Copy me or copy you? The effect of prior experience on social learning

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Abstract

The current study investigated children's solution choice and imitation of causally-irrelevant actions by using a controlled design to mirror naturalistic learning contexts in which children receive social information for tasks about which they have some degree of prior knowledge. Five-year-old children (N = 167) were presented with a reward retrieval task and either given a social demonstration of a solution or no information, thus potentially acquiring a solution through personal exploration. Fifty-three children who acquired a solution either socially or asocially were then presented with an alternative solution that included irrelevant actions. Rather than remaining polarised to their initial solution like non-human animals, these children attempted the newly presented solution, incorporating both solutions into their repertoire. Such an adaptive and flexible learning strategy could increase task knowledge, provide generalizable knowledge in our tool-abundant culture and facilitate cumulative culture. Furthermore, children who acquired a solution through personally acquired information omitted subsequently demonstrated irrelevant actions to a greater extent than did children with prior social information. However, as some children with successful personally acquired information did copy the demonstrated irrelevant actions, we suggest that copying irrelevant actions may be influenced by social and causal cognition, resulting in an effective strategy which may facilitate acquisition of cultural norms when used discerningly.

Key words: social learning, source of information, imitation, irrelevant actions, overimitation

Children are prolific social learners and the extent of their faithful imitation of a model's behaviour is matched by no other species including other great apes (Dean, Kendal, Schapiro, Thierry, & Laland, 2012; Tennie, Greve, Gretcher, & Call, 2010; Whiten, McGuigan, Marshall-Pescini, & Hopper, 2009). A wealth of previous research demonstrates that providing children with social information about a novel artefact can lead to the canalisation of behaviour, whereby children faithfully reproduce an observed behaviour without attempting possible alternatives (Flynn & Whiten, 2008a; Hopper, Flynn, Wood, & Whiten, 2010; Horner, Whiten, Flynn, & de Waal, 2006), sometimes leading to the copying of clearly causally irrelevant actions (Horner & Whiten, 2005; Wood, Kendal, & Flynn, 2012). Children's copying of irrelevant actions appears in different cultures (e.g. Kalahari Bushmen, Nielsen & Tomaselli, 2010 and western society, Horner & Whiten, 2005), increases with age (McGuigan, Whiten, Flynn, & Horner, 2007; Nielsen, 2006) into adulthood (Flynn & Smith, 2012; McGuigan, Makinson, & Whiten, 2011), and persists despite many forms of intervention (Lyons, Young, & Keil, 2007; Lyons, Damrosch, Lin, Macris, & Keil, 2011). As children often receive social information regarding artefacts about which they have some degree of prior knowledge, the overarching aim of the current study was to understand how children's imitation of socially demonstrated solutions and causally irrelevant actions are influenced by experiencing multiple solutions to a problem.

When new social information contrasts with prior information children may draw upon 'social learning strategies', heuristics guiding their use of social information (Laland, 2004). Boyd and Richerson (1985) suggest that learning one solution can inhibit further exploration of a problem, with such conservatism common in non-human animals. Chimpanzees that discover one solution for food retrieval are unlikely to try a more efficient solution and when one solution is precluded, those expert in the blocked solution do not adopt an alternative solution (Hrubesch, Preuschoft, & van Schaik, 2009). Similarly, Hopper,

Schapiro, Lambeth and Brosnan (2011) found conservatism to initial social information even when an alternative behaviour, which was similar in difficulty, produced a higher value reward. Conservatism to personally acquired information continues in the face of equally beneficial alternate social information in a number of species (starlings, Templeton & Giraldeau, 1996; guppies, Kendal, Coolen, & Laland, 2004; sticklebacks, van Bergen, Coolen, & Laland, 2004; see Kendal, Coolen, van Bergen, & Laland, 2005 for a review). This reluctance to weight social information over personally acquired information can be overcome with sufficiently persuasive social information (nutmeg manikins, Rieucau & Giraldeau, 2009), costs to using personal information (fish, Kendal et al., 2004; orangutans, Lehner, Burkart, & van Schaik, 2011), or when individuals are allowed continued attempts to retrieve a reward (capuchin monkeys, Dindo, Thierry, de Waal, & Whiten, 2010).

We address children's use of these strategies by investigating children's behaviour after prior task experience and subsequent demonstrations of alternate task solutions which included causally irrelevant actions. Specifically, relating to differing solutions of an artificial-fruit task, we investigate: (1) how children weigh an initial socially demonstrated task solution with a subsequent socially demonstrated task solution, (2) whether personally acquired information affects children's copying of subsequent socially demonstrated solutions, (3) solution choice over time and (4) the influence of prior experience on the often prevalent reproduction of irrelevant actions.

1.1 Demonstrations of alternative solutions

Our first research question investigated how children weigh an initial socially demonstrated task solution with a subsequent socially demonstrated task solution. Traditionally, social learning studies have presented social information in the form of one or multiple demonstrations of the same solution, resulting in children faithfully copying the

demonstrated solution in subsequent trials (Flynn & Whiten, 2008a, 2008b; Hopper et al., 2010; Horner et al., 2006). For example, Flynn and Whiten (2008a) found that only one child out of 80 attempted a solution that was different to the one witnessed. Similarly, in infancy use of a familiar tool is inflexible relative to a novel tool (Barrett, Davis, & Needham, 2007). Further, in studies of normativity children protest when an individual subsequently performs a behaviour that the child associates with a different, previously socially learnt behaviour (Rakoczy, Warneken, & Tomasello, 2008), suggesting that once a model demonstrates a solution children are quick to establish how something 'ought' to be done and do not accept the more recently demonstrated behaviour.

