Journal of Language Evolution, 2022, 81–94
https://doi.org/10.1093/jole/lzac007
Advance Access Publication Date: 6 July 2022
Research article

OXFORD

Teaching, sharing experience, and innovation in cultural transmission

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Abstract

Teaching is widely understood to have an important role in cultural transmission. But cultural transmission experiments typically do not document or analyse what happens during teaching. Here, we examine the content of teaching during skill transmission under two conditions: in the presence of the artefact (no-displacement condition) and in the absence of the artefact (displacement condition). Participants built baskets from various materials to carry as much rice as possible before teaching the next participant in line. The efficacy of baskets increased over generations in both conditions, and higher performing baskets were more frequently copied; however, the weight of rice transported did not differ between conditions. Displacement affected the choice of strategy by increasing innovation. Teachers shared personal experience more to discuss non-routine events (those departing from expectations) than they did other types of teaching, especially in the presence of the artefact. Exposure to non-routine experience sharing during teaching increased subsequent innovation, supporting the idea that sharing experience through activities such as storytelling serves a sensemaking function in teaching. This study thus provides experimental evidence that sharing experience is a useful teaching method in the context of manual skill transmission.

Key words: cumulative cultural evolution; cultural transmission; cultural evolution; displacement; teaching; sharing experience

Introduction

Human culture involves the social transmission of information along generations. Teaching is a common way for information to be socially transmitted. Although it is widely argued that teaching has an important role in cultural transmission (Thornton and Raihani 2008), it is unclear to what extent it is necessary and what its specific components and functions are. While observational learning (such as emulation or imitation) is found in many species, teaching is more prominent in humans than in non-humans and perhaps one of the keys to our particular trajectory of cultural evolution (Kline 2015; Burdett et al. 2018). In light of this, it is surprising that transmission chain experiments typically do not document or analyse what actually happens during teaching sessions (Caldwell and Millen 2009; Zwirner and Thornton 2015). Thus far, there has been no investigation of how teaching takes place in this context, or what aspects of it may be beneficial. In this study, we experimentally compare teaching situations involving displacement—that is, requiring communication about things not spatially or temporally present—to non-displacement teaching. Additionally, we analyse the content of teaching and in particular the role of sharing experience to investigate how various conditions of teaching influence learners' choices to copy or innovate (Burdett et al. 2018).

1.1 Teaching in cultural transmission

Teaching underpins human culture (Galef 1992). It is a form of cooperative behaviour that has evolved to promote learning in others (Caro and Hauser 1992). This includes a range of cross-species behaviours differing in their level of intentionality: less intentional forms of teaching are those that can be picked up from chance observation, by teachers merely allowing the learner to observe them using an object. Direct active teaching (Kline 2015), on the contrary, goes beyond the concrete level to a conceptual one, with teachers communicating concepts and explaining the relationships between them, mapping onto sequential instructions, or experience-based advice. These forms of teaching are only observed in humans (Kline 2015).

The role of teaching in the context of cultural transmission has been experimentally investigated using the transmission chain method. These experiments have examined how cultural products (i.e., information or artefacts) are modified when passed through a succession of individuals and demonstrate cumulative cultural evolution—the mechanisms by which behaviours or artefacts are incrementally refined over generations (Caldwell et al., 2018). Manipulating the amount of social interaction between participants allows investigating the social learning mechanisms involved in cultural transmission. Social interaction can take the form of teaching, and the conditions allowing interaction to occur between generations are referred to as 'teaching conditions' (Zwirner and Thornton 2015; Caldwell et al., 2018). Contrasting different situations of teaching and learning enables comparisons of different forms of information transmission. For example, teaching (e.g., when interaction about the task occurs between generations) is compared to imitation (watching the previous generation perform the task), emulation (reverse engineering by examining the previous generation's completed product), or asocial repetition (one participant performs repeated trials of the task). This research has indicated beneficial effects of teaching in cultural transmission (Morgan et al. 2015; Lombao et al. 2017).

1.2 Stick-or-switch: Roles of teaching

The dual engines of cumulative cultural evolution are high-fidelity information transfer (precise copying) and innovation (Legare and Nielsen 2015). Cultural evolution research strives to understand the mechanism behind the decision to stick with a current solution (copy) or switch to a different one (innovate) (Rogers and Fay 2016). Both sticking and switching are inherently social phenomena (Muthukrishna and Henrich 2016). They are also interdependent, as both strategies must be employed at some point to enable culture to accrue; precise copying is required to prevent loss of advancements (Tomasello 1999), but without innovation there would be cultural stasis. This is especially important in technological domains such as the development of functional tools (Acerbi et al. 2016).

