Experimental 'microcultures' in young children: Identifying biographic, cognitive and social predictors of information transmission

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Abstract

In one of the first open diffusion experiments with young children, a tool-use task that afforded multiple methods to extract an enclosed reward and a child model habitually using one of these methods were introduced into different playgroups. Eighty-eight children, ranging in age from 2 years 8 months to 4 years 5 months, participated. Measures were taken of how alternative methods and success in extracting rewards spread across the different groups. Additionally, the biographic, social, cognitive and temperamental predictors of social learning were investigated. Variations in social learning were related to age, popularity, dominance, impulsivity, and shyness, while other factors such as sex, theory of mind, verbal ability and even imitativeness showed little association with variance in children's information acquisition.

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It is well established that young children learn a great deal from the social world (Bandura, 1977; Vygotsky, 1981), with multiple processes, including tutoring (Rogoff, 1990), conflict (Piaget, 1932), collaboration (Tudge, 1992) and observation (Bandura, 1977; Whiten, McGuigan, Marshall-Pescini & Hopper, 2009) facilitating such learning. Evidence regarding young children's social learning comes from a wide base, including ethnographic observations (for a review see Lancy, Bock, & Gaskins, 2010) and microgenetic analyses of experimental dyadic interactions (Pine, Lufkin, & Messer, 2004). Such work shows that children learn from both adults (Fagot & Gauvain, 1997; Radziszewska & Rogoff, 1988) and peers (Flynn & Whiten, 2008a, 2008b; Wood, Wood, Ainsworth, & O'Malley, 1995) across many domains including problem solving (Charlesworth & Dzur, 1987; Cooper, 1980; Flynn 2008), scientific reasoning (Azmitia & Montgomery, 1993; Pine et al., 2004) and planning (Radziszewska & Rogoff, 1988).

Extensive experimental work, often involving an adult-experimenter demonstrating a behavior to a child-participant, has yielded a plethora of findings regarding whom, what and when a child will imitate (Carpenter, Akhtar, & Tomasello, 1998; Gergely, Bekkering, & Király, 2002; Meltzoff, 1995). While the larger phenomenon of the repeated transmission of behaviors across groups that underlies culture has received attention in the anthropological literature (see Lancy et al., 2010 for examples), experimental manipulations of such phenomena have been rare (although we note work on 'distributed cognition', which shows how intelligent processes in humans transcends the boundaries of individual actors; Salomon, 1993). The present study aimed to experimentally examine the spread of information in groups by investigating the affect of children's biographic, social, cognitive and temperamental characteristics on the transmission of tool-use techniques within groups of familiar peers using a 'diffusion' design.

Diffusion experiments, initiated by Bartlett (1932), have seen a recent resurgence (Mesoudi & Whiten, 2008; Flynn & Whiten, 2010). In diffusion studies, two groups are seeded with different methods that achieve the same outcome to a task. In our study this involved introducing into one group a model trained to use a specific method to extract a reward from a novel box (the ‘panpipes’ (PP); see Figure 1). In the PP a reward (a capsule containing a sticker) could be extracted by using a stick tool in one of two alternative ways, either lifting or pushing an obstructing block. If these methods spread preferentially in the groups seeded with them, then the two groups have been shown to adopt and maintain different traditions, sometimes called ‘micro-cultures’ (Jacobs & Campbell, 1961). In the current study a third group of children were presented individually with the task without a demonstration. This established the children’s level of success and predisposition to use a specific method when no demonstration was given, and thus refined conclusions about the depth of observational learning in the diffusion groups.

The current study is one of the first to use an ‘open diffusion’ approach, in which a model and task are introduced to a group of freely-interacting novices, although alternative diffusion designs have been used previously (see Flynn & Whiten, 2010, for an overview). Such an open diffusion study addressed four key issues: (i) child-to-child horizontal transmission, (ii) learning in children’s everyday environments, (iii) the experience of multiple demonstrations and attempts at mastering new tasks, and (iv) the iterative process of learning across multiple transmissions of information. In open diffusion, not only do children choose when and whom they observe, but they have freedom to employ different processes including observation and instruction.

Elsewhere we describe in some detail the learning outcomes of our experiment and the underlying transmission dynamics (Whiten & Flynn, 2010). In the present paper we build on the current understanding of information transmission by exploring how

biographic, social, cognitive and temperamental factors shape this process. In the remainder of the introduction we review each factor considered and the predictions arising.

Biographic Factors: The effect of a child's age, sex and siblings on social learning

Children can imitate others soon after birth (Meltzoff & Moore, 1977), but as the current study focused on pre-school children it is this age group that will be the focus here. Flynn (2008) and Flynn and Whiten (2008a) presented studies with similarities to the current study: in 'diffusion chains' individual pre-school children learnt by observing the behavior of the previous child in the chain, working on a novel task which required tool-use to extract a reward. Flynn (2008) found that chains of 2-year-olds were efficient social learners, who imitated task-relevant means but removed behaviors that were redundant to achieving a goal. Flynn and Whiten (2008a) found 5-year-olds displayed more robust transmission of a witnessed behavior than 3-year-olds, as their behavior showed a higher fidelity to the witnessed actions, supporting the results of dyadic studies (e.g., Flynn & Whiten, 2008b). Thus young children are able to learn by observing the behavior of others, but older children show a higher level of fidelity by imitating exactly what they witnessed, even task-redundant actions.

Wood, Wood, Ainsworth and O'Malley (1995) found developmental change in the context of dyadic peer tutoring, with 3-year-old task-experts teaching mostly through demonstrations, 5-year-old experts providing verbal instructions, and 7-year-old experts flexibly adapting their tutoring to the needs of the learner. Thus different forms of social learning may be pertinent at different ages, with younger children learning through observation, while the development of an ability to reflect on others' views highlights the process of negotiation, with older children relying more on reasoning (Ellis & Gauvain, 1992; Selman, 1980).

The behavior of the learners in Wood et al. (1995)'s study also displayed interesting age effects. All three age-groups (3-, 5-, and 7-year-olds) were able to learn the task, but it

took the youngest children much longer, with much trial and error. Five-year-olds' learning was mainly observational, while the 7-year-olds, in contrast, took advantage of the tutoring available from their expert-tutor. In the present study, as our sample consisted of children aged 2 years 8 months to 4 years 2 months, we predicted that most learning would occur through observation, rather than tutoring.