In contrast, Siegler and Opfer (2003) found that when working through mathematical problems children possess multiple numerical representations, such that a single child could utilise different methods to obtain the correct answer to similar problems. They suggested that children are motivated to acquire multiple strategies to solve a problem and that when similar problems are presented close in time children may use different solution strategies in their repertoire. In the current study, where some children were provided with social demonstrations of alternative solutions, we predicted that children would imitate the model's first demonstration. We made no clear predictions about what children would do upon witnessing a second, alternative solution. Such an investigation, however, is important as it reflects real-life learning and reveals the relative prevalence of solution canalisation and multiple strategy acquisition.

1.2 Personally acquired information

The relation between children's acquisition of knowledge through their own experience (personal learning) and through their interactions with others (social learning) has been of interest since the beginning of the empirical study of developmental psychology (e.g.

Piaget, reviewed by DeVries (1997)). Adults can demonstrate an inherent resistance to changing their opinion (Ehlrich & Levin, 2005) and although the number of, consensus among, and performance of demonstrators can result in adults disregarding their personal choice, participant confidence, success rate and non-public answers increase the probability of maintaining one's own choice (Asch, 1951, 1956; Morgan, Rendell, Ehn, Hoppitt, & Laland, 2012). Children with divergent personal information, regarding solutions to a reward extraction task, tend to converge upon a single solution in a social setting (Flynn & Whiten, 2010) suggesting children have some degree of social conventionality. If, however, social information is inaccurate (Clément, Koenig, & Harris, 2004), if the model is demonstrating an inefficient (Pinkham & Jaswal, 2011) or non-affordant method (DiYanni & Kelemen, 2008), or if the model has an 'unreliable' reputation (Ma & Ganea, 2010), children are more likely to rely upon their personally acquired information. Equally, when children are presented with a difficult experience of retrieving a reward, they copy an alternative technique (Williamson, Meltzoff, & Markman, 2008; Williamson & Meltzoff, 2011). Likewise, when a child's personally-acquired easy solution to a task becomes ineffective s/he defers to a model's task actions (Williamson et al., 2008). In the current study the difficulty or effectiveness of the solution was not manipulated. Therefore, the current study makes a significant contribution to previous research by addressing children's relative weighting of prior, personally-acquired information against subsequent socially-acquired information when both provide solutions of comparable efficiency and validity. Due to the novelty of our research question we made no specific predictions regarding children's solution choice.

1.3 Solution choice over time

Traditionally, observational learning studies provide children with a single phase consisting of a demonstration of either a single (Lyons et al., 2007) or two or three (Flynn &

Whiten, 2008b; Wood et al., 2012) demonstrations of the same solution, followed by a response phase. In the current study there were two phases of demonstrations (differing varieties) and responses consisting of two to seven trials. This allowed investigation of whether the number of solutions children experience and the source (personal/social) of those solutions affected their behaviour as their task experience increased. Whilst previous studies show canalisation to a demonstrated solution (as outlined above), there are rare instances of innovation and behavioural spread of such innovations (Whiten & Flynn, 2010) suggesting that as a child's experience with a task grows and as other solutions are witnessed s/he may be motivated to explore alternative solutions.

1.4 Irrelevant action imitation

There are conflicting theories as to why children imitate irrelevant actions. Lyons et al. (2011) suggest that when naïve children receive social information their causal beliefs become distorted by the demonstration of irrelevant actions to the extent that they believe that such actions are causally necessary. Alternatively, children may not encode these actions as functionally necessary to acquiring the reward. Instead, they are unsure of the purpose of the actions and copy them as a default strategy which is refined later (Whiten, Horner, & Marshall-Pescini, 2005), or they interpret the model's actions as meaningful (Nielsen & Tomaselli, 2010), or normative (Kenward, Karlsson, & Persson, 2011; Kenward, 2012). Conversely, children may copy irrelevant actions to serve a social function of sharing an experience with a model (Užgiris, 1981) whereby children's social goals, identification with the model and with the social group in general, influences the copying of irrelevant actions (Over & Carpenter, 2012).

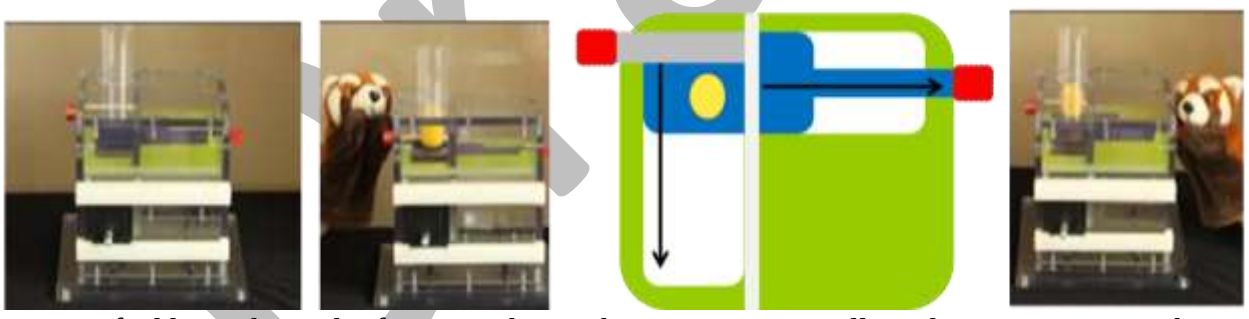
The current study aimed to discern between these explanations by asking a number of critical questions. First, does the social demonstration of two alternative methods lead to the

