our participants were White European and all spoke fluent English. The study was conducted pre-OSF. However, prior to commencing the study we aimed to stop data collection at 25 children per condition, a sample size that was derived from that used in similar work (Burdett et al., 2018; Kenward, 2012; McGuigan & Burgess, 2017).

2.2 Design

Participants were allocated to one of four conditions in a 2 (Prior knowledge: *value known* or *unknown*) x 2 (Payoff: *equal* or *unequal*) between-participants design (see Table 1). Irrespective of the condition to which they were allocated, each child first viewed a video demonstration showing a group majority retrieve a plastic capsule (contents hidden) from one of two boxes, before next being allowed to retrieve their own capsule on each of 5 trials. In two *Value Unknown* conditions (*equal* or *unequal payoff*) the children did not know the value of the rewards contained in either box prior to retrieving a capsule on trial 1. In contrast, in two *Value Known* conditions (*equal* or *unequal payoff*), children were allowed to pull apart a capsule from each box before viewing the video demonstration, and thus entered trial 1 with knowledge of the contents of each capsule. When unequal payoffs were employed one box contained exclusively lower value rewards (black stickers), and the other box contained exclusively higher value rewards (colorful animal stickers). In contrast, under *equal payoff* conditions each box contained exclusively higher value rewards. The relative value of the higher and lower value rewards was established prior to the study by asking 15 preschool children (different to those who took part in the main study) to indicate their preferred sticker (all 15 preferred colorful over black). In order to aid the children in distinguishing between the different boxes, they contained capsules of different colors (green or blue).

2.3 Apparatus/Stimuli

Apparatus. The apparatus comprised two identically sized clear boxes, measuring 22 x 17 x 15 cm (see Fig. 1), each of which was filled with opaque plastic capsules housing rewards. To ensure that there were no color or position, biases the color of the capsule containing the higher/lower value rewards, and the left-right position of the box containing the green/blue capsules was fully counterbalanced across the four conditions.

Task demonstration. In order to show the participant, the selection made by a majority of their peers, 4 five-year-old children (2 boys and 2 girls) from a local school were trained as models, before acting in a video demonstration. In all four conditions the video showed three of the children (the majority) each select 1 capsule from the same box, and a single child (the minority) select 3 capsules from the alternative box. The content of the capsules selected by the peer models in the video display was not shown, allowing the role of prior knowledge of reward value to be manipulated. The color of the capsule (green or blue) containing the higher/lower value rewards, the left-right position of the green/blue capsules, the gender of the model, and the order in which the minority and the majority children were shown in the demonstration were counterbalanced across the four conditions.

2.4 Procedure

Children and their parents were invited to take part in the experiment during their visit to a science center in Scotland, UK. Following written consent from the parents, and verbal assent from the children, each child was led to a quiet area to participate. Children were seated at a small table and shown two clear boxes, one filled with green capsules and the other with blue capsules. The experimenter said to the child, "I have some boxes here filled with capsules. All capsules have different stickers inside." In the *Value Known* conditions only, children were allowed to open one green capsule and one blue capsule to see what stickers were inside. Each capsule held one sticker and children were allowed to keep both stickers. From this point on, the procedure in the *Value Known* and *Value Unknown* conditions was identical, with the experimenter instructing the children that, "You will be able to get some stickers from the capsules, but first, I'm going to show you some videos of children just your age. They are all going to choose some capsules with stickers. After you watch the videos, you will be able to get your own stickers. Let's watch the videos."

The video began with all four of the models waving to the participant. As the children in the video waved, the experimenter said, "Here are four children who want to say hello to you! Hello! Now, let's see what capsules they chose." The participants then viewed, in a counterbalanced order, a single child (the minority) chose a capsule from the same box three times, and three different children (the majority) each select a capsule from the other box (see Fig. 1). The content of the capsules (i.e., lower or higher value reward) selected by the children in the video was not shown. As a memory aid, upon completion of the video, the children were presented with a still screen shot that comprised 6 pictures showing the selections made by both the minority (3 pictures), and the majority (3 pictures-one of each individual). The still screen shot was available as a memory aid throughout all 5 trials and was accompanied by a verbal reminder of the selections made by the minority/majority, "So, *this* girl/boy chose the green/blue capsules, and *they* chose the green/blue capsules." As children younger than that tested here have performed successfully on a similar, but more complex, version of the task (Haun, 2012) we were confident that the task was well within the capabilities of our sample.