Sex differences have also appeared in diffusion chains, with boys being both more competent, and displaying stronger transmission than girls in a tool-use task (Flynn & Whiten, 2008a). In a collaborative problem solving scenario with 4- and 5-year-olds, Charlesworth and Dzur (1989) found no sex difference in the level of success or engagement with the task, but girls tended to use more verbal behavior than boys and boys engaged in significantly more physical behavior than girls. We thus predicted that girls would use more verbal behavior in our study than boys, such as giving verbal directives about how to solve the task. However, if Flynn and Whiten's (2008a) findings were to generalise to the current study, boys would show stronger transmission than girls, represented as higher fidelity to a seeded method.

As older siblings facilitate an individual's development of theory of mind (ToM; Ruffman, Perner, Naito, Parkin, & Clements, 1998) and it is clear that older siblings are a significant source of information for young children (Gaskins, 2006), it could be the case that children with older siblings are more used to observing and learning from others compared to children without older siblings. Accordingly we predicted a sibling effect in social learning: specifically that children with older siblings would show stronger fidelity to an experimentally seeded method and an earlier rate of acquisition of this behavior compared to those without older siblings.

Cognitive Factors: The effect of a child's theory of mind, inhibitory control, verbal ability and imitative skills on social learning

Wood et al. (1995) suggested that changes in ToM parallel changes in children's competence in different forms of social learning. Supporting this, children expert on a construction task who had passed second-order tests of ToM presented more contingent tutoring to a same-aged novice than task-expert tutors who did not pass tests of second-order ToM (Flynn, 2010). Similarly, Meltzoff (1995) has shown that 18-month-olds are adept at reading the intentions of others, as they copy the intended goal of actions they witness rather than the unsuccessful actions. A direct examination of the relation between ToM and social learning is problematic because any association may be mediated by the robust correlations between ToM and other cognitive skills, including inhibitory control (Flynn, 2007) and verbal ability (De Villiers & Pyers, 2002). The current study offered an opportunity to take these relations into account by exploring the role of ToM, inhibitory control and verbal ability in children's social learning, as children in the playgroups were of an age to show variance in these abilities. We predicted that children with better ToM skills would be more likely to tutor their peers by providing verbal advice, and to copy the intended actions. Similarly, providing verbal advice would be related to a child's verbal ability (in line with Cooper, 1980). Such potential multi-directional relations illustrate the importance of assessing the role of these skills in social learning simultaneously.

Within our cognitive battery we included a measure of imitative ability (Gleisser, Meltzoff, & Bekkering, 2000). Imitation is believed to play a critical role in information transmission across groups, as children need to be able to replicate what they have witnessed (means and outcome) with a high level of fidelity for it to be transmitted across multiple others. Indeed, it is argued that as some cultural behaviors are opaque, high fidelity imitation plays a significant role in the acquisition and transmission of 'culture' (Boyd & Richerson, 1996; Tomasello, 1999). We predicted that children with high imitation accuracy task scores would show the strongest fidelity to the method seeded in the open diffusion setting.

Social Factors: The effect of friendship, popularity and dominance on social learning

A child's level of mental state understanding may have an indirect effect on social interactions. Children who are friends may find learning together easier than less familiar peers, as they may read the intentions of their friend more efficiently and thus require less cognitive resources to monitor the interaction. Gottman (1983) and Hartup (1996) found that for 5-year-olds, conversations between friends, rather than non-friends, showed greater mutuality; while Azmitia and Montgomery (1993) found that 11-year-olds collaborating with a friend fostered greater scientific reasoning than collaborating with an acquaintance. The role of friends as learning partners is also of theoretical import as Laland (2004, page 11) suggested that, "if 'friends' are regarded as individuals with whom one trades altruistic acts (Trivers,1971), by similar lines of reasoning we might expect more social learning among friends than among non-friends in a *copy-friends* strategy." In line with this strategy, we predicted that children would spend more time observing their friends, and be more likely to copy the method used by them, than non-friends.

The social dynamics of a group affects the process of information transmission, and so we asked, do more dominant children have more access to a task, than less dominant children, and, is a child's popularity an important factor in relation to which individuals children observe? Blurton Jones (1972) and Grusec and Lytton (1988) found that a child's age relates to their social status and dominance, with dominant and popular children also being those who are oldest within a group. The current study overcame this confound as measures were taken of age, popularity and dominance, as well as peer preference and peer rejection. It may be that popularity is more important than dominance in social learning, as although dominant children may have more access to a task, if this dominance is not accompanied by popularity they are not observed. Glachan and Light (1982) found that dominance did not promote social learning in a problem solving context with 8- to 9-year-olds, as it impeded verbal exchanges useful for learning and dominant partners directed

moves rather than providing instruction and support. We predicted that popular children would be watched more than less popular children, although we were unsure whether this would be irrespective of age, as older children are often seen as a resource from which to learn by younger children (see French, 1987 and Lancy et al., 2010, for examples). Also dominant children would likely gain more access to the task than less dominant children, as found in Flynn and Whiten (2010), but if this was not accompanied with high popularity then they would not be watched more than other children.

The role of temperament in social learning

Individual differences in children's reactivity and self-regulation, critical features of temperament (Rothbart & Derryberry, 1981), are known to impact on social interactions. Temperament has been shown to affect social learning in mother-child dyads, as 2 ½ year-olds rated a year earlier by their mothers as having more difficult temperaments, required more cognitive assistance during joint problem-solving (Gauvain & Fagot, 1995) with these effects persisting in problem-solving at 5 years (Fagot & Gauvain, 1997). Similarly, Fouts and Click (1979) found children rated as extraverts to imitate more observed behaviors than those rated as introverts. Thus we also tested the relation between children's temperament and information transmission.

In summary, the principal goal of the current study was to identify biographic, social, cognitive and temperamental predictors of young children's social learning in the naturalistic setting of 'open diffusion'. To do this, relations were tested between the children's performance on a battery of social and cognitive tasks, along with parental responses to a temperament questionnaire, and children's behavior during open diffusion sessions, including measures such as the number of successes, number of methods used, fidelity to the seeded method and production of verbal directives.