extraction of only the critical sequences of actions required to reach a desired goal (Buchsbaum, Gopnik, Griffiths, & Shafto, 2011; Byrne, 1999)? Second, would children incorporate irrelevant actions presented in a demonstration that used the same solution as the children had themselves previously discovered? With both these questions, if the children omit the irrelevant actions it would suggest that the imitation of irrelevant actions may be due to adapted casual reasoning or, more simply, employ a strategy of 'copy now, refine later' (Whiten et al., 2005). Alternatively, if children copy these irrelevant actions faithfully it would suggest a more normative or social explanation. Third, does personally acquired experience decrease the copying of irrelevant actions of a previously unseen solution? Williamson et al. (2008) and Williamson and Meltzoff (2011) found that children with personally acquired success do not adopt an alternative technique involving the use of an opaque, causally irrelevant action. By presenting both an alternative solution and irrelevant actions within that solution we investigated whether children would be faithful to their previous solution, or whether they would adopt the new solution, either only including the relevant actions, or in its entirety. If children imitate the alternative strategy but do not imitate the irrelevant actions it would suggest that there is an absence of social or normative motivation towards copying the puppet's irrelevant actions. Instead, their omission would suggest that children's personally acquired information gives them a casual understanding of the task (Lyons et al., 2011), or already refines their understanding of the task (Whiten et al., 2005) suggesting a more causal explanation for irrelevant action reproduction.

1.5 Summary

This study investigated how 5-year-old children behave after experiencing multiple solutions to a problem. Children of this age were chosen to allow for a comparison with related empirical work investigating imitation of tool use (e.g. Buchsbaum et al., 2011;

McGuigan et al., 2010; Nielsen & Tomaselli, 2010; Wood et al., 2012). Our study adopted a two-action artificial fruit paradigm (Dawson & Foss, 1965; Whiten, Custance, Gomez, Teixidor, & Bard, 1996), the Sweep-Drawer Box (SDB, see Figure 1), a puzzle-box that contained a reward held in place by a series of defences. Critically, there were two separate solutions to the SDB, a drawer and a sweep mechanism that could be used to release the reward. Using a task with two possible solutions allowed a number of distinctions to be identified: (a) the propensity to discover each of these solutions during personal exploration, (b) the level of replication of a demonstrated solution compared to the level of production of an alternative solution, and (c) fidelity or exploration of solution use once an alternative solution was demonstrated. Irrelevant actions were incorporated into the demonstrations allowing investigation of whether personally acquired information, or multiple solution demonstrations, would reduce the copying of irrelevant actions. We made no specific predictions regarding a child's solution choice or irrelevant action reproduction following receipt of additional social information but such an investigation allowed us to examine such real-life contexts in a controlled manner.



(a) *(b)* *(c)* *(d)*

Figure 1. The Sweep-Drawer Box (panel a). Puppet using the sweep (panel b). Top view of SDB showing movement of sweep and drawer (panel c). Puppet using the drawer (panel d).

2. Method

2.1 Design

The experiment had two phases both consisting of task information and task interaction. Phase 1 manipulated the source of the child's original task information such that children either had personal or social experience. Phase 2 manipulated the subsequent task information such that successful children either had agreeing or opposing solutions or no further information and unsuccessful children either had their first demonstration or no further information. This design facilitated the investigation of children's behaviour after experiencing multiple solutions to a problem through the following assessments: (1) children's behaviour following alternative (Phase 1 and Phase 2) socially-demonstrated task solutions; (2) children's solution choice following personally acquired information (Phase 1) and subsequent social information (Phase 2); (3) tracking solution choice over time (in multiple Phase 2 response trials); and (4) investigating the often prevalent reproduction of irrelevant actions following both phases.

2.2 Participants

One hundred and seventy children were recruited from eleven primary schools in County Durham, UK. Three participants were excluded from the study due to experimenter error leaving 167 (79 males, M = 65.7 months, SD = 3.52 months). There were no significant differences in sex [χ^2 (7, N = 167) = 3.22, p = .86] or age ($F_{7, 159} = 0.76$, p = .62) distribution across the eight conditions.

2.3 Apparatus

A two-action task, the 'Sweep-Drawer Box' (SDB, see Figure 1), was used. The SDB is a transparent box with an opening at the top where a capsule containing a reward (a sticker) can be inserted. After insertion the capsule falls onto an opaque platform where one of two spatially separated and functionally unique mechanisms can be manipulated in order to push

the capsule to a lower level. These two manipulandi are, (1) a silver sweeper with a red handle (see Figure 1b) that when pushed moves the capsule to a hole through which the capsule falls to the lower level, and (2) a blue drawer with a red handle (see Figure 1d) that can be pulled outwards producing a gap through which the capsule falls to the lower level. Once in the lower level the capsule rests behind a black opaque door which can be opened to obtain the sticker. The capsule containing the sticker was inserted into the SDB by the experimenter with her left hand and on her right hand was a puppet, 'Pip'. A puppet was used to avoid a model-based bias of copying the irrelevant actions of an adult model (see Wood et al., 2012). Whilst there is a potential issue with the experimenter also being the controller of the puppet we found that children were markedly different in their reactions to Pip than they had been to the same experimenter in previous studies (Wood et al., 2012), instead their behaviour was similar to studies where a second experimenter had operated puppets (e.g. Rakoczy, Warneken, & Tomasello, 2009; Kenward, 2012). For example, participants exclaimed (when Pip performed irrelevant actions), 'Silly Pip, why is Pip doing silly things?' and (when demonstrating the alternate method), 'Pip, you are cheating'. Although anecdotal, this suggests that the experimenter operating the puppet did not influence children's copying any more than another adult operating the puppet.