Teaching tends to be associated with precise copying (Lewis and Laland, 2012); however, it also impacts innovation. The social interaction inherent in teaching may facilitate precise copying over and above other forms of information transmission. When passing on narrative text, face-to-face interaction slows the rate of information loss, compared to listening to an audio-recording of the previous generation (Tan and Fay 2011). Feedback and active participation in the conversation facilitate this. Collaborative accounts of dialogue have shown the importance of feedback to ensure that what is said is mutually agreed, or grounded (Clark 1996), as active interlocutors comprehend information better than passive overhearers (Schober and Clark 1989). Similarly, in experiments with reproduction goals, interactivity slows the rate of information loss over generations for knot-tying (Caldwell et al., 2018) and stone-knapping (Morgan et al. 2015; Lombao et al. 2017), but not for a collaborative cooking task (Bietti et al. 2019). In studies with a performance goal, that is to functionally improve rather than copy the predecessor's artefact, teaching interactions support cumulative improvement (Caldwell and Millen 2009; Zwirner and Thornton 2015). Thus, teaching not only facilitates precise copying, but can also stimulate innovation.

Several aspects of teaching promote innovation in cumulative cultural evolution. First, the flexible and multifaceted nature of teaching often leaves learners the creative freedom to modify information being taught (Burdett et al. 2018). In cumulative cultural evolution, adaptive traits are spread while maladaptive ones are filtered out (Enquist and Ghirlanda 2007). Teaching provides opportunities to socially appraise solutions and decide whether to spread or filter certain variants, thus enabling coordination of strategies (Fay et al. 2018).

Content bias (perceived effectiveness of a solution) is instrumental in the decision to transmit one's own solution over someone else's (Tamariz et al. 2014). Access to socially transmitted information during teaching enables better evaluation of one's artefact compared to others, and thus a better-informed decision about which variants to adopt. This enables group-level coordination and may help maintain the optimal balance between innovation and copying.

1.3 Displacement

Displacement is one of the fundamental design features of human language, referring to its possibility to communicate about things that are not spatially or temporally present (Hockett 1960). It is a universal in human languages but rare in non-humans (Lameira and Call 2018). Displacement requires cognitive abilities similar to those required for mental time travel (Suddendorf and Corballis 2007) and engagement in prospective reasoning (Schacter et al. 2007). The necessity to communicate about absent things may have been a critical evolutionary pressure leading to the emergence and evolution of language (Gärdenfors and Osvath 2010). For early humans, the periodic spatial separation of mutually dependent group members created pressure to communicate about things not in the here-and-now (Kendon 1991), for example, the location of a distant food source (Bickerton 2009). Teaching under displacement is by necessity intentional as it cannot occur through chance observation of the teacher using an artefact. It requires communication about concepts and explanations of relationships between them (Gärdenfors and Högberg 2017). There are two forms of enactment in teaching that may be used to accompany verbal communication: demonstration with the artefact and pantomime without the artefact (Gärdenfors 2017). Both demonstration and pantomime constitute multimodal communication, involving for instance gesture, posture, and gaze seamlessly coordinated with language to facilitate understanding (Bavelas and Chovil 2000; Mondada 2019). They differ in that the referent is present in demonstration and absent in pantomime (Gärdenfors 2017), which makes pantomime a case of displacement (Hockett 1960). Researchers have even suggested that humans have an innate predisposition to socially share generalisable knowledge and have evolved perceptual sensitivity to multimodal cues in order to do so, termed 'natural pedagogy' (Csibra and Gergely 2006, 2009).

People prefer copying to inventing, especially when they are uncertain (Caldwell and Millen 2010) or when they lack confidence (Tamariz et al. 2014; Rogers and Fay, 2016). For most everyday problems, we seek to copy solutions that have been transmitted socially (Whiten et al. 2009). This makes sense from an evolutionary perspective, as most species with long life expectancies prefer social information if available (Forss et al. 2017), avoiding the uncertainty of novelty unless necessary (van Schaik et al. 2019). This copying tendency may be especially strong following exposure to a visual referent. Fixation, a term introduced by Gestalt psychologists (Duncker and Lees 1945) refers to the default tendency to rely too heavily on familiar or easily accessible information (George and Wiley 2020). We are constrained by previous examples, particularly when they are visual. When asked to interpret abstract inkblots, we adopt other people's interpretations if available (Rose and Felton 1955). Even when instructed to be as 'wild' as possible, people still tend to preserve the properties of known examples (Smith et al. 1993; Goldenberg et al. 2013). In the context of cultural transmission, 'tweaking', that is, the modest refinement of an existing solution, is a popular and successful strategy (Derex et al. 2019). Tweaks are associated with smaller changes in payoff, while large innovative leaps tend to lead to spectacular successes or failures (Miu et al. 2018). People are thus most likely to make small incremental improvements to the best available solution rather than drastic changes, especially when exposed to a visual example. This also has the implication that the displacement of artefacts may encourage learners to make larger innovative leaps: the lack of a visual referent during teaching may stimulate learners to produce creative and divergent solutions, fostering innovation.

1.4 Sharing experience and storytelling as a teaching method

All human groups have a natural proclivity to donate information to other group members (Tomasello et al. 2012; Burkart et al. 2018). Sharing knowledge is widespread in human groups, for example in hunter-gatherer societies (Salali et al. 2016). But perhaps the most common type of information shared in everyday life involves personal experiences. For example, in dinnertime conversations, American families reminisce about the events experienced during the day (Bohanek et al. 2009). In the workplace, photocopy repair technicians share their experiences ('war stories') of particularly difficult-to-fix machines with each other (Orr 1996). And members of nursing teams who are about to leave their shift share experiences about conflicts with patients or extraordinary clinical events with members of the incoming shift in handover meetings (Bangerter et al. 2011).