The experimenter then placed the two boxes in front of the children and said, "Which capsule would you like to choose?" After their first choice of capsule, children were allowed to open the capsule and keep the sticker. Children were then allowed to choose four more capsules, and asked to open each capsule after each choice, allowing us the opportunity to examine children's flexibility in reward selection across trials. On completion of the experiment, all children were asked to explain their initial selections "Why did you choose this color capsule first?", and indicate which type of sticker they preferred, "Which stickers do you like best, the black stickers or the colorful stickers?". The vast majority of children (n = 106) indicated that they selected the capsule as it contained a colorful animal sticker, with a small number of children (n = 5) indicating that they made their selection based on the colour of the capsule. Children who indicated a preference for the black stickers were excluded from the study (N = 11) as their preferred sticker type was in line, rather than in conflict, with the behavior of the majority in the *Unequal payoff* conditions.

[Figure 1 here]

2.5 Coding

For each of the 5 trials the experimenter live coded whether the child selected a reward from the box chosen by the majority, or the box chosen by the minority.

2.6 Data Analysis

Of primary interest in our first set of analyses was whether the participants would select the option chosen by the majority or the minority in trial 1 of each of the 4 conditions. To determine whether the children displayed a majority/minority preference we used a binomial test to directly compare the number of children in each condition that chose the minority or the majority selection (test proportion of .5). We opted to apply a one-tailed binomial analysis for this purpose as we had specific predictions as to the direction of the effect (see Fig. 2). In a second set of analyses, we were interested in whether children would maintain their initial preference or switch approach between trial 1 (T1) and trial 2 (T2). In order to explore this possibility we first compared the number of children selecting the minority/majority option in trial 1 to the number of children selecting the minority/majority option in trial 2 of each condition using chi-square analyses, before using binomial tests to more specifically explore the nature of the switch (T1-T2: both majority choice; T1T2: both minority choice; T1-T2 majority-minority choice or T1-T2 minority-majority choice; test proportion of .25) Once again, we opted to use one-tailed analysis for this purpose as we had specific predictions as to the direction of the effect (see Figs. 2; 3a; 3b). In a third set of analyses, we were interested in whether children would switch approach across trials 3 to 5. Mirroring exactly the approach for trial 1/2 we used chi-square analyses to compare the number of children in each condition that selected the minority/majority option in trial 2 to the number of children that selected the minority/majority option in trial 3, before repeating the analysis to compare trial 3 to trial 4, and trial 4 to trial 5. In a final set of analyses, we were interested in the selection made by individual children across each of the 5 trials. In order to explore individual performance, we used a series of binomial tests to compare the number of children in each condition that opted for the majority selection on 0, 1, 2, 3, 4, or 5 trials (test proportion of .17; see Fig.4). We used two-tailed analyses for this purpose as we predicted that children would likely vary in their approach (some following the majority and some following the minority). For each of the binomials 95% confidence intervals were calculated using the Clopper Pearson interval.

3. Results

In the analyses that follow we first ask whether the participants' choice of box in trial 1 was consistent with the adoption of either a majority or a payoff-based social learning strategy. We next ask whether any bias evident in trial 1 shifted as participants were provided with the opportunity to open, and thereby gain knowledge of the (un)equal payoff housed within the capsules, on a further 4 trials. Preliminary analyses revealed that there was no significant difference in children's tendency to follow the majority irrespective of the gender of the minority model, the color of the capsules containing the higher and lower value rewards, or the location of the box (left/right). These factors are therefore excluded from all subsequent analyses.

3.1 Do children copy the majority or maximize personal payoff in trial 1?

3.1.1 Value Unknown conditions. We first examined trial 1 performance in the two conditions in which children had no knowledge of the value of the rewards prior to making their first selection (*value unknown* conditions). As predicted when children were naïve to the value of the rewards contained within each box they relied on the information provided by their peer group, selecting the box chosen by the majority significantly more often than the box chosen by the minority in both the *unequal* (18 majority vs 7 minority; p = .022, 95% CI [.51, .88], test proportion .5, one-tailed binomial test) and the *equal* (19 majority vs 9 minority; p = .044, 95% CI [.48, .84], test prone-tailed binomial test; see Fig. 2) payoff conditions. This suggests that in the absence of other information to guide their choice, children were influenced by the selection made by the majority.