2.4 Procedure

Children were tested individually at a table in a quiet area in their school. First the experimenter introduced the child to the puppet 'Pip' and completed a few easy tasks, such as finding stickers, to relax the child and introduce the concept of turn-taking with the puppet. The child was then asked to sit in front of the SDB and the experimenter said, "Today I have brought in this toy. I would like you and Pip to take turns to see if you can get the sticker out. Take a really good look at it. Can you see it Pip? (Pip nods). Can you see it (child's name)?"

The experiment then consisted of two phases which involved information acquisition and the child's subsequent task interaction. Which condition a participant was placed into was determined by systematic allocation in Phase 1 (every third child was given social information, and the other two-thirds were given no initial social information), their subsequent behaviour in Phase 1 and systematic allocation in Phase 2 (with distribution partly predetermined to ensure correct participant numbers per condition). Due to high levels of personal success at solving the task there were fewer children in no-information (Phase 1) conditions than personal (Phase 1) conditions. This design resulted in eight conditions (see Table 1).

In Phase 1 children were given either no information and were told, "You play with it first," and progressed straight to the task interaction part of Phase 1, or were told, "It's Pip's turn first" and given a demonstration prior to interacting with the task themselves; the children watched as the experimenter put the capsule in the SDB and then used her other hand, with the puppet on, to extract the reward twice, both times using the same solution (see Figure 1). The puppet's sequence of actions was as follows: the capsule was moved from the opaque level to the lower level using either the sweep or drawer solution. Immediately after the capsule fell a further five *irrelevant* actions were performed with whichever manipulandi was being used, either the drawer or sweeper, so that it was moved a further five times (forwards and backwards for the sweeper and in and out for the drawer). Then the door was opened and the capsule obtained.

After extraction, a sticker was put on Pip's pile and the experimenter said, "That's a sticker for Pip." Demonstration of the two solutions (sweep or drawer) was counterbalanced across all conditions. Children then had two response trials, T1 and T2, and could interact with the task to successfully extract the reward using either the sweep or drawer solution ('success') or fail to extract the reward ('fail') after three minutes. Three minutes allowed

sufficient time for success with the SDB but did not make unsuccessful participants uncomfortable. If required, the child was given prompts such as, "You can play with it as much as you like. You won't break it." They were never explicitly told to touch any part of the SDB. If successful in T1 a sticker was added to a child's pile and the child was allowed a second trial (T2). The children's behaviour partly determined which Phase 2 information they received.

In Phase 2 all children were told, "Now it's Pip's turn" and watched as the puppet did one of four things: (a) *No information* (conditions 3, 6 and 7a), in which the puppet looked at the SDB for 20 s but made no contact with it. Halfway through Pip was encouraged by the experimenter, "You can do whatever you like Pip, you won't break it" and after 20 s the experimenter said, "I don't think Pip wants a turn. It's your turn now," (b) *Agreeing* demonstration (conditions 2 and 5), in which the puppet extracted the reward twice, both times using the same solution as the child had used in Phase 1, (c) *Alternate* demonstration (conditions 1 and 4), in which the puppet extracted the reward twice, both times using the solution that the child had *not* previously used in Phase 1, and (d) *First demonstration* (condition 7b), 21 children who received no information and were unsuccessful in Phase 1, watched the puppet extract the reward twice using the same solution, with solution choice counterbalanced.

At the beginning of the task interaction trials in Phase 2 all children were told, "It's your turn again. See if you can get the sticker out." The child was allowed to interact with the SDB until s/he retrieved the reward successfully or three minutes had elapsed. If children were successful a sticker was added to their pile and they were told, "It's your turn again," until they had finished the maximum number of trials. The first 82 children tested were given two trials (T3, T4); at this point it became apparent that solution alternation was occurring and so the remaining 85 children were given five response trials (T3, T4, T5, T6, & T7) to

310 investigate this further. At the end of testing all children were told they had done very well

311 and were rewarded with stickers irrespective of their level of success.

Table 1: Overview of the six initial-success and two initial-failure conditions

	Initial-success groups						Initial-fail groups	
	1	**2**	**3**	**4**	**5**	**6**	**7a**	**7b**
	Personal-then-social-alternate	**Personal-then-social-agreeing**	**Personal-then-none**	**Social-then-social-alternate**	**Social-then-social-agreeing**	**Social-then-none**	**No information**	**None-then-social**
Phase 1								
Information	No information	No information	No information	Demonstration	Demonstration	Demonstration	No information	No information
Response Trials	Success	Success	Success	Success	Success	Success	Failure	Failure
Phase 2								
Information	Alternate	Agreeing	No information	Alternate	Agreeing	No information	No information	Demonstration
Response Trials	T3 to T7	T3 to T7	T3 to T7	T3 to T7	T3 to T7	T3 to T7	T3 to T7	T3 to T7
Sample size (males)	32 (17)	21 (10)	21 (11)	21 (10)	21 (11)	21(10)	9 (3)	21 (7)
Age months *M (SD)*	66 (4)	66 (3)	66 (3)	66 (4)	66 (3)	65 (4)	64 (3)	65 (4)

Note. In Phase 1 children were given either (a) no information, "You play with it first" or social information (B)"It's Pip's turn first" and given a demonstration. Children then had two response trials, T1 and T2, and could interact with the task to successfully extract the reward ('success') or fail to extract the reward ('failure'). In Phase 2 all children watched either (a) no information, (b) an agreeing demonstration, (c) an alternate demonstration or (d) a first demonstration (for those who had failed). Children then had two or five response trials.