Method

Participants

Four playgroups were recruited. In two groups diffusion across the entire group was studied, while the other two groups provided baseline assessments (see Table 1). These playgroups were established, non-profit, well-resourced, parent-run centres for pre-school children to come to regularly to play with children of a similar age, overseen by several trained adults. Letters describing the details of the study were initially sent to the playgroup leaders, who were trained adults assigned daily responsibility for overseeing the playgroup's activities, and follow up meetings with the playgroup leaders and the first author (EF) resulted in consent from the playgroup leaders. Then EF met with the parents of the children in the playgroup to explain the purpose and procedure of the study, and provide an opportunity to answer questions, and again all parents consented to their child's participation. All children agreed to participate in the profiling sessions or the no demonstration condition, and children were free to participate or not during the open diffusion session. No payment was made for participation, but a gesture of thanks (£30 book token) was later sent to each playgroup.

Eighty-eight children, ranging in age from 2 years 8 months to 4 years 5 months, from four playgroups based in two towns in the east of Scotland participated. Children did not differ significantly between playgroups according to age ($F(3, 88) = 1.66$, n.s.), vocabulary ability ($F(3, 88) = 1.98$, n.s.) or sex (χ^2 (3, 88) = 1.40, n.s.), as shown in Table 1, nor by number of siblings (χ^2 (3, 62) = 1.80, n.s.). The playgroups were 98% ethnically white, with one child of Chinese and one of African decent (these children did not attend the same playgroup). All children had English as a first language and the SES was similar across playgroups, with a mixture of working and middle class parents.

Design

The study used a quasi-experimental design. In a first phase, which took approximately a week for each playgroup, children were tested individually on a battery of tasks (described below). In a second phase, a between-group, open diffusion was

undertaken to compare social learning in the playgroups and learning with no demonstration. Two experimental conditions, in which single child models trained to use different methods on the PP were introduced into their respective playgroups, allowed the pathways and manner of social transmission to be charted. A third condition involved no demonstration, so that individual children's natural proclivities on the task were established. The two larger playgroups were used in the open diffusion, which took place over five mornings for approximately an hour each morning in the week following the first phase, with the method seeded in each group allocated randomly. The two other groups were used in the no demonstration condition, which again took place in the week following the profiling session. All testing was undertaken by the first author (EF).

Task Battery

There were nine tasks in the battery: five ToM tasks, an inhibitory control task, a verbal ability task, a test of imitation accuracy and a test of children's peer preference. Not all children completed all of the tasks, due to refusals to which there was no specific pattern. The smallest sample size for any task was 80. Parents of 62 of the 88 children completed a temperament measure (Children's Behavioral Questionnaire, CBQ; Rothbart, Ahadi, Hershey, & Fisher, 2001).

Theory of mind. The five ToM tasks were: a prediction version of the unexpected transfer task; a deceptive box task, which assessed a child's understanding of his or her own previous false belief as well as a naive other's false belief, and two tasks of false belief understanding in which the location of the desired object was explicitly stated. All of these tasks have been used extensively elsewhere, and are described in full in Flynn (2006). Each answer was coded as correct (scoring 1) if children inferred that they or a story character held an incorrect belief; otherwise children were coded as failing (scoring 0).

Inhibitory control. Inhibitory control was measured using the Luria hand-game (Flynn, 2007). Initially a child was trained to copy two different hand gestures made by the experimenter, i.e. a fist and a pointed finger. When the child was competent at this, the task was changed and the child was asked to make whichever gesture was different to the experimenter's. After six practice trials, the child completed 15 task trials. The number of correct gestures out of 15 resulted in the final score.

Verbal ability. The children's verbal ability was tested using a measure of receptive vocabulary, the British picture vocabulary scale, (BPVS; Dunn, Dunn, Whetton, & Pintilie, 1997).

Imitation accuracy. A measure of children's imitative ability was adapted from Gleissner et al. (2000). Children were asked, "Can you do exactly what I do?" The experimenter then produced one of six possible gestures counterbalanced across participants: right hand touches right ear, right hand touches left ear, left hand touches left ear, left hand touches right ear, right hand touches right ear *and* left hand touches left ear, and right hand touches left ear and left hand touched right ear, crossing in front of the body. Children were given a point for each gesture imitated correctly, producing a score between 0 and 6.

Peer preference and dislike. Peer preference and its opposite, dislike, were measured using the photograph task (McCandless & Marshall, 1957; Sebanc, Pierce, Cheatham, & Gunnar, 2003). Each child was shown photographs of the other children in the playgroup and asked to point to three children she or he liked and three who she or he 'doesn't like much'. A peer preference score was created by summing the 'like' nominations each child received, while a peer dislike score was created by summing the 'dislike' nominations.

Open Diffusion Equipment

The PP (Figure 1) consisted of two parallel pipes, one on top of the other. A reward, a plastic capsule containing a sticker, was introduced through a hole in the top pipe. On entry the capsule rolled down the pipe, but was trapped by a plastic block. This obstructing block could be removed in one of two ways: in ‘lift’ (Figure 1A), a stick lifted a T-bar connected to the block, thus allowing the capsule to roll forward and out for retrieval. Alternatively, the block could be pushed back (‘poke’) by poking a stick through a flap door at the front of the PP, forcing the block and capsule back, (Figure 1B) so the capsule fell through a hole at the end of the top pipe and rolled down the lower pipe and exited. In order to stop children using their hands to manipulate the PP directly, the PP was placed in a transparent plastic box with holes at the front through which the tool had to be inserted (see Figure 1D). Only one tool was provided, so that only one child was able to manipulate the PP at any time. All sessions, open diffusion and no demonstration conditions were recorded on video. EF, who was familiar to the children as she had completed the profiling sessions, sat next to the PP to re-bait it.