[Figure 2 here]

3.1.2 Value known conditions. Next, we examined performance in the first trial of those conditions in which the value of the rewards was known to the children prior to observing the behavior of the majority (*value known* conditions). When the option selected by the majority was of lower value than that selected by the minority, the children did not follow the less profitable majority behavior, and instead opted to maximize personal payoff by selecting a capsule from the box containing the higher value rewards (19 higher value minority vs 8 lower value majority; one-tailed binomial test, p = .026, 95% CI [.50, .86], test proportion of .5,). However, when the rewards were equally valued (both boxes contained higher value rewards), the children were as likely to choose the box selected by the majority as they were the box selected by the minority (12 majority vs 14 minority; one-tailed binomial test, p = .423, 95% CI [.27%, .67], test proportion of .5; see Fig. 2), suggesting, counter to predictions, that the children did not show an arbitrary preference for the majority behavior.

Unequal payoff - influence of prior knowledge. In addition to exploring performance in each individual condition we were interested in the relative impact of prior knowledge under those two conditions in which the payoff was unequal. We anticipated that when knowledge of the unequal payoff was pitted against the behavior of the majority that fewer children would follow the majority as compared to those instances where the payoff imbalance was yet to be discovered. A chi square analysis supported this prediction with children opting for the reward selected by the majority significantly less often when the payoff imbalance was known from the outset (8 from 27 children), than when the imbalance was unknown (18 from 25 children); χ^2=7.39, p =.007, φ = .544.

3.2 Do children shift strategy between trials 1 and 2?

As well as exploring whether the participants opted to follow the majority or maximize personal payoff in their first attempt, we were interested in whether children switched, or indeed maintained, their initial strategy across the multiple trials presented. In doing so we aimed to obtain an indication of the strength of any majority or payoff bias revealed in the children's initial selections, and whether the strength of any such bias was influenced by the value of the reward initially received and the subsequent discovery of the payoff imbalance in the *value unknown* conditions. We first consider performance in trial 2.

3.2.1 Unequal payoff conditions. The total number of children opting for the majority approach changed dramatically between trials 1 and 2 in both *unequal payoff* conditions, with 60% and 67% of the children switching their choice of box in the value unknown and known conditions respectively (see Fig. 3a). In the *value unknown* condition most of the children initially opted to follow the majority (18 majority vs 7 minority) and received a relatively unappealing lower value reward for doing so. By contrast in trial 2 the children shifted their approach with most now selecting, and thereby discovering the more highly valued reward available in the box chosen by the minority (9 majority vs 16 minority; $x^2(1) = 6.52$, $p = .022$, $\varphi = .511$). An inspection of performance at the level of the individual children (with a test proportion of .25) revealed that the shift in behavior between trials 1 and 2 was underpinned by significantly more children switching from the majority to the minority selection (48%) as opposed to the children (grouped together) who chose alternative approaches (switch from minority to majority = 12%, no switch = 40%; one-tailed binomial test $p = .011$; 95% CI [.28, .69], test proportion of .25; see Figure 3a).

In the *value known* condition, somewhat surprisingly (as children were aware of the unequal value of the rewards), children also switched approach between trial 1 (8 majority vs

19 minority) and trial 2 (18 majority vs 9 minority strategy; $x^2(1) = 7.42$, $p = .013$, φ = .524; see Fig. 3a). Rather than sticking with the minority selection and receiving a second higher value reward, the children switched approach to follow the majority behavior, thereby obtaining a less valuable reward in trial 2. This shift was underpinned by individual children more frequently switching from the minority to the majority selection (52%) as opposed to the alternative approaches (switch from majority to minority = 15%, no switch = 33%; one-tailed binomial test $p = .002$; 95% CI [.32, .71], test proportion of .25, see Fig. 3a).