2.5 Coding and inter-rater reliability

Each participant's performance was scored on three separate variables for each response trial, (a) success (sticker capsule removal), (b) solution used and (c) number of irrelevant actions copied (out of five). The experimenter, LW, coded 100% of the sample from video tape. An independent observer coded 26% of the sample. All Cronbach's Alpha scores were 0.90 or above, showing an excellent level of inter-rater reliability. All tests are two-tailed unless otherwise stated.

3. Results and discussion

Following a brief description of behaviour of children who were initially unsuccessful, the results and discussion are presented in four sections: (1) the effect of demonstrations of alternative solutions upon children's subsequent solution choice, (2) the effect of personally acquired experience upon the imitation of subsequent socially demonstrated alternatives, (3) solution choice over time and (4) irrelevant action imitation.

Of the 104 children who witnessed no demonstration, 30 children (29%) were unsuccessful. In Phase 2, these children were given either no further information (condition 7a, n = 9) or a demonstration (condition 7b, n = 21). In the no further information condition, two of the nine children went onto successfully retrieve the reward. In the none-then-social condition, 20 of the 21 children successfully retrieved the reward after the demonstration, with all copying the solution witnessed, a statistically significant level of fidelity ($p < .001$, Binomial test). Fourteen of these 20 children copied an irrelevant action in T3, their first response trial in Phase 2. As the remaining two-thirds of children were able to retrieve the reward without social information, the SDB was challenging but within the capacity of most children.

3.1 Demonstrations of alternative solutions

The first research question focused on children's behaviour following demonstrations of alternative methods. In Phase 1 sixty-three children received a social demonstration and all were successful in Phase 1 response trials. Children who witnessed a demonstration were significantly more successful at T1 than children who had not witnessed a demonstration ($p <$ .001, one-tailed Fishers Exact Test, FET). Sixty-two children (98%) used the same solution as they had witnessed in both T1 and T2 responses. In Phase 2, twenty-one children were allocated to the social-then-social-alternate condition. These children were more likely to use the demonstrated alternative ($N = 16$, 76% did so) than the originally demonstrated method ($p < .05$, Binomial test) in their first Phase 2 response (T3). This tendency to switch solutions was a result of the alternate social demonstration as children in the social-then-social-alternate condition were significantly more likely to use an alternative method in T3 than those in the social-then-none ($N = 21$, $p < .001$, FET) and the social-then-social-agreeing ($N = 21$, $p < .001$, FET) conditions, of which only 4 and 1 children respectively discovered a previously unused alternative.

Witnessing a demonstration led to a significant increase in success, relative to those who received no demonstration, with children imitating the specific solution used by the model. This supports the widely held view that children are prolific social learners who faithfully imitate (Whiten et al., 2009). The children receiving social information in Phase 1 were canalised to the socially demonstrated method in their Phase 1 response trials. However, when children with initial social information were shown an alternative solution of reward retrieval in Phase 2, the majority of them performed the newly demonstrated solution in their first subsequent Phase 2 trial which stands in contrast to chimpanzees who fail to adopt subsequent social information (Hopper et al., 2011).

3.2 Personally acquired information

The second research question investigated whether the source of the prior information affected the copying of subsequent, socially demonstrated solutions. In Phase 1 seventy-four (71%) children who witnessed no demonstration were successful at retrieving the reward in both Phase 1 response trials. Forty-three used the drawer and 31 the sweep solution, indicating no natural bias in solution choice (p = .201, Binomial test). Sixty-three of these children (85%) used the same solution on both trials; however, eleven children switched solution between T1 and T2. Therefore, children with personal information were significantly more likely to find more than one solution in Phase 1 than children with social information (N = 167, p < .01, FET). These eleven children either had no further demonstration (personal-then-none) or a demonstration of one method (included in personal-then-social-agreeing). In Phase 2 thirty-two children were allocated to the personal-then-social-alternate condition. These children were more likely to use the demonstrated alternative solution (N = 24, 75% did so) than their personally discovered solution in their first task Phase 2 response (T3, p < .001, Binomial test). Multiple comparisons indicated that this tendency to switch solutions was a result of the social information demonstrated as children in the personal-then-social-alternate condition were significantly more likely to use an alternative method in T3 than those in the personal-then-none (N = 15, p < .01, FET) and personal-then-social-agreeing (N = 16, p < .01, FET) conditions, with 2 and 1 children respectively discovering a previously unused alternative.

Children with personally acquired information were more likely than children with prior social information to discover multiple solutions in Phase 1. Allowing children to interact with artefacts before social demonstrations may encourage exploratory behaviour. Children with personally acquired information have been shown to disregard subsequent social information if it is inaccurate (Clément et al., 2004), unreliable (Ma & Ganea, 2010) or

unsuccessful (Williamson et al., 2008). In the current study the difficulty or effectiveness of the initial solution acquired was not manipulated, yet children in the personal-then-social-alternate condition were still motivated to copy the alternative solution, predominantly attempting the alternative demonstrated solution in their first subsequent interaction with the task. This use of social information, when personally acquired information is sufficient and not costly, contrasts with studies of our closest living relatives, chimpanzees (Hrubesch et al., 2009), and many other non-human species (Kendal et al., 2005). The demonstration appeared to be the key element in driving exploration as the vast majority of children with successful personally acquired information who received no further information, or social information that agreed with their personal information, did not discover the alternative solution. It could be argued that children who receive demonstrations of a solution in agreement with their prior solution may view the puppet as imitating the child. However, we deem this an unlikely explanation as children may be unaware that any alternatives exist and the puppet also includes irrelevant actions so does not faithfully imitate the child.