Sharing experience often occurs in episodes of storytelling, where individual experiences are verbalized, compared to those of others in the group and interpreted to create shared meaning. This corresponds to the process of sensemaking, or giving meaning to experience (Weick 1995; Bietti et al. 2018). The human cognitive system arranges experiences into knowledge structures, such as schemas, scripts, or frames (Goffman 1974; Mandler 1984) that structure perceptual meaning top-down and create expectations for everyday life. Mismatches between expectations and an event (e.g., an unexpected problem experienced in repairing a photocopying machine) produce surprise and negative arousal (Proulx and Inzlicht 2012) which in turn enable the generation of inferences (Sperber and Wilson 1986) to explain the mismatch. In a nutshell, then, storytelling allows groups to share and collectively give meaning to the experiences of their individual members, especially those experiences that depart from routines and expectations.

Storytelling and sharing experience can be used for teaching (Scalise Sugiyama 2017, 2021). Teachers may retell time-honoured stories from the remote past of a group, or they may share their recent experiences with learners. This may facilitate vicarious learning, whereby learners benefit from teachers' experiences. For example, foraging groups use storytelling to transmit knowledge about plants and animals, saving novices the risk and potential costs involved in acquiring experience first-hand (Sugiyama 2001). Sharing experience may be especially valuable in the case of negative experiences or failures. Experiencing mistakes, or productive failure, has educational value (Kapur 2016), and sharing those mistakes and the insights that accrued from them may help learners develop new strategies and avoid making the same mistakes. Thus, sharing experience may potentially favour innovation, and telling stories is indeed used as a pedagogical strategy for innovation, for example in engineering design communities (Karanian and Kress 2010).

Displacement may be conducive to sharing experience as a teaching method. Unlike the present moment, which can be shared through copresence, in situations of displacement, the past and future must be constructed through mental and linguistic representations (Hockett 1960). Storytelling is a pervasive way to achieve this (Bruner 1991). In contexts of cultural transmission, the displacement of the model artefact during teaching may therefore stimulate experience sharing.

1.5 This study

Existing lab-based transmission chain studies have only allowed for very restricted forms of teaching. For example, participants learn from artefacts without any interaction with the participants who produced them (Derex et al. 2019, 2013; Fay et al. 2019), or observe their actions without being able to talk to them (Wasielewski 2014). Studies with these observational conditions generally do not specify whether or not the participant is engaged in intentional teaching, such as slowing down their manual actions to perform demonstrations, making it difficult to draw conclusions about teaching. In studies where face-to-face, interactive teaching is allowed, it commonly occurs while teachers (Caldwell and Millen 2009) or learners (Morgan et al. 2015; Zwirner and Thornton 2015; Osiurak et al. 2020) are simultaneously engaged in the task, and analyses focus on task performance rather than the content of the teaching itself (Caldwell and Millen 2009; Zwirner and Thornton 2015). The presence of component materials primes particular strategies such as demonstration or monitoring by step-by-step instructional feedback. Time pressure also often prevents reflection on broader strategies.

The goals of this study were therefore first to investigate the mechanisms balancing innovation and fidelity in cultural transmission and secondly to investigate the prevalence and functions of sharing experience as a teaching method. We predict that sharing experience will reflect non-routine events, such as poor performance or mistakes, and that it will stimulate innovation.

In the study, chains of adult participants completed a construction task: to make a basket to carry as much rice as possible from various materials (Zwirner and Thornton 2015). The basket designs were transferred between multiple generations in two conditions: no-displacement where participants taught the next-in-line with the basket they had just created to hand, and displacement where teaching occurred with the basket absent. Building on existing experimental work on storytelling in teaching during cultural transmission (Bietti et al. 2019), we provide additional analyses of teaching.

The study tests hypotheses concerning the rice-carrying performance of baskets as a function of our experimental manipulations (inter-generational transmission and displacement), and how these effects interact with the content of teaching and sharing experience. We predict that the artefacts will become increasingly refined and thus more functional over generations as a result of cultural transmission. From this follows our first hypothesis that the mass of rice transported will increase over generations (Hypothesis 1, H1). We also predict that the teaching condition (displacement/no-displacement) together with the performance of the previous generation predicts the choice of strategy in the current generation. This motivates the following hypotheses: There will be more innovation in the displacement condition than in the no-displacement condition (Hypothesis 2, H2), while there will be more low-risk, incremental improvement in the no-displacement condition than in the displacement condition (Hypothesis 3, H3), and participants will innovate more when predecessors produce poor-performing baskets (Hypothesis 4, H4). Additional hypotheses relate to the role of sharing experience as a specialised teaching method that differs in prevalence across teaching contexts, measured in the form of memory utterances (see Section 2.5). These are: there will be more sharing experience in the displacement condition than in the no-displacement condition (Hypothesis 5, H5), and shared experience concerns more non-routine events than do other kinds of talk (Hypothesis 6, H6), and that non-routine sharing of experience during teaching increases the likelihood that a learner will subsequently choose to innovate (Hypothesis 7, H7). Additional exploratory analyses are presented in the Supplementary Materials.