[Figure 3a here]

3.2.2 Equal payoff conditions. In the *equal payoff* conditions, there was no cost to the participant for switching from one box to another as both contained higher value rewards. In the *value known* condition where children were aware that the rewards were equally valued there was no significant shift in the number of children adopting the majority approach between trials 1 and 2 ($x^2(1) = .693$, $p = .579$, φ = .163; see Fig. 3), or in the strategy adopted at the individual level (see Fig. 3b). In contrast in the *value unknown* condition children shifted from adopting the majority approach in trial 1 (19 majority vs 9 minority) to adopt the minority approach in trial 2 (11 majority vs 17 minority; $x^2(1) = 4.595$, $p = .030$, φ = .405, one-tailed; see Fig. 3b), perhaps to explore the rewards on offer. This pattern was reflected in the performance of the individual children (test proportion of .25) where the most common strategy was to switch from the majority to the minority selection across the first two trials (54%) rather than adopting an alternative approach (switch minority to majority = 25%, no switch = 21%, one-tailed binomial test $p = .001$; 95% CI [.34, .73], test proportion of .25; see Fig. 3b). The least common approach in the *value unknown* condition was to stick with the minority selection with only 7% of the children opting for the minority selection in trials 1 and 2 as opposed to other approaches (one-tailed binomial test $p = .017$; 95% CI [.09, .24], test proportion of .25; see Fig. 3b).

[Figure 3b here]

3.3 Do children switch strategy across trials 3-5?

We presented children with three additional trials to provide them with ample opportunity to both open a capsule from each box, and subsequently change approach. This opportunity was particularly important in those conditions where the value of the value of the rewards was initially unknown to the participants. The degree of switching in the later trials varied across conditions with children in the *value known unequal payoff* condition alternating between the minority and the majority options in trials 2 and 3 ($x^2(1) = 4.747$, $p = .028$, $\varphi = .419$, one-tailed), trials 3 and 4 ($x^2(1) = 3.63$, p = .050, $\varphi = .367$, one-tailed), and trials 4 and 5 ($x^2(1) = 7.500$, $p = .007$, $\varphi = .527$, one-tailed; see Fig. 2). Such switching was not evident in the later trials of the remaining three conditions. Indeed, the majority bias that was evident in trial 1 of the two *value unknown* conditions did not reappear in the later trials, with only the payoff bias initially revealed in the *value known unequal payoff* condition in evidence by the final trial (trial 5: 7 majority vs 20 minority; one-tailed binomial; $p = .038$, 95% CI [.11, .46], test proportion of .5; see Fig. 2. The vast majority of children in the *value unknown* conditions (84% *unequal* and 86% *equal payoff* respectively) had retrieved a reward from each box by the end of trial 5 (see supplementary Fig. 1). Importantly, it appeared that discovering the existence of the payoff imbalance influenced the selection made, with those children in the *value unknown unequal* payoff condition who had retrieved a reward of each type displaying a significant payoff bias (38% majority vs 62% minority; one-tailed binomial test, $p = .049$, 95% CI [.48, .75], test proportion .5; see supplementary Fig. 2).

The tendency of the children in the *unequal payoff* conditions to adopt, either from the outset or upon discovery of the payoff imbalance, a social learning strategy in which they maximized personal gain at the expense of the majority behavior is mirrored when we consider the approach of individual children (see Fig. 4). We compiled the responses of each participant across all 5 trials into 6 categories that reflected the strength of the respective bias. In 3 'majority bias' categories a child could be categorized as exclusively (child matched majority on all 5 trials), strongly (matched majority on 4 trials), or weakly (matched majority on 3 trials) biased towards the majority. Likewise, in 3 'minority bias' categories a child could be categorized as exclusively (matched majority on 0 trials), strongly (matched majority on 1 trial), or weakly (matched majority on 2 trials) biased towards the minority.