Procedure

All the participating children were seen individually in a quiet room in their playgroup by EF for the profiling session, where they were tested on the battery of tasks, which was counterbalanced across participants. As well as providing biographical information (dates of birth and sex of the participant and any of the participant’s siblings), parents completed the CBQ. The CBQ covered children’s activity level, anger and frustration, approach, attentional focusing, discomfort, falling reactivity and soothability, high intensity pleasure, impulsivity, inhibitory control, low intensity pleasure, perceptual sensitivity, sadness and smiling and laughter (see Rothbart et al., 2001 for a full description of these factors). There were no difference between those parents who filled out the CBQ and those who didn’t based on playgroup, condition, a child’s gender, or teacher’s rating of popularity or dominance. There was a difference for a child’s age ($t(1, 88) = 4.24$, $p <$

.001) with parents of older children (mean = 41 months) being more likely to fill out the CBQ than parents of younger children (mean = 36 months) and also parents with children with higher BPVS standardised scores (mean = 102; $t(1, 88) = -2.33$, $p < .05$) were more likely to complete the CBQ than parents of children with lower BPVS scores (mean = 95).

Two playgroup leaders from each playgroup, who work with the children daily and had worked at their respective playgroups for at least three years, provided information on each child's level of dominance and popularity. They were asked to rank who would win a conflict over a toy or game and also who had more friends, across all dyadic combinations of children (Mliner, Tarullo, & Gunnar, 2005). This information was used to select a model from each playgroup, who was trained to use one of the methods to remove the capsule from the PP. The models were selected using four criteria: sex (female models were used), full-time attendance, and high popularity and dominance scores. Children rated high in dominance were chosen so they could maintain initial control of the PP and model the learnt technique. A girl, 'AN' (aged 4 years 2 months), acted as a 'lift' model for playgroup A. She attended the playgroup on every day of the study, was ranked as the most popular and second most popular female by the two playgroup leaders, and was ranked as the second and third most dominant female in the playgroup. 'GM' (aged 3 years 8 months) acted as a 'poke' model for playgroup B. She attended the playgroup on every day of the study, was ranked as the second most popular female in the playgroup by both raters, and had the highest and second highest dominance scores for a female in the group.

At the beginning of the training, which took place in a quiet room away from the other children, the model was told, "I've got this toy. It has something special inside and I'm going to show you how to get it out." The experimenter then demonstrated the designated method, extracted the capsule and opened it for the child to see the sticker. The experimenter repeated this demonstration and then said, "Would you like a turn?" If the child said "Yes", she was allowed a turn. If not, further demonstrations were given until

the child wished to attempt the task. Both models immediately used the demonstrated method to extract the capsule, and the experimenter allowed the child to take turns until she showed clear proficiency. No verbal instructions were given about extracting the reward using a specific manner, or teaching other children about how to do the task or use a specific method. AN was given four demonstrations and then allowed six attempts, on which she showed 100% proficiency. GM witnessed two demonstrations and then had three attempts, on which she showed 100% proficiency.

Once the models were proficient at their designated method, they received no further instructions regarding their behavior during the open diffusion and they returned to their playgroup. In both playgroups, once the model's training was complete the PP was immediately placed in a location that was accessible to all children. Then a playgroup leader, following previous instruction from EF, said, "There is a new toy for you all to play with. Everyone can have a go if they want." The stick tool was placed on the table in front of the PP; it was never given to any child. Children were then allowed to manipulate the PP. As soon as a child successfully retrieved a reward, the PP was re-baited and the stick placed on the table in front of the PP. EF sat next to the PP and refilled it as necessary, but she never made any introductory overtures to the children. If spoken to she was polite, but provided as little interaction as possible. Our aim was to create an environment in which children would be neither encouraged nor discouraged from using the PP by EF's presence. The PP was in each playgroup for a total of 4 ½ hours over five days, always in the same location, and available only during free-play sessions, when all children had access.

The no demonstration condition took place in a quiet room with only the experimenter (EF) and participant. The PP and stick tool were placed on a table in front of the child. EF said, "Now it's your turn", looking and pointing at the PP; this instruction was used to parallel the lack of instructions given in the open diffusion. Such instructions have been used previously, for example in Flynn (2008), and children appear to have little

problem in interacting with the task following it, as it often leads to successful extraction of the reward. This was followed by four minutes of exploration time. After four minutes, if the child hadn't already picked up the stick, the experimenter said, "You can use the stick if you want to". This was followed by three minutes of further exploration time. After this time, if a child had not already done so, the experimenter said, "Why don't you try putting the stick through one of these holes?" which was followed by three minutes of exploration time. If a child had not succeeded after the full ten minutes, the experimenter showed the child how to retrieve the reward using a designated method. Children were then asked to copy this. All children were able to do so, showing that lack of success was not due to physical difficulty. Children in the no demonstration condition were coded according to whether they successfully removed the capsule, and if so, which method they used, how long it took and what hints they received. Children who were not successful were coded for whether they attempted to extract the capsule, they picked up the tool, and whether they inserted the tool into the outer box.

Scoring and Inter-rater Reliability

Coding of the method used included the lift and poke methods described above, but also included a new method children introduced, where they pushed the T-bar (see Figure 1C) rather than the block, to release the capsule (Whiten & Flynn, 2010). No other methods were introduced. The number of, and order of children producing, successes (capsule extracted) or attempts (capsule not extracted) were recorded. A turn was either a success or attempt on the PP, and a bout was a series of turns by the same child, ceasing only when that child finished and another child picked up the tool to manipulate the PP. Sources of potential learning were also recorded, including the number and identity of each child observing a turn and verbal directives (Ashley & Tomasello, 1998), where children spontaneously instructed another child (described further in Results, below).

Nine 15-minute episodes selected at random, producing a total of 116 turns and including both experimental and no demonstration conditions, were coded by an independent rater, who was unaware of each segment's assigned condition. Cohen's kappa scores for level of success, number of lift turns, T-bar turns and poke turns were all above 0.91, an excellent level of agreement. Inter-rater reliability was also achieved for the popularity and dominance questionnaires given to the playgroup leaders. Cronbach's Alpha for the coders' dominance rankings was 0.97 and for the popularity rankings 0.91, again an excellent level of agreement.

Results

The results are divided into three sections. Section 1 presents the results from the children's performance on the battery of tests, including inter- and intra-construct correlations. In section 2 children's behavior in the open diffusion and no demonstration conditions is described. The trained models' actions were not included in this analysis, except for coding of who watched their attempts, as their experience was quite different to that of the other children. Finally, in section 3, behavior in the open diffusion is examined with reference to children's performance on the individual-differences measures. Table 2 presents the means and standard deviations for the tasks in the battery.