2. Methods

2.1 Participants

There were 168 French-speaking participants recruited at the University of Neuchâtel (88 female, $M = 24.2$ years of age, $SD = 4.53$). Participants received eight CHF for taking part in the study plus one individual incentive (two CHF for every additional 500 g of rice transported relative to their predecessor, or to a pilot average if first in the chain) and one group incentive (twenty CHF per person for the four best groups). Participants were randomly assigned to conditions (displacement versus no-displacement) and chains (one to twenty-eight, see Figure 1); however, assignment to generation (one to six) was non-random as based on availability. During debriefing, participants completed the group cohesion scale (Treadwell et al. 2001) and rated how well they knew others in their chain. Over half (56%) of the participants knew at least one other person in their chain, while the rest did not. This did not affect group cohesion ($M_{\text{'Know' group}} = 4.15$, $M_{\text{'Do not know' group}} = 4.25$, $t(166) = 0.85$, $p = 0.40$).

2.2 Task

The task involved building a basket in 5 min to carry as much rice as possible (Zwirner and Thornton 2015), measuring performance as the amount of rice in grams successfully transported by each basket. This task mimics challenges faced by early humans and is unlikely to relate to participants' previous experience, while helping build the case for mobile containers as tools in cognitive evolution (Fisher 1979; Langley and Suddendorf 2020). Each participant was given an identical set of materials (see Table 1) and a timer.

2.3 Design

A vertical transmission chain method was adopted, with two conditions: teaching with the basket to hand (no-displacement) or removed (displacement). Teaching was separated from task performance and there was no time constraint. Building and teaching sessions were video recorded.

2.4 Procedure

After completion of the consent forms, participants proceeded to the experiment which consisted of three phases: building, testing, and teaching. During the building phase, participants completed the task of assembling a basket from various materials. During testing, participants loaded their baskets with as much rice as they dared from the 8 kg container, carried it 5 m, and then poured the rice into a bowl on digital scales. Participants were informed about the mass of rice they had transported, which was also recorded for analysis. During the teaching phase, participants were told to interact with the next participant to help them build their basket. Task materials were replenished and the basket hidden in the storage area if in the displacement condition. The next participant entered the room and the two were allowed to talk for an unlimited amount of time ($M = 3.58$ min, $SD = 2.21$ min). Once finished, the initial participant left the room for debriefing, their basket was hidden if in the no-displacement condition, and the incoming participant now completed the building, testing, and teaching phases as above. This routine was repeated for the following four participants. The last participants in each chain were debriefed and allowed to leave following the testing phase.

2.5 Measures

2.5.1 Task performance

For H1 (mass of rice transported will increase over generations), task performance was measured as the total weight in grams of rice carried by each basket for two trials. The first by participants during the testing phase of the experiment, and the second by experimenters aiming to fill each basket with the absolute maximum quantity of rice. The purpose of this second trial was to

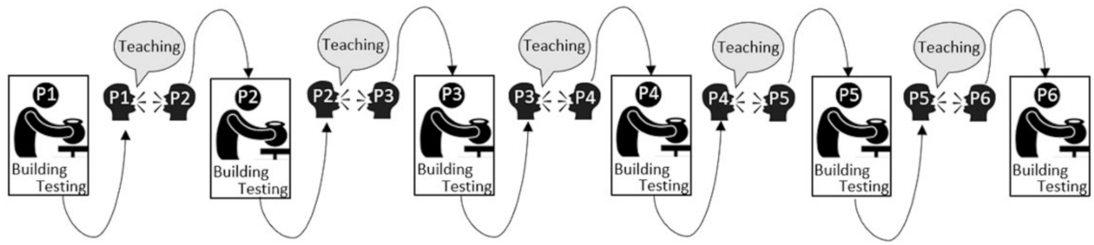


Figure 1. One transmission chain. Reads left to right, each participant in the chain noted as 'P' followed by a number representing their generational position in that chain (e.g. P1 = Participant 1).

Table 1. List of task materials.

Quantity	Material and dimensions
2	String (40 cm)
1	Fabric gauze (25 × 27 cm)
1	Newspaper sheet
1	Bubble wrap (40 × 10 cm)
1	Wooden stick (42 × 1.5 × 1.5 cm)
2	Bottle tops
3	Drawing pins
3	Rubber bands
2	Drinking straws (21 cm)
2	Skewers (25 cm)
1	Paper napkin
2	Strips of adhesive tape (42 cm)
1	Stapler with stapes

reduce individual variance in the quantity of rice with which participants dared to charge their baskets (Tennie et al. 2009; Zwirner and Thornton 2015).