In line with predictions in the two *unequal payoff* conditions, the children displayed a preference for the minority, most often opting for the minority selection in 3 of the 5 trials (*value unknown*, weak payoff bias = 36%; two-tailed binomial test, $p = .032$, 95% CI [.18, .58], test proportion of .17; two-tailed binomial test; *value known*, weak payoff bias = 59%, $p < .001$, 95%CI [.39, .78%], test proportion of 17; see Fig. 4). This payoff bias was particularly powerful in the *value known* condition where 78% of the children displayed a minority bias of some sort (either weak, strong, or exclusive) as opposed to a majority bias (either weak, strong, or exclusive) (two-tailed binomial test, $p = .006$; 95% CI [.58, .91], test proportion of .5; see Fig. 4). In contrast, children in the *equal payoff* conditions varied in their approach depending on whether they had prior knowledge of the reward value. When children were initially unaware that the rewards were equally valued, as predicted, they evidenced a majority bias, with a weak majority bias being the most common approach adopted (*value unknown*, weak majority bias = 50%, $p < .001$, 95% CI [.31, .69], test proportion of .17, two-tailed binomial test; see Fig. 4). However, counter to predictions, when children were aware that the rewards were equivalent, despite the most common approach on display was to opt for the minority selection on 3 of the 5 trials (*value known*, weak minority bias = 39%; two-tailed binomial test; $p = .014$, 95% CI [.20, .59], test proportion of .17; see

Fig. 4), the children were as likely to adopt a majority approach (51%) of some type (either weak, strong, or exclusive) as they were a minority (49%) approach.

[Figure 4 here]

3.4 Summary of Results

In sum, in the first trial of the two conditions in which children were unaware of the value of the rewards available, children relied on social learning and copied the approach adopted by the majority. In contrast, under conditions where the value of the rewards was known, the approach adopted by the children varied according to the payoff available. When the value of the rewards was known and equal, children were equally likely to copy the majority or minority selection. In contrast, when the value of the reward was known to be unequal, the children were more likely to maximize payoff, at the expense of copying the majority behavior. When presented with additional trials the children were somewhat exploratory, and upon individual discovery of unequal payoffs (when this knowledge was not available initially), the children adopted a payoff bias.

4. Discussion

We employed a reward retrieval task to investigate whether children would adopt a majority-biased, or a payoff-biased strategy when the value of the available rewards (*equal* or *unequal*) was either known or unknown prior to retrieval. Our results are the first to demonstrate that children's approach to reward retrieval is both selective and flexible, with reliance on the social information provided by the majority decreasing as knowledge of the payoff disparity increases. Specifically we show that: a) children adopted a majority-biased learning strategy when they were unaware of the value of the payoffs available, b) children adopted a payoff-biased strategy when they were aware (either from the outset or through self-discovery) that the payoff was unequal, and c) that, counter to predictions, children did not show a preference for the majority behavior when the rewards were known to be of equal value.

Cultural learning theory predicts that when faced with task uncertainty an individual learner may usefully capitalize on available social information by aligning their own solution to that already on display within the social group (Boyd & Richerson, 1985). This capacity to adopt a ‘copy-when-uncertain’ strategy is likely more advantageous and less costly than an individual investing the time to generate their own solution to the problem at hand (Boyd & Richerson, 1988; Laland, 2004). Our results are consistent with the adoption of such a strategy, with those children who were uncertain of the task payoff learning the solution socially, through copying the behavior of the group majority. This adoption of a majority-biased strategy is consistent with children’s tendency to follow the majority in previous studies (e.g., Burdett et al., 2016; Haun et al., 2012; Herrmann et al., 2013; McGuigan & Burgess, 2017; McGuigan & Robertson, 2015; McGuigan & Stevenson, 2016; Whiten, 2019; Wilks et al., 2014) and is a pattern of copying that is indicative of children preferring to benefit from social learning, rather than opting for the more risky, and potentially costlier, option to learn asocially.

However, the tendency of children to adopt the behavior of the majority was reduced when copying the majority came at a personal cost. When children were provided with knowledge, or self-discovered, that the option selected by the majority was the less profitable one, the children were disinclined to act on social information, and instead maximized personal gain. This tendency towards payoff-biased learning is consistent with previous conformity studies which have shown that when presented with a fixed choice of 12 stickers or 1 sticker (the selection modeled by the majority) preschool children maximized personal payoff (i.e., selected 12 stickers) rather than following the less profitable group behavior (Flynn et al., 2018). Our findings are also consistent with previous research which has shown that children tend to maximize personal gain by using social learning (Vale et al., 2017), and more generally that children are less likely to use social information under conditions of cost (Einav, 2014; Morgan et al., 2014; Schillaci & Kelemen, 2014; Wilks et al., 2014). It therefore appears that preschool children, armed with the knowledge of payoff discrepancies, show a strong payoff bias, and use social learning and/or previous experience to strategically maximize payoff.