Section 1a Profiled data: Construct correlations for popularity and theory of mind

Two separate measures were obtained for popularity, one from playgroup leaders' ratings and one from children's selections in the photograph task; these correlated significantly, $r(59) = .57$, $p < .001$. Thus, for economy and clarity, and because at no point were different effects produced for these two measures, just one of these measures, playgroup leaders' ratings, was used in the following analyses.

There were five ToM tasks, all coded using a dichotomous score (0, fail and 1, success; phi correlations are presented in Table 3). As there was good agreement between the ToM tasks, the scores were combined to produce a ToM score ranging from 0 to 5.

Section 1b Profiled data: Inter-relations across constructs

As can be seen in Table 4, the tasks in the battery were appropriately chosen insofar as they replicated previous findings (Flynn, 2006; Flynn, 2007). Age was significantly related to all the measures except peer dislike scores and number of older siblings. ToM correlated with inhibitory control, imitation accuracy, BPVS raw scores and popularity.

Section 2a Success in the no demonstration condition

Eight of the twenty-eight children in the no demonstration condition (29% of the no demonstration sample, six females) successfully retrieved the reward. Five of these children (18% of the no demonstration sample) achieved this with no hints, taking a mean time of 4 minutes 45 seconds. Three further children achieved success after being encouraged to insert the tool into the box (mean time = 8 minutes 42 seconds). All eight successful children used the poke method, with four inserting the tool through the front flap and poking the block (as GM had been trained to do), and four poking the base of the T-bar. No child spontaneously used the lift method. All children who were not independently successful were able to imitate EF's subsequent demonstration.

Section 2b Open diffusion: Overall behavior in the open diffusion conditions

Level of success in the open diffusion conditions was significantly higher than in the no demonstration condition ($\chi^2(1, 75) = 22.20$, $p < .001$). No differences were found between the 'lift' and 'poke' groups in the mean number of successes ($F(1, 39) = 0.18$, n.s.), or mean number of attempts ($F(1, 47) = 0.58$, n.s.). Children in the 'lift' group had a total of 689 turns, containing 177 (26%) successes, similarly children in the 'poke' group had a total of 633 turns, containing 141 (22%) successes. Finally, across both groups, successes and attempts were watched by a similar number of children (mean (poke) = 1.84, mean (lift) = 2.13; $t(285) = -1.95$, n.s.) and children watched a similar number of successes and attempts (mean (poke) = 46.22, mean (lift) = 42.82; $t(44) = .31$, n.s.).

Section 2c Open diffusion: Comparisons of the 'lift' and 'poke' groups

Both the lift and poke methods appeared at some stage, and were witnessed by children, in both playgroups. Nevertheless, a significant difference was found in the proportion of lift turns (lift turns/lift turns + poke turns) that the children made depending on the playgroup (2-tailed Mann-Whitney *U*-test, $Z = 2.49$, $p < .05$). Children in the 'lift' group made a significantly higher proportion of lift turns (median = 61%, $n = 32$) than children in the 'poke' group (median = 0%, $n = 28$). A difference also existed for the absolute number of lift successes (2-tailed Mann-Whitney *U*-test, $Z = 2.10$, $p < .05$; median 'lift' group = 1.00, median 'poke' group = .00), although it only approached significance for the absolute number of lift turns (2-tailed Mann-Whitney *U*-test, $Z = 1.79$, $p = .07$; median 'lift' group = 4.00, median 'poke' group = 1.00).

By contrast, there was no significant difference in the absolute number of poke successes or turns (poke success, 2-tailed Mann-Whitney *U*-test, $Z = 1.14$, n.s.; poke turns, 2-tailed Mann-Whitney *U*-test, $Z = 1.10$, n.s.), with the 'lift' children having a median of 1.50 poke successes and 3.00 poke turns and the 'poke' children having a median of 4.00 poke successes and 6.00 poke turns. However, this analysis is complicated by the fact that a new method (T-bar, Figure 1C) was introduced on the first day of testing in both groups. Overall, the T-bar method accounted for 44% of turns, resulted in 18% of the successes, and was used by 10 (24%) of the forty-one successful children. There was a significant difference in the number of successes using the T-bar method, as children in the 'poke' group achieved significantly more T-bar successes than the 'lift' group (2-tailed Mann-Whitney *U*-test, Z = 2.55, $p < .05$; median 'lift' group = 0, median 'poke' group = 0).

Section 2d Open diffusion: The process of transmission

Before examining the role of the biographic, social, cognitive and temperamental factors on social learning, we present an overview of the process of transmission (for a more detailed analysis see Whiten and Flynn, 2010). First we describe the models' behavior. The two models only ever used the method they were trained to use, thus proving

to be reliable models. Model AN completed nine successful lifts over eight bouts spread across the five days, while model GM completed 16 successful poke extracts over 16 bouts, across this period. Interestingly, neither model initially demonstrated the task, but instead instructed adjacent children in the method seeded. GM was only the sixth in her group to actually perform the task; she directed the first child attempting the task to poke by saying, "Here…no, not that bit…at the bottom, at the bottom…put it here (pointing to a specific hole in the outer cage)...then open that wee door…not that…that door…that one…push it up". Likewise, AN directed the first child attempting the task (CG) to lift, "C, you put it in here (pointing to specific hole in the outer box) and you lift it up…lift…put it under there and do it up…C, put it under there…do it up". Both of these instructed children used the taught method successfully.

Analysis focused on two transmission processes: observation and teaching. Each child's turn was witnessed by up to eight children, with a mean of two children watching each of the 1,322 turns. Each child who attempted to retrieve the capsule watched a mean of 44 turns (range 0 to 179). Overall, 91% of the turns were observed by at least one other child. Forty-eight of 1,322 turns at the task were accompanied by an instruction (an illustration is presented above in the section on the model's behaviour).

Section 3 The role of individual differences in social learning.