2.5.2 Teaching content

Transcripts were created for 140 teaching sessions totalling approximately 8 h of discussion. All talk was segmented into units of analysis, that is, utterances, corresponding approximately to a sentence in written language. Each utterance was coded for the presence of one of four categories of teaching content (see Supplementary Materials). To test H5 (there will be more experience sharing in the displacement condition than in the no-displacement condition), experience sharing was operationalised in the form of memory utterances (MUs), defined as past-tense utterances thematically related to the task and produced by the outgoing partner (Bangerter 2000), or non-experience sharing, non-MU, constituted by any present, future or conditional tense utterance relating to the task. Interrater agreement between two coders of a randomised subsample (20%) of the dataset revealed almost perfect agreement for the distinction between MUs and non-MUs, $\kappa = 0.985$. To verify that past tense is an adequate operational approximation of experience sharing, we coded a different 20% subsample of the dataset to check for the presence of sharing experience in any other tenses. This resulted in just a 4.2% increase from 544 to 567 utterances, therefore the original past-tense criterion was maintained. To control for amount of talk, utterance density was calculated by dividing each participant's raw utterance count by word count. Non-MUs and MUs were produced by the outgoing partner (teacher), while Learner responses were produced by the incoming partner (learner), see Supplementary materials.

Routineness was measured for H6 (sharing experience concerns more non-routine events than does non-experience-sharing talk) by coding both MUs and non-MUs as either routine (mundane, not describing unexpected events) or non-routine (describing events departing from expectations in either a positive or negative or problematic way; Bietti et al. 2019). Interrater agreement between two coders (OT, and a naïve coder) for the full data set revealed sufficient agreement for routineness, $\kappa = 0.635$ (see Table 2).

2.5.3 Innovation

To test H2 (there will be more innovation in the displacement condition than in the no-displacement condition) and H7 (non-routine experience sharing during teaching increases the likelihood that a learner will subsequently choose to innovate), each basket was classified in one of eight gestalts (its main structural shape, see Figure 2) by three independent raters, ICC = 0.896. Innovation was coded as the decision to change gestalt (1) instead of exploiting that of the predecessor (0). Each chain could feature 0–5 changes (Figure 3). In cases where baskets were 'hybrids' combining features from two different gestalts, the most commonly coded gestalt between the three independent raters was selected.

Table 2. Examples of routine and non-routine memory utterances and non-memory utterances.

Type of talk	Routine	Non-routine
MUs	'I folded and stapled the newspaper'	'I underestimated the timings and ran out of time'
	'I used sticks to reinforce the base'	'The handle snapped off while I was filling the rice'
Non-MUs	'You have five minutes to build a basket'	'Maybe you've got some better ideas'
	'There's a stapler and two pieces of string'	'It's better to use the strings than the Sellotape'

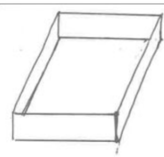
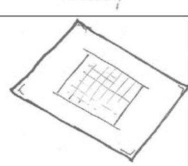
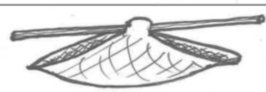
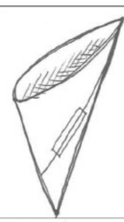
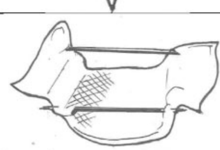
Gestalt	Examples	Definition
Envelope		Newspaper folded in half, in a flat, rectangular shape. Can also be in a canoe shape with lower, more rounded sides
Puppeteer		Four corners folded upwards and each opposing corner brought together with a skewer.
Tray		Low, rectangular shape with pinched sides. A tray always has four corners, folded either inwards or outwards. Corners may be very low, but must be present.
Sheet		A flat sheet with no sides, carried by picking up the edges. It may be reinforced. Some edges may be loosely connected by tape, string or straw.
Sloth		Basket suspended from the large stick, at one, two or several points
Cone		Cornet shape with one end a closed point and the other end open
Stretcher		Carried by two parallel sticks. It often has open sides, which distinguish it from the envelope.
Other		Any basket that doesn't fit into the above categories

Figure 2. Coding criteria for eight basket gestalt categories.