Unexpectedly when children were aware that the rewards were equally valued no majority bias was evident. That children were disinclined to copy the majority in such instances was somewhat surprising as we had predicted that increased ambiguity would encourage majority biased copying. The lack of a majority bias is counter to the findings of previous studies (Haun et al., 2012, 2014) that found, using a similar paradigm, that children displayed a strong majority bias despite each option delivering an identical reward. This discrepancy may be a consequence of differences in the way in which the models were presented across studies. In contrast to the current study where unfamiliar models were presented via a televised display, the models in Haun et al. (2012; 2014) were familiar peers who performed live, and were present when the participant make their selection. The use of televised models, despite having many benefits (e.g., consistency of the demonstration), may arguably be somewhat limited in that the observer is prevented from having the types of real-life social interactions with the model(s) that may encourage majority copying, such asocial desirability, social pressure, social affiliation, familiarity with the model(s), ingroup membership, and the possibility of interactions with the model(s) in the future (Haun & Tomasello, 2011; Nielsen et al., 2008; Over, 2020). This social disconnect may have reduced the drive to learn socially. However, the use of televised models did result in a strong majority bias in the *value unknown* conditions where televised models were also used, suggesting that an explanation based solely on a lack of real-life interactions cannot fully account for the pattern of results witnessed.

A second, non-social, explanation for the greater levels of conformity witnessed in the Haun et al. (2012; 2014) studies is the larger number of retrieval options available to the models. In the Haun studies the models could select one of three boxes (i.e., each model had a 33% chance of selecting that particular box) whereas the models in the current study each retrieved a reward from one of two boxes (i.e., each model had a 50% chance of selecting that particular box). This may have resulted in the choices made by the models in Haun et al. (2012; 2014) appearing more purposeful (i.e., less random), and therefore more worthy of copying, than that of the current two models. A further structural aspect of the task that may have influenced the results is the number of rewards selected by the majority models (each retrieved only one reward) and the minority model (retrieved three rewards). The children may have mistakenly assumed that they could obtain three rewards if they chose the minority option. However, this explanation seems unlikely as children in previous studies, employing an identical modelling structure, did not show a difference in levels of conformity when there were different frequencies of reward retrieval (Haun, 2012). Future studies could usefully explore the interplay between social and structural factors in displays of majority-biased learning.

Of primary interest in the current study was the selection made by the children in trial 1, immediately following the demonstration. However, we designed the experiment to include multiple trials, thereby affording children the opportunity to individually learn the value of the rewards inside each capsule, information that may feed into the likelihood of adopting the majority or minority behavior across trials. Performance on trial 2 suggests that children were frequent ‘switchers’, who switched strategies on the second trial of all but the *value known equal payoff* condition. This initial, likely exploratory, switching behavior appeared to drive individual learning in the *value unknown unequal payoff* condition, where after opening a capsule of each kind, and thus discovering individually, that differently valued rewards are available, children opted for the greater payoff in subsequent trials. Further work should preferably employ a larger sample whilst exploring the impact of both increasing the relative value of the rewards available and the salience of the majority models. For example, manipulations could include live peers (Haun & Tomasello, 2011), priming for an in/outgroup (Over & Carpenter, 2009), or include a greater number of models in the majority (Morgan et al., 2014).

A secondary interest was to examine children's behavior across trials. We found that following the first trial, children often switched preferences in subsequent trials. This switching behavior was most evident in those conditions that involved unequal payoffs, where after a period of exploratory switching children ultimately converged on a strategy in which they maximized payoff by opting for the higher value reward in the remaining trials. This result confirms work from the literature on learning and exploration that suggests that it is optimal to explore choices or solutions to acquire new knowledge until eventually settling on the optimal selection (Gopnik, 2020; Kirkpatrick et al., 1983).