A series of multiple regressions were conducted to examine the power of the individual-differences variables to predict the number of successes, attempts, and methods used, the order of successes and attempts, the number of turns children witnessed, the amount a child was watched, the proportion of a child's turns that were faithful to the seeded method and the number of directives given to other children. Hierarchical regressions were used with biographical details (age, sex and number of older siblings) entered in the first step, social measures (popularity, peer dislike nominations and

dominance) entered in the second step and cognitive measures (ToM, inhibitory control, imitation accuracy, verbal mental age) entered in the final step.

The independent variables predicted two of the dependent variables: the number of overall successes and the amount a child was watched. For the number of overall successes, a stepwise regression revealed a good fit, explaining a high proportion of the variance (R^2 = 87%). Analysis of Variance (ANOVA) revealed that at the first and second steps the model was significant (second step, R = .93; F (3,13) = 7.69, p < .01). The number of successes children produced was predicted by their age (β = .77, p < .01) and dominance (β = -.66, p < .05); older, more dominant children had more successes than younger, less dominant children. No other factors affected a child's number of successes, although popularity approached significance (β = .41, p = .09). For the number of turns a child was watched by others, the stepwise regression revealed a good fit (R^2 = 71%). The ANOVA revealed that at the second step the model was significant (R = .85; F (6, 10) = 4.27, p < .05). The amount a child was observed was predicted by age (β = .62, p < .05) and dominance (β = .-.71, p < .05); older, more dominant children were watched more than younger, less dominant children.

Simple Pearson correlations, shown in Table 5, support the findings of the regression analysis but also revealed further interesting associations. Older children were more faithful to the seeded method than younger children, and older, more popular and dominant children watched other children's turns more than younger, less popular and less dominant children. Older children gave more directives than younger children, and more popular and more dominant children provided more verbal directives.

Peer acceptance also played an important part in task engagement. Children were twice as likely to watch turns made by 'liked' peers, than 'not liked' peers (paired sample

t-test, $t(32) = 2.41$, $p < .05$, mean percentage of liked peer's turns watched = 12.32, mean percentage of not liked peers' turns watched = 6.49).

Analysis of the data from the CBQ showed that children who were rated as more fearful were more likely to attempt the PP later than children who were rated as less fearful ($r(32) = .39$, $p < .05$). Children rated as more impulsive were more likely to attempt the task before less impulsive peers ($r(32) = -.42$, $p < .05$). These children rated as high in impulsivity also had more turns ($r(32) = .39$, $p < .05$) and also witnessed more turns by others ($r(32) = .38$, $p < .05$). Finally, children rated as shy attempted the task after peers who were rated as lower on the shy dimension ($r(32) = .42$, $p < .05$).

Discussion

Our central aim was to establish whether biographic, social, cognitive and temperamental factors predicted information transmission. We discovered that age, popularity, dominance, fearfulness and impulsivity shaped children's social learning. Perhaps more surprisingly, cognitive skills including ToM, inhibitory control, imitative accuracy and verbal ability did not predict the social learning outcomes examined here.

Before exploring these findings further, four features of the present study should be highlighted. First, the tests used in the battery were valid, reliable, and produced effects found previously in the literature (see Flynn, 2006; Flynn, 2007). Second, children in the open diffusion and no demonstration condition found the PP task engaging, as nearly all of them (81% in the open diffusion and 100% in the no-model condition) interacted with the task. The PP presented an appropriate challenge as 67% of children in the open diffusion and 29% in the no demonstration condition were successful, and as children in the open diffusion were more successful than children in the no demonstration condition, it was clear that observational learning had taken place. However, it is also important to note that 29% of the children were able to successfully negotiate the PP without witnessing a demonstration, 18% with no hints and 11% after a hint to insert the tool into the outer box.

This condition cannot be viewed as simply non-social, as the presence of another individual may have induced social facilitation processes, and the staged hints provided instruction, but this control does provide an important indication of what children can achieve on this novel task without a demonstration, while in the presence of another individual. Third, at the end of the no demonstration condition children were invited to copy the method shown by an adult, which along with two other studies with similar-aged children (both presented in Hopper, Flynn, Wood and Whiten, 2010) illustrated that all children could physically perform the actions involved. Fourth, it is clear that significantly different microcultures were produced, as children in the different playgroups seeded with different methods displayed different method use at the end of the five days (see also Whiten & Flynn, 2010). Such distinctions illustrate a form of ‘distributed cognition’, in which the interactions among groups of individuals with reference to a technological device result in a common ‘representational’ state. As different methods were adopted and transmitted across these two playgroups, we can address the central questions of the present study: whether biographic, cognitive, social and temperament factors predict young children’s information transmission.

In the present study the age range of individuals was relatively narrow, 2 years 8 months to 4 years 2 months, yet age effects occurred. Older children had more successes, were watched more, watched others more and, importantly, were more faithful to the method that was seeded in their playgroup than younger children. This latter result replicates findings in social learning experiments across dyadic settings with adult models (Flynn & Whiten, 2008b; Nielsen, 2006) and diffusion chain studies (Flynn & Whiten, 2008a), that older children, rather than becoming more selective in their copying, tend to faithfully replicate all elements of a demonstration, even causally-irrelevant actions. Older children were also *watched* more by others, perhaps because they are often seen as a source of instruction (French, 1987) and because they were more engaged with the task. This task

engagement appears to extend to older children’s observation, as they also watched others more, perhaps because the children in the study were of a similar age, such that a sample with a larger age difference may not have produced such a finding.

Along with age, popularity and dominance were related to the children’s levels of success, the amount they were watched, and the amount they watched others. It is unlikely that these effects are to be explained simply by age, as the effect of age was taken into account early in the regression analysis. More popular and dominant children had more success, and, perhaps for this reason, were watched more by others. The direction of causality of this link is not yet clear. However, all children had access to the task and there were periods during the testing when the PP was free for any child to attempt. Therefore it was not the case that popular and dominant children monopolised the task. Instead, children who succeed at new activities, including games and tasks, may become more popular with other children, than children who are less willing to attempt such activities. Indeed, there appears to be a persistent relation between popularity and imitation; being imitated increases attraction to or liking for the imitator, and has a role in facilitating social interactions (Hanna & Meltzoff, 1993; Roberts, Wurtele, Boone, Metts, & Smith, 1981; Thelen, Frautschi, Roberts, Kirkland, & Dollinger, 1981). Our results suggest that popularity and dominance have a very close relation and further work needs to differentiate their roles in social learning.