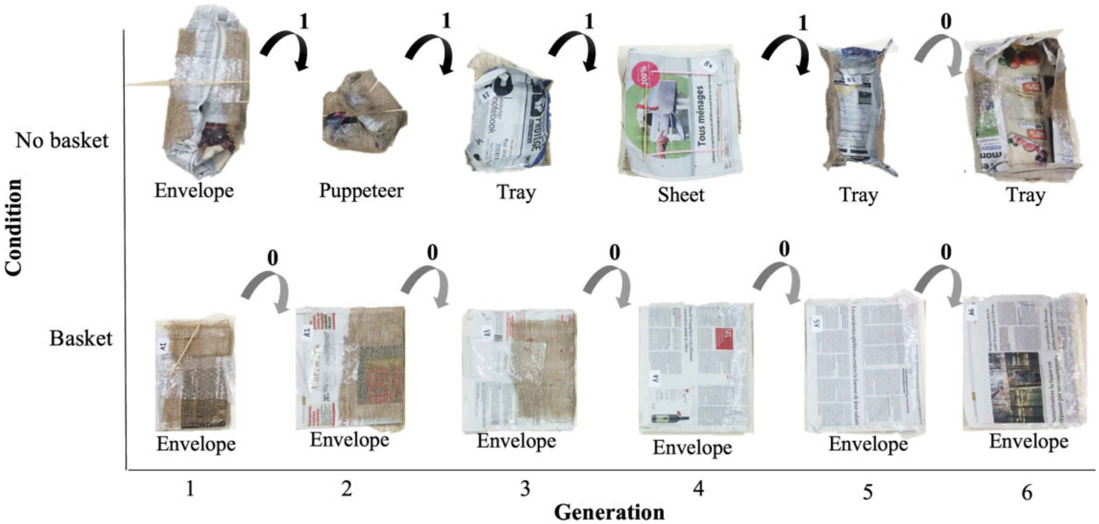


Figure 3. Two example chains of baskets from different conditions and their associated gestalts. The chain pictured in the top row had an overall innovation score of 4, while the chain pictured on the bottom row had an overall innovation score of 0.

2.5.4 Low-risk improvement

To test H3 (there will be more low-risk, incremental improvement in the no-displacement condition than in the displacement condition), low-risk improvement was measured as baskets that had the same gestalt shape as their predecessors (i.e., innovation = 0) but that also carried more rice than their predecessor. This is a binary variable, 1 meaning a basket has met the criteria, and 0 meaning it has not.

2.6 Analysis

The full data set consisted of variables relating to the features of 168 baskets and 140 transcribed conversations. There was one missing data point: the weight of rice transported by one basket that broke during the testing phase, which was included as a missing value. Data were fitted with linear mixed-effects models (lmer) or generalised linear mixed models (glmer). All statistical analyses were conducted in R using packages lmerTest (Kuznetsova et al. 2017) and tidyverse (Wickham et al. 2019) for RStudio (2020). For each analysis, the fixed effects combination accounting for most variance was identified using model comparisons relying on AIC. The position of participants within their group (1–6) is referred to as the generation and the serial transmission between six participants is referred to as a chain. To account for between-chain variance, the chain identity was included in all models as random intercept. All models also contained condition as a fixed effect (see Table 3). The data underlying this article are available in the Dryad Digital Repository, at https://doi.org/10.5061/dryad.wwpzgmsmz.

3. Results

Weight of rice carried. Weight of rice carried significantly increased over generations (H1, supported) ($\beta = 117.21$, SE = 54.26, $t = 2.16$, $p = 0.03$), but this did not differ between conditions ($\beta = 74.99$, SE = 351.72, $t = 0.21$, $p = 0.83$) (see Figure 4).

3.1 Displacement and strategy

There was more innovation in the displacement condition ($M = 0.73$, $SD = 0.24$) than in the no-displacement condition ($M = 0.36$, $SD = 0.24$), $\beta = 1.68$, SE = 0.45, $z = 3.76$, $p < 0.001$ (H2, supported). There was more low-risk improvement in the no-displacement condition ($M = 0.39$, $SD = 0.49$) than in the displacement condition ($M = 0.16$, $SD = 0.37$), $\beta = 1.21$, SE = 0.41, $z = 2.96$, $p = 0.003$, (H3, supported). The weight of rice carried by the previous participant's basket predicted propensity to innovate (H4, supported), $\beta < 0.001$, SE < 0.001, $z = -2.57$, $p = 0.01$, as participants were more likely to copy the shape of high-performing baskets.

3.2 Experience sharing

There was no more sharing of experience in the displacement than in the no-displacement condition, $\beta = 0.01$, SE = 0.03, $t = 0.28$, $p = 0.78$ (H5, not supported) (see Figure 5). Content of shared experience

Table 3. Models created to test research questions and hypotheses.

	Outcome variable	Fixed effect(s)	Random effect
H1	Weight of rice ∼	Condition + Generation	+ (1|chain)
H2*	Innovation ∼	Condition	+ (1|chain)
H3*	Low risk improvement ∼	Condition	+ (1|chain)
H4*	Innovation ∼	Condition + Previous basket's weight of rice	+ (1|chain)
H5	Proportion memory utterances (mu)∼	Condition	+ (1|chain)
H6	Proportion non-routine ∼	Condition × Experience sharing	+ (1|chain)
H7*	Innovation ∼	Condition + Proportion of non-routine experience sharing	+ (1|chain)

Hypotheses marked with asterisks were tested with generalised linear mixed models as they have binary outcome variables, otherwise linear mixed models were used.