3.3 Solution choice over time

Our third question addressed whether children would be motivated to incorporate multiple methods into their repertoire. All 137 children in the six initial-success conditions were given at least two trials (T3 and T4) in Phase 2 and 76 of these children were given the opportunity to perform a further three trials (see Table 2). Multiple comparisons (Bonferroni corrected; $p = .017$) were made based on whether initial information had been personal or social. There was no difference between children in the social-then-social-alternate and the personal-then-social-alternate conditions in relation to which solution (original or newly demonstrated) was used at T3 ($N = 53$, $p = 1.0$, FET) or T4 ($p = .16$, FET) or whether they used the same solution for both T3 and T4 or two different solutions over these trials ($p = .17$,

FET). Similarly, children with no information in Phase 2 (personal-then-none and social-then-none) did not differ from each other in their likelihood of using one or two methods in Phase 2 whether those children who discovered two methods in Phase 1 were included (p = .05, FET) or excluded (p = .43, FET). Children with agreeing information in Phase 2 (personal-then-social-agree and social-then-social-agree) did not differ from each other in their likelihood of using one or two methods in Phase 2 whether those children who discovered two methods in Phase 1 were included (p = .23, FET) or excluded (p = .43, FET).

Comparisons were also made based on whether children had received alternate, agreeing, or no information in Phase 2, regardless of the source of their initial information. Children who received an alternate demonstration in Phase 2 (N = 53) used the recently demonstrated solution, significantly more than chance at T3 (75%, p < .001, FET), but by T4, only 23 (43%) used the recently demonstrated solution which did not differ from chance (p = .41, FET). Twenty-seven of these 53 children used two solutions in Phase 2 (T3 and T4 only) which was significantly different from the one child (out of 37) who did so from social-agreeing conditions (excluding those who discovered two methods in Phase 1; p < .001, FET) and the one child (out of 35) who did so from conditions receiving no information in Phase 2 (excluding those who discovered two methods in Phase 1; p < .001, FET). This difference between groups remained when analysing the 69 (excluding 9 that discovered two solutions in Phase 1) children that received five trials in Phase 2 [χ^2 (2, N = 69) = 18.02, p < .001].

436 *Table 2: Number (and %) of children who alternated their solutions in Phase 2 (excluding children who discovered two methods in Phase 1).*

Condition	Phase 2: T3 and T4 Completed T3 & T4 (N = 125)	Used a new solution in T3- T4		Two solutions T3 & T4		Phase 2: T5-T7 Completed T5, T6 & T7 (N = 76)	Used a new solution in T5-T7
Personal-then-social-alternate	32	27	84%	19	60%	15	1
Personal-then-social-agreeing	15	1	7%	1	7%	13	0
Personal-then-none	16	2	14%	1	6%	15	3
Social-then-social-alternate	21	18	86%	8	38%	7	0
Social-then-social-agreeing	21	1	5%	0	0%	15	0
Social-then-none	20	3	15%	0	0%	11	0

In Phase 1, children with personal information were more likely than children receiving social information to discover multiple methods. However, by Phase 2 there was no difference in whether one or two methods were employed when comparing across matched conditions. For example, the majority of children who witnessed a social demonstration of an alternate solution regardless of Phase 1 information source alternated between the two solutions in Phase 2. This was markedly different to children who received no further information or social-agreeing information who predominantly used their original solution. It seems that personally acquired information encourages initial exploration and when children witness alternative strategies they are motivated to incorporate these solutions into their repertoire. The children did not appear to interpret the new solution as a 'correction', but rather a possible alternative. As in Siegler and Opfer (2003), children adopted multiple strategies to solve a single problem. It is important to note the exceptions in all of these conditions: ten children from conditions where no alternate social information was received found an alternative solution in Phase 2. Thus, whilst the initial response trials of those with prior social information mirrored the canalisation shown in studies providing children with one or two attempts at a task (Flynn & Whiten, 2008b; Horner et al., 2006), the current results indicate that continued interaction encourages exploration (Whiten & Flynn, 2010).

3.5 Irrelevant actions

To begin this section the baseline production of the irrelevant actions is established. In Phase 1, of the children who were successful through acquiring personal information (N = 74), 19 (26%) performed an irrelevant action. Apart from one child who performed three irrelevant actions in T1, all others performed just one irrelevant action (Mdn = 0.0, IQR = 0.0, 0.0), resulting in the sweep or drawer being placed back to its original position, revealing a possible propensity to 'tidy up'. Of those children who witnessed a demonstration including

irrelevant actions in Phase 1 (N = 63), 54 (86%) performed an irrelevant action. Thirty-three of these 54 children (61%) performed more than one irrelevant action (*Mdn* = 1.5, *IQR* = 1.0, 5.0). Thus, despite the inclusion of 'tidying up' as an irrelevant action, children who witnessed a demonstration containing irrelevant actions produced significantly more irrelevant actions than those who did not in both T1 (χ^2 (1, N = 137) = 57.61, p < .001) and T2 (χ^2 (1, N = 137) = 49.73, p < .001).