We predicted that because the children in our study were young, ranging from 2 years 8 months to 4 years 2 months, they would be more likely to learn through observation than other forms of social learning such as tutoring. Observational learning did emerge as the main form of social learning in this study, with 91% of turns being watched by another child. But this is not to suggest that other forms of learning did not occur; notably, children were seen to tutor others with verbal directives. There were additional interesting individual differences effects related to the production of verbal directives;

older, more popular and more dominant children gave more verbal directives than younger, less popular and less dominant children. Such an effect needs further exploration as these children were also more successful at the task, and so these directives may have been facilitated by knowledge and experience rather than a predisposition of such children to give directives. While coding the open diffusion it became clear that other processes, such as negotiation, collaboration and conflict were either very rare (differing from other studies with similar-aged children, including Flynn & Whiten, 2010) or never occurred. However this informal judgement provides a future avenue for exploration. It may be the case that children benefit from the cognitive skills we have measured when participating in other forms of social learning, explaining their relative inertia in the current study.

Although the inhibitory control task within the battery showed no relation with social learning abilities, the temperamental measures of inhibitory control did show an association. Children who received higher parental ratings on impulsivity attempted the task sooner, had more turns and also watched others more, potentially because they were keen to participate and so spent more time at the task than those who received lower ratings of impulsivity. In contrast, children who were rated as shy or fearful attempted the PP later than children who were rated as less shy and fearful (similar to Fouts and Click, 1979). One of our more intriguing results is that the temperamental aspects of some cognitive skills (e.g., impulsivity) are more influential in the process of social learning than our range of cognitive factors, at least within a reasonably normal range.

The social dynamics of a group were shown to affect a child’s ability to acquire a skill by observing others; children were more likely to learn from children they rated as liking than those they liked less. Such a finding may seem intuitive, but alternative predictions might have been entertained; for example, children may elect to learn from others who are successful at the task, irrespective of their personal relationship with the observed child. Yet, it was clear that children were more likely to observe others whom

they rated as liking rather than those rated as ‘don’t like much’. Children may learn from friends, not because they make a conscious decision to do so, but simply because they remain in close proximity to their friends, and so have more opportunity to observe them.

Other biographic and social factors that previous research led us to predict would influence children’s social learning did not relate to our transmission measures. For example, children with older siblings did not show stronger fidelity, or an earlier acquisition of the seeded method. Similarly, we found no sex differences. Girls were not more likely to provide verbal directives, as suggested by Charlesworth and Dzur (1989), and boys were not more faithful to the seeded method than girls, as found by Flynn and Whiten (2008a). This lack of a sex difference in social learning may seem surprising given this previous literature and the fact that the PP task is another tool-use task, a domain which may facilitate social learning for boys in comparison to girls. Yet, perhaps the open diffusion design, where children are free to come and go and to choose from whom to learn, and is thus so different from Flynn and Whiten (2008a)’s diffusion chain design, helps eradicate sex differences. Starting with female models may also have had an effect.

Similarly, the considerable range of children’s cognitive skills we assessed did not play a critical role in their social learning. One might have expected that, to the extent that social learning involves the understanding of the intentions of others, ToM would have been associated with different elements of social learning (such as providing verbal directives); yet this was not the case. Zentall (2001) argues that because imitation has been shown in “species as varied as rats, pigeons, and Japanese quail…the responsible mechanism is not likely to be theory of mind or perspective taking” although he adds that “in cases in which stimulus matching is inadequate to account for imitation, some precursor of perspective taking is likely to be involved” (p. 85). However, we predicted that as children are more socially sophisticated creatures, capable of refined cooperation (Flynn & Whiten, 2010; Tomasello, 2009), we may see more of a propensity to provide

help, such as joint collaboration or action, and that might be expected to be linked to their socio-cognitive skills, such as ToM. But not only was ToM not related to social transmission (such as the production of verbal directives), neither were verbal ability, imitative accuracy or inhibitory control.

Many opportunities remain for exploring information transmission within an open diffusion context. For example, the role of the experimenter in the open diffusion and no demonstration conditions can be examined. The PP required re-baiting after each success, but using a task that could be remotely re-baited, with no adult present (see Flynn and Whiten, 2010) may produce different results. Also, the no demonstration condition in this study proved to be informative in assessing individual children's levels of success and propensities to use different methods. However, future studies could use different control conditions to address related questions, such as how innovation and transmission occurs when there are no trained models to seed a method (see Flynn & Whiten, 2010), and what individual differences are important under such conditions? Future work can also explore the role of the status (perhaps taking measurements from observation as well as peer and teacher ratings) and number of models, the copying of actions that are relevant and irrelevant to the goal of the task, the characteristics of the task (gender-specific versus gender-neutral tasks) and the characteristics of the participating group. We believe that our findings make an important, initial step in understanding the dynamics of information transmission among groups of children. Our study took place within the context of a play-like setting, so one further important next step would be to explore how behavior and information is transmitted within groups of peers in more school-like settings that children experience increasingly as they develop.

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Figure Caption

Figure 1. The panpipes: (A) illustrates the lift method, (B) illustrates the poke method, (C) illustrates the T-bar method and (D) is a picture of the actual panpipes within the Perspex box, with the lift method being demonstrated.

Figure 1.

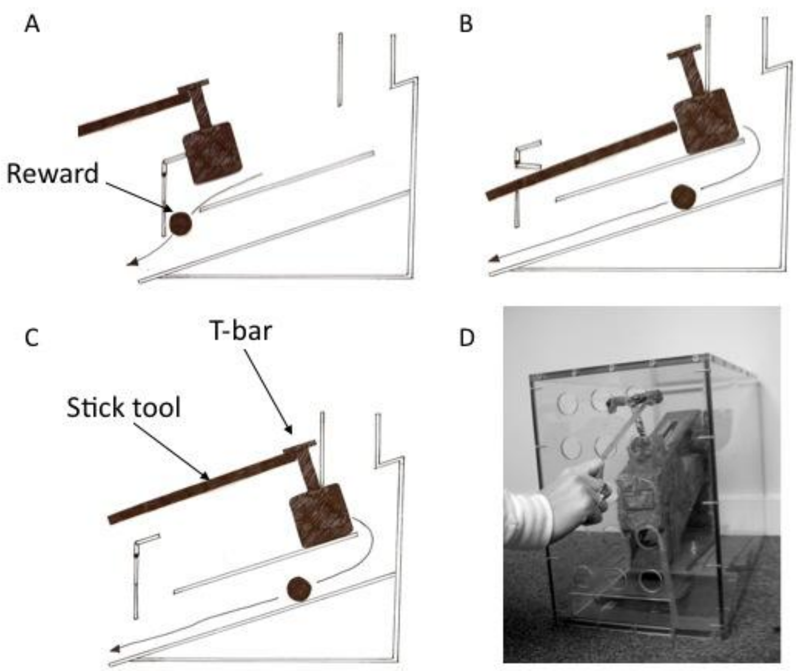

Table 1 Descriptive statistics for the playgroups.