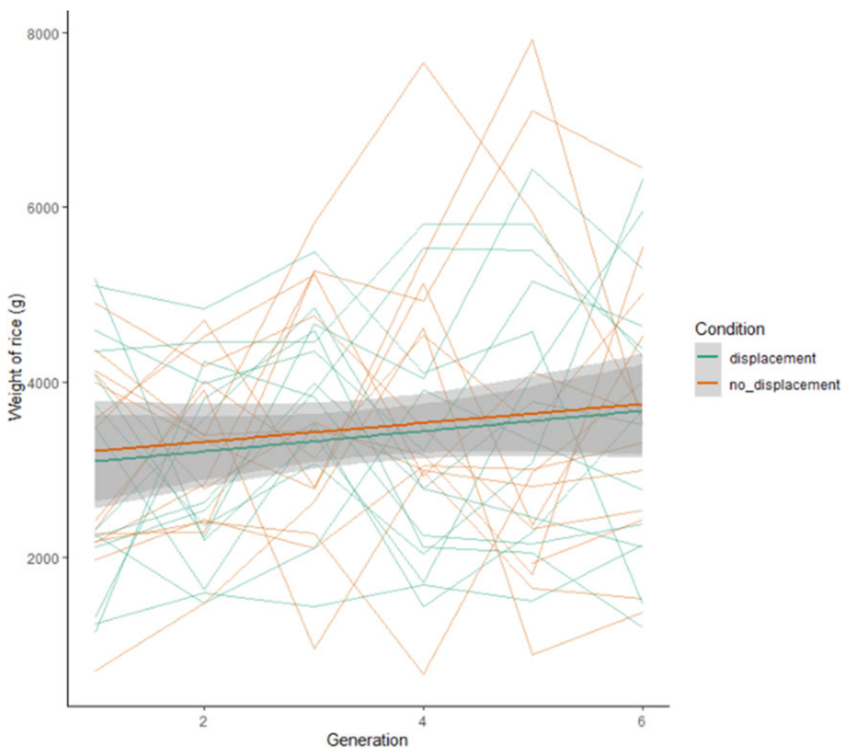


Figure 4. Weight of rice (g) carried by each basket by generations (1–6) and condition. Weight of rice (g) refers to sum of rice transported by each basket during two transportation trials (one by the participant during the testing phase of the experiment and the other by the experimenters). Each line corresponds to the performance of one chain, while the lines of best fit correspond to average performance per condition, green referring to the no-displacement condition (basket to hand during teaching), and red referring to the displacement condition (basket hidden during teaching).

was proportionally more non-routine than non-shared-experience content (H6, supported), $\beta = 1.33$, SE = 0.08, $z = 16.42$, $p < 0.001$, and this significantly interacted with displacement, $\beta = 0.46$, SE = 0.12, $z = 3.85$, $p < 0.001$, with more non-routine utterances in the no-displacement condition (see Figure 5). The proportion of non-routine experience-sharing utterances predicted innovation (H7, supported), $\beta = 2.71$, SE = 1.11, $z = 2.43$, $p = 0.01$. Non-routine utterances in other forms of teaching (i.e., not involving experience sharing) had no effect on innovation, $\beta = 2.61$, SE = 2.44, $z = 1.11$, $p = 0.29$.

Additional analyses investigating, for instance, teaching content can be found in the Supplementary Materials.

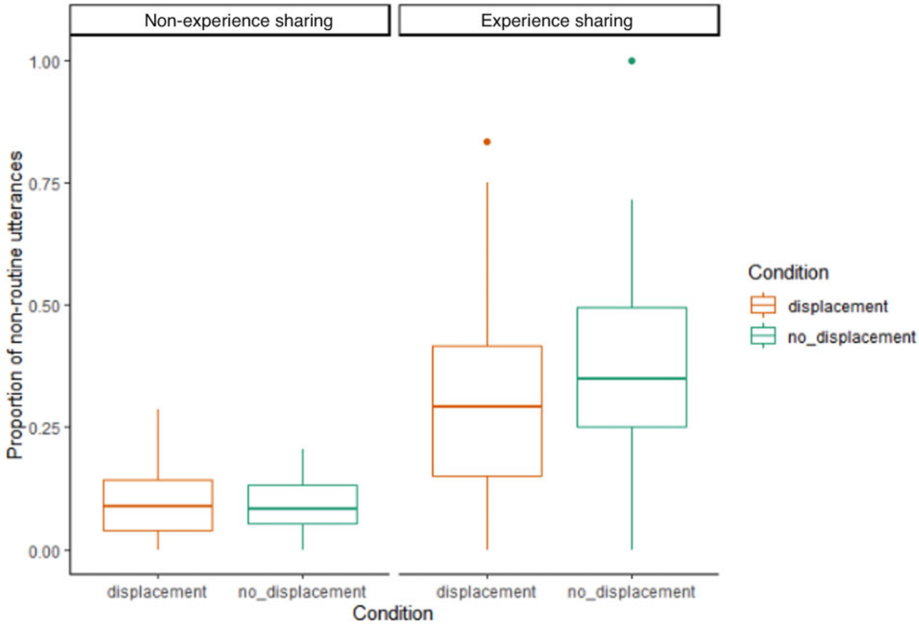


Figure 5. Proportion of non-routine utterances by condition and type of talk: Experience sharing or non-experience sharing.

4. Discussion

In this study, we investigated the impact of displacement during teaching on the cultural transmission of a complex manual skill. The study is the first to experimentally investigate the content of teaching in the context of cultural transmission, as well as the potential use of sharing experience as a teaching method in the context of cumulative improvement of a manual skill. To investigate the content of teaching, we redesigned the typical microsociety experiment in two ways: teaching was separated from task performance and the time constraint was removed. When teaching occurs simultaneously to task performance, the teacher observes the learner, giving them step-by-step advice and feedback on their task performance as it happens (Caldwell and Millen 2009; Zwirner and Thornton, 2015; Caldwell et al., 2018; Osiurak et al. 2020). This corresponds to teaching by evaluative feedback (Kline 2015). Teaching content is likely to be continually affected by the changing affordances of the component materials as learners act upon them. The urgency of time constraints also causes teachers to focus on immediate aspects of the task, rather than reflect on broader strategies. Moreover, participants may be more focused on creating a shared representation of the task than on the task itself (Osiurak et al. 2020). By isolating teaching from pressures of task performance, then, we create the possibility of observing a wider range of teaching behaviours.