A critical question was whether prior task experience would reduce the copying of causally irrelevant actions in subsequent response trials. This was addressed in a number of ways looking at Phase 2 behaviour. First, would children with two alternate social demonstrations copy irrelevant actions when attempting the second solution or would viewing multiple methods enable them to extract only the critical causal sequence of actions? For children in the social-then-social-alternate condition there was no significant change in whether a child performed an irrelevant action between Phase 1 (T2) and Phase 2 (T3; Binomial, N = 21, p = .25) and in the number of irrelevant actions produced between T2 (*Mdn* = 1.0, *IQR* = 0.5. 4.5) and T3 (*Mdn* = 1.0, *IQR* =1.0, 4.0, Wilcoxon Z = -0.91, p = .93). There was also no significant difference in the number of irrelevant actions produced in T3 between children in the social-then-social-alternate condition and children in the social-then-none (*Mdn* = 1.0, *IQR* = 0.0, 5.0, $U_{(41)}$ = 176.5, Z = -1.20, p = .23) and the social-then-agreeing (*Mdn* = 1.00, *IQR* = 0.0, 5.0, $U_{(41)}$ = 216.5, Z = -0.11, p = .92) conditions.

Second, what actions will children with personally acquired information perform following subsequent social information including irrelevant actions? In the personal-then-social-agreeing condition six children (29%), who had not performed an irrelevant action in Phase 1, performed an irrelevant action in T3 (following a demonstration of the *same* solution). In this condition, whilst the number of children performing an irrelevant action did not increase significantly (McNemar, N = 21, p = .13), the number of irrelevant actions

produced did increase significantly from Phase 1 (T2: *Mdn* = 0.0, *IQR* = 0.0, 0.0) to Phase 2 (T3: *Mdn* = 0.0, *IQR* = 0.0, 1.00, Wilcoxon Z = -2.11, $p < .05$). Similarly, for the 32 children in the personal-then-social-alternate condition, the number of children performing an irrelevant action increased significantly from T2 (N = 6) to T3 (N = 16; Binomial, N = 32, $p < .01$) as did the number of irrelevant actions (T2; *Mdn* = 0.0, *IQR* = 0.0, 0.0, T3; *M* = 0.5, *IQR* = 0.0, 1.0, Wilcoxon Z = -3.16, $p < .01$). Of the 24 children in this condition that attempted the alternative solution in T3, 12 (50%) used an irrelevant action. These 12 children performed a median of 1 (*IQR* = 1.0, 3.0) irrelevant action, which was not significantly different from the 16 children in the social-then-social-alternate condition (*Med* = 1.0, *IQR* = 1.0, 4.0, Mann-Whitney $U_{(28)}$ = 86, Z = -0.53, p = .60).

For all 137 children in the initial (Phase 1) success conditions there was no significant difference, in the number of irrelevant actions produced, between T3 and T4 (Wilcoxon Z = -1.71, p = .09), and so children's mean scores across T3 and T4 were investigated across conditions (see Figure 2). Considering the mean number of irrelevant actions in T3 or T4, there was no main effect of Phase 2 information for those with personal information in Phase 1 (personal-then-social-alternate/-agreeing/-none; Kruskal Wallis χ^2 (2, N = 74) = 3.7, p = .16) or for those with social information in Phase 1 (social-then-social-alternate/-agreeing/-none, T3: [χ^2 (2, N = 63) = 1.27, p = .53]). Therefore, conditions were collapsed according to the source of the original information. Children with personally acquired information performed significantly fewer irrelevant actions (*Mdn* = 0.0, *IQR* = 0.0, 1.0) than children with prior social information (*Mdn* = 1.0, *IQR* = 1.0, 3.0, Mann-Whitney, $U_{(135)}$ = 1108.0, Z = -5.51, $p < .001$) during Phase 2 (T3 and T4).

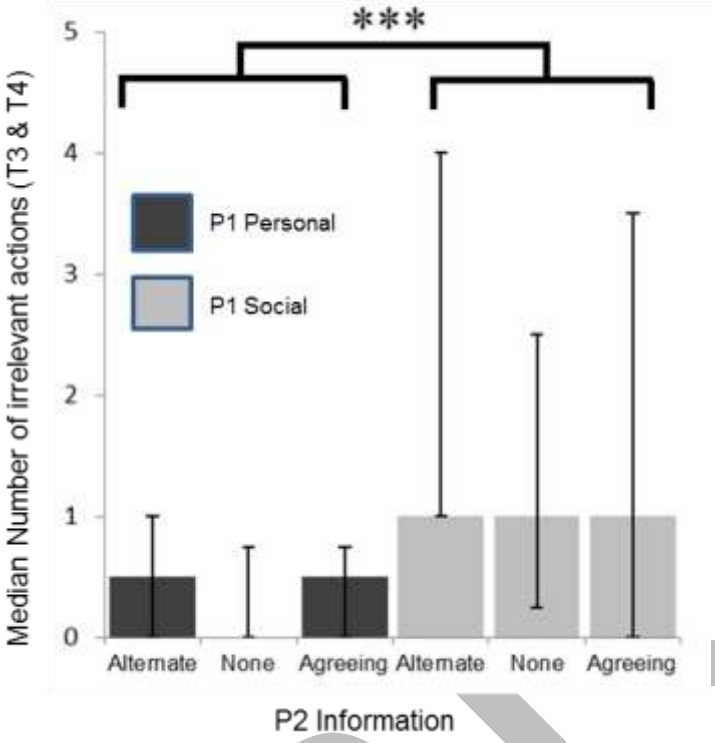


*Figure 2: Median and interquartile range of mean number irrelevant actions (out of a possible five) in Phase 2 (Mean of T3 & T4) for the six initial-success conditions.P1 Personal; personal information in Phase 1, P1 Social; Social demonstration in Phase 1. *** $p < 0.001$.*