Playgroup	N	Mean Age in months	Sex (F:M)	BPVS (Standardised)
A Poke	28	42 (4, 37-52)	15:13	99 (12, 79-129)
B Lift	32	41 (5, 34-50)	17:15	105 (10, 89-129)
C Control	16	39 (6, 32-51)	11:5	99 (13, 79-117)
D Control	12	40 (7, 33-53)	8:4	97 (11, 74-107)

Note. Numbers is parentheses are (standard deviations, minimum-maximum).

Table 2 Descriptive statistics for the performance of children in the open diffusion.

Task	Means or Success Rate	Standard Deviation	Real Range (Possible Range)
Age (months)	42	4	32-50
No. of older siblings	.68	.83	0-3
ToM: Unexpected Transfer Task	28%	.45	0-1 (0-1)
ToM: Deceptive Box, Own Previous False Belief	41%	.50	0-1 (0-1)
ToM: Deceptive Box, Other's Naïve False Belief	37%	.49	0-1 (0-1)
ToM: Explicit Location, Qu 1	26%	.45	0-1 (0-1)
ToM: Explicit Location, Qu 2	28%	.46	0-1 (0-1)
Composite ToM Score	1.60	1.61	0-5 (0-1)
Inhibitory Control	10.00	4.67	1-15 (0-15)
Imitation accuracy	3.33	1.12	0-6 (0-6)
BPVS	102.13	11.26	79-129
Popularity	13.67	7.99	0-28
Peer 'not like' nominations	2.01	1.61	0-6
Dominance	12.57	7.72	0-28
Open Diffusion:			
No. of successes	7.80	9.05	0-36
No. of turns	8.13	9.58	0-51
Methods used	1.89	.81	0-3 (0-3)
Witnessed others' turns	44.15	36.35	0-179
Turns watched by others	14.02	16.62	0-66
Prop. of fidelity success	40.06	43.49	0-100
Prop. of fidelity for all turns	38.86	40.29	0-100
Verbal directives	2.25	1.97	0-9

Table 3. Phi correlations for the theory of mind tasks.

	(1) Unexpected Transfer Task	(2) Deceptive Box: Own Previous False Belief	(3) Deceptive Box: Other's Naïve False Belief	(4) False Belief : Explicit Location Question 1	(5) False Belief: Explicit Location Question 2
(1) Unexpected Transfer Task	-				
(2) Deceptive Box: Own Previous False Belief	.17 *p* = .13	-			
(3) Deceptive Box: Other's Naïve False Belief	.23*	.35**	-		
(4) False Belief: Explicit Location Question 1	.19 *p* = .08	.35**	.35**	-	
(5) False Belief: Explicit Location Question 2	.24*	.19 *p* = .06	.29**	.45***	-

Note. *$p < .05$, **$p < .01$, ***$p < .001$, N = 88.

Table 4. Inter-correlations for the children's performance on the battery of tasks.

	Age	No. of older sibs	ToM	Inhibitory control	Imitation Accuracy	BPVS	Popularity	Peer rejection	Dominance
Age	-	.01	.20*	.32*	.41***	.58***	.39**	-.01	.39**
No. of older sibs		-	-.03	-.02	.14	-.19	.04	-.08	.01
ToM		.15	-	.47**	.23*	.31**	.34**	-.06	.08
Inhibitory control		.05	.40 *p* = .08	-	.17	-.05	.11	-.17	-.04
Imitation		.30	.03	-.05	-	.34**	.32*	.14	.47**
BPVS		-.38	.32	-.26	-.18	-	.41**	.01	.36**
Popularity		.09	.31	-.13	.01	.18	-	.14	.63**
Peer reject		-.07	-.20	-.47*	-.30	.07	.07	-	.32*
Dominance		.03	-.17	-19	.24	.33	.29	.25	-

Note. *$p < .05$, **$p < .01$, ***$p < .001$; Pearson correlations above the diagonal and partial correlations (controlled for age) below. All correlations were based on N = 80 to 88, except for those with number of older siblings, where N = 59-62.

Table 5. Correlations between the children's profiled data and their behavior on the open diffusion task.

	Age	No. of older sibs	Theory of Mind	Inhibitory control	Imitation Accuracy	BPVS	Popularity	Peer rejection	Dominance
No. of successes	.51**	.12	.21	.09	.16	.10	.51**	.38	.41*
No. of turns	.02	.07	-.02	.09	.23	.10	.09	.33	.14
No. of methods	-.09	.32 *p* = .09	.00	.01	.21	.27	.11	.26	.24
Order of success	-.20	-.20	-.03	.09	-.13	.11	.29	-.27	.20
Order of turns	-.17	-.18	-.04	.04	-.06	-.05	.28	-.15	.08
Witnessed others' turns	.47**	.08	.19	.05	.27	.14	.65**	.40	.49**
Turns watched by other	.45**	.20	.09	.08	.18	-.00	.49**	.36	.30 *p* = .07
Prop. of fidelity success	.29 *p*=.07	.28	.18	.17	-.12	-.26	.17	.07	.002
Prop. of fidelity attempt	.33*	.03	.11	.03	-.17	.17	.24	.03	.043
Directives	.50***	.06	.18	.01	.28	.15	.36*	.35*	.39*

Note. *$p < .05$, **$p < .01$, ***$p < .001$, N = 39-47.