In sum, the pattern of results suggests that in the first trial, children (with the exception of those in the *value known equal payoff* condition) are heavily reliant on social learning. However, when presented with additional trials, children explored the task and almost all ultimately discovered the value of the rewards housed within each capsule. When the rewards were discovered to be unequal, this knowledge, gained through individual learning, resulted in children opting for the higher value payoff in the majority of trials of the *value unknown unequal payoff* condition. This pattern of performance suggests that task uncertainty (through a lack of knowledge) initially reduced individual learning and drove social learning, whereas incurring a cost for following the majority reduced social learning and drove individual learning. The switching behavior we observed suggests that children were selective in their choice to explore and use social and/or individual learning with cost ultimately driving behavior across trials of the unequal payoff conditions and the behavior of the majority driving the selections made under (some) equal payoff conditions.

We conclude that children are savvy social learners who utilize social information strategically to maximize personal gain, consistent with cultural evolutionary theories and well illustrating the functioning of adaptive social learning strategies (Kendal et al., 2018). When children were uncertain as to the payoffs involved their decisions were informed by the social information available to them - the behavior of the majority. However, once children were provided with, or acquired, knowledge that the selection made by the majority was a costly one, the children sought to maximize their own payoff at the expense of following the majority behavior. These results suggest that preschool children flexibly adopt different learning strategies, both majority-biased and payoff-biased, so deriving maximum benefit from the information available to them.

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Data availability

The data associated with this research will be available at [link to Mendeley data at time of submission].

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Figure Captions

Main figures

Figure 1.

Illustration of the procedure employed in each phase of the experiment.

Figure 2.

Percentages of children that matched the capsule chosen by the majority and the minority in each of the four conditions.

Note. Predicted effects for each condition are indicated at the top of each cell. Black bars show the percentages of children matching the majority selection. Gray bars show the percentages of children matching the minority selection. Curved arrows indicate a significant shift in strategy between consecutive trials. Asterisks indicate a significant difference [from chance (50%)] in the percentage of majority and minority selections made in individual trials.

* $p < .05$

Figure 3a.

Percentages of children who switched/maintained their trial 1 response in trial 2 of the unequal payoff conditions

Note. Solid bars show the percentages of children that chose the same capsule in trial 1 and trial 2. Solid gray bars show percentages of children that maintained the minority choice; Solid black bars show percentages of children that maintained the majority approach. Dotted bars show the percentages of children that switched capsule in trial 1 and trial 2. Dotted black bars show percentages of children that switched from the minority to the majority choice;

Dotted gray bars show percentages of children that switched from the majority to the minority choice. Asterixis indicate a significant switch between trials 1 and 2. * $p < .05$

Figure 3b.

Percentages of children who switched/maintained their trial 1 response in trial 2 of the equal payoff conditions

Note. Solid bars show the percentages of children that chose the same capsule in trial 1 and trial 2. Solid gray bars show percentages of children that maintained the minority choice; Solid black bars show percentages of children that maintained the majority choice. Dotted bars show the percentages of children that switched capsule in trial 1 and trial 2. Dotted black bars show percentages of children that switched from the minority to the majority choice; Dotted gray bars show percentages of children that switched from the majority to the minority choice. Asterixis indicate a significant switch between trials 1 and 2. ** $p < .01$

Figure 4.

Percentages of children that matched the capsule chosen by the majority on 0, 1, 2, 3, 4 or all 5 trials

Note. Solid bars show percentages of children who matched the majority selection on 3, 4 or 5 trials (majority preference). Dotted bars show children who matched the majority selection on 0, 1, or 2 trials (minority preference). Asterixis indicate which of the six approaches differ from chance. * $p < .05$; *** $p < .001$

Supplementary Figures

Supplementary Figure 1.

Percentages of children who had opened a capsule of each type after trials 2, 3, 4 and 5 as a function of condition.

Supplementary Figure 2.

Percentage of trials in which children matched the capsule selected by the minority and the majority after obtaining knowledge of the content of each capsule.

Note. In the value unknown conditions, the children would have acquired knowledge of the content of each capsule through exploration; in the value known conditions the children would have been aware of the content of the capsules from the outset. Asterixis indicate a significant preference for the majority or the minority selection. * $p < .05$