It appears that it is not prior experience itself which affects the copying of causally irrelevant actions but the type (personal or social) of prior experience. Those who had personal information in Phase 1 consistently performed fewer irrelevant actions than those who had social information in Phase 1. Children with prior social information continued to perform irrelevant actions regardless of the absence or presence of subsequent social information. Thus the copying of irrelevant actions was not affected by alternate demonstrations indicating that the children did not extract, from multiple alternatives, only the critical, causal sequence of actions to reach a desired goal (Byrne, 1999, Buchsbaum et al., 2011). We do not suggest that children are not capable of such efficiency but that in this

524 context, involving different irrelevant actions pertaining to different solutions with the same
525 artefact, the ability is constrained. Children with prior social information, who copy
526 demonstrated actions and succeed, may be more likely to assume that copying of subsequent
527 actions is a successful strategy in this context.

528 Successful prior-personal information appeared to give children both immunity and
529 susceptibility to copying causally irrelevant actions. Of the children who produced no
530 irrelevant actions at Phase 1, two-thirds (social agreeing) and half (social alternate) did not
531 copy irrelevant actions following social demonstration. However, the remainder did and did
532 so at a rate similar to children possessing prior-social information. The variance of behaviour
533 of the children with prior-personal information suggests that irrelevant action reproduction
534 may well be influenced by both the functional aspects of the task and social context. For
535 example, possession of prior-personal, versus prior-social information may make children
536 more sceptical about the function, whether social or causal, of observed causally irrelevant
537 actions; possibly explaining why Williamson et al. (2008) and Williamson and Meltzoff
538 (2011) found that children did not incorporate subsequent (albeit opaque) irrelevant actions
539 after a successful and easy experience with the task. However, for individuals in the prior-
540 personal-social-alternate condition who did copy the demonstrated irrelevant actions, the
541 unfamiliarity of the alternate solution may have resulted in children encoding the actions as
542 causally relevant (Lyons et al., 2007) especially as more irrelevant actions were produced in
543 this condition than where social information agreed with prior-personal information. As the
544 task design ensured that these children already had a good understanding of the causal
545 properties of the task we suggest, however, that children's copying of irrelevant actions in
546 this context was more likely a result of motivation to adopt the model's seemingly purposeful
547 (Nielsen & Tomaselli, 2010) or normative behaviour (Kenward et al., 2011; Kenward, 2012)
548 or due to a motivation to share an experience with another (Užgiris, 1981). This highlights

549 the persuasiveness of social information, even when emitted by a puppet and this
550 persuasiveness may be adaptive if it enables acquisition of cultural norms.
551
552 **4. General discussion**
553 The comprehensiveness of the current study enabled valuable insight into the role
554 prior experience plays in children's social learning strategies pertaining to solution choice
555 and imitation of irrelevant actions. Our results extend the field of social learning in a number
556 of important ways. We found that children who are allowed to interact with a task before
557 witnessing social demonstrations manipulate the task in more ways than those that witness an
558 initial social demonstration. Further, after new solutions are discovered, whether through
559 personal or social experience, children were motivated to incorporate these new solutions into
560 their repertoire but they were not 'converted' to these alternatives, instead they switched
561 between solutions. This multiple strategy use is seen in other domains in children's learning,
562 such as mathematics (Siegler & Opfer, 2003) and continues into adulthood (Dowker, Flood,
563 Griffiths, Harriss, & Hook, 1996). Adopting further strategies when one already has a
564 successful strategy may seem cognitively inefficient, but there are several reasons why it is
565 beneficial. First, learning about a new strategy is useful in the event that an original strategy
566 fails. Second, learning multiple strategies increases one's overall knowledge of the task and
567 provides generalisable knowledge regarding the properties of each strategy and the
568 affordances of different manipulandi. In a tool-abundant culture the latter is valuable
569 knowledge. Third, a motivation to acquire additional knowledge enables modifications over
570 time. This 'ratchet effect' has been speculated to be the bedrock of cumulative culture, a
571 process thought to be unique to humans (Dean et al., 2012; Tennie, Call, & Tomasello, 2009).
572 The current study also makes a valuable contribution to our understanding of the
573 phenomenon of copying causally irrelevant actions. Overall, children who hold personal

information about a task are less likely than those receiving only social information to incorporate causally irrelevant actions after observing them displayed by others. Children with initial social information faithfully copy causally irrelevant actions even after continued personal task interaction and despite the fact that the actions occurred with a transparent box (revealing the irrelevance of the actions) and *after* the relevant action (the reward capsule had been successfully moved to the lower level barrier) as has been found previously (Simpson & Riggs, 2011). Successful prior-personal information appeared to give some children immunity from copying causally irrelevant actions whilst other children were still susceptible to copying these actions, illustrating that the copying of causally irrelevant actions is an intricate phenomenon and no one explanation may capture its complexities. Children's solution choice, their reasoning about causality, their motivation to share an experience with a model and the pressure to conform to norms will all vary depending upon task difficulty (Williamson & Meltzoff, 2011), the number of models (Asch, 1951), the characteristics of the model(s) (Wood et al., 2012), the audience (Haun & Tomasello, 2011) and, as has been shown in the current study, the prior information a child has regarding a task. These variables can be addressed individually or in combination and will enable a better understanding of children's motivation to learn certain aspects of a task from others. Studies that establish the complexity of children's social learning will shed more light on how and why humans stand alone in the breadth, detail, and cumulative nature of their culturally-rich world.

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