Our first hypothesis, that the artefacts would become refined and thus more functional over generations was supported, as the weight of rice carried by baskets increased over generations (H1, supported). The following hypotheses, that the teaching condition (displacement/no-displacement) together with the performance of the previous generation predicts the choice of strategy in the current generation were also supported: there was more innovation in the displacement condition (H2, supported), more low-risk, incremental improvement in the no-displacement condition (H3, supported) and participants innovated more when predecessors produced poor-performing baskets (H4, supported). Although experience sharing was not affected by displacement (H5, not supported), it concerned more non-routine events than did non-experience-sharing talk (H6, supported) and exposure to non-routine experience sharing during teaching increased subsequent learner innovation (H7, supported).

Our findings contribute to three important issues: the role of displacement, sharing experience as a teaching method, and the range of manual tasks explored in cultural transmission research. The first contribution made by this study concerns displacement during teaching.

Displacement did not affect cumulative improvement, nor did it affect the content or quantity of teaching. This points to the effectiveness of human teaching under displacement (Gärdenfors and Högberg 2017), as the learning process appeared not to be impaired by the absence of a visual example. Indeed, displacement in our study encouraged innovation by reducing fixation on a certain shape or gestalt. The fact that we observed a wider range of basket designs under displacement is interesting given that other transmission studies have found memory constraints to reduce variation (Ferdinand et al. 2013; Tamariz and Kirby 2015). Results of this study converge with the finding that people prefer to copy visual referents if available (Henrich and Gil-White 2001). There may be decreased opportunities for simple copying when there is no visual referent, but strategy choice may also depend on whether or not the referent has been visually accessible. There is a possible explanation for this. Cultural transmission does not depend on recall ability alone—people do not always copy everything they remember and may omit aspects from onwards transmission (Lyons and Kashima 2003). Those teachers who had their basket present during teaching may therefore have been perceived as more 'credible' and therefore more frequently copied, demonstrating 'content bias' (Tamariz et al. 2014). Content bias is also indicated by participants' choice to copy better-performing models more often. The presence of the artefact is likely the most common context in which manual skill transmission occurs (Lindwall and Ekström 2012). Our study suggests that teaching in this context elicits a bias to copy that prevents over-innovating, an example of group-level coordination of cultural transmission strategies.

The sensemaking function of sharing experience and storytelling (Bietti et al. 2019) was replicated in our results. Teachers' memory utterances were about unexpected, non-routine events more than non-memory utterances were. Interestingly, non-routine experience sharing seemed to have direct effects on cultural transmission strategy. While non-routine content (across all teaching) had no direct effect on strategy choice, non-routine memory utterances were positively related to learner innovation. Sharing experience about unexpected scenarios encouraged participants to deviate from existing examples and switch designs. This advances the case for sharing experience and storytelling as a functional tool in cultural transmission.

This study helps broaden the range of manual tasks used to experimentally investigate cultural transmission. The traditional focus on stone tools (Morgan et al. 2015; Lombao et al. 2017) is being expanded to include other varied skills in a large range of domains, such as language (Nölle et al. 2020), food preparation (Bietti et al. 2019), and art (Tamariz et al. 2016). In particular, this study helps build the case for mobile containers in cognitive evolution (Fisher 1979). Mobile containers such as bags, baskets, or slings remain largely unexplored in this context despite the fact they may have been the primary tool of early humans, enabling collection and sharing of food as well as transportation of tools to solve multiple future problems (Langley and Suddendorf 2020).

A limitation of our study is worth pointing out. Like all lab-based cultural transmission experiments, this study 'miniaturises' generational change to fit laboratory conditions and uses a limited population of participants, that is university students (Miton and Charbonneau 2018). As the effects of population size (Fay et al. 2019) and connectivity (Segovia-Martın et al. 2020) are increasingly understood, the representation of each generation with a single participant in our study may affect the ability to generalise findings. Having multiple participants per generation benefits transmission of stories (Eriksson and Coultas 2012) and manual skills (Muthukrishna et al. 2014). This horizontal, as opposed to vertical, aspect of social transmission may play an important role, especially in view of the collective reasoning facilitated by sensemaking through storytelling (Bietti et al. 2019). Future studies should investigate sharing experience and storytelling in these contexts while continuing to broaden task types and participant populations.

In this article, we have provided the first experimental evidence that sharing experience is a useful teaching method impacting cultural transmission strategies. Results also shed light on the role that displacement of the artefact during teaching plays on choice of cultural transmission strategy.

Supplementary data

Supplementary data is available at *JOLEVO* Journal online.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflict of interest statement. None declared.

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