The Interactive Shaping of Social Learning in Transmission Chains

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Abstract

This study investigated the social transmission of memories and skills collected from a collaborative cooking task (ravioli-making) and across transmission chains. The transmission over three generations of pairs of participants occurred under two conditions. In the *interactive* condition, transmissions over generations occurred in face-to-face conversations, whereas in the *non-interactive* condition, generations video-recorded their instructions to the next generations. We analyzed the effects of verbal and embodied features of informational transfer on task performance. Our results show that performances improved over generations regardless of interactivity. In the discussion we suggest that tools (like cooking utensils) may have operated as cultural affordances encapsulating and transmitting important cultural knowledge for the successful completion of the task.

Keywords: social transmission; embodied interaction; social learning; joint complex task; cultural affordances; cooking

Social learning and the necessary ingredients for cumulative cultural evolution

Social learning (e.g. Bandura, 1977) is learning by observing or interacting with another individual or a product. Social learning mechanisms enable individual improvements in the efficiency or productivity of cultural artefacts (e.g. Ramstead, Veissière, & Kirmayer 2016) to accumulate from one generation to the next (e.g. Boyd & Richerson, 1994; Tomasello et al., 1993;). Such mechanisms include teaching (Kline, 2015), imitation or emulation (reverse engineering) (Caldwell & Millen, 2008). Teaching and imitation represent cases of high-fidelity transmission, allegedly allowing "complex behaviors to disseminate and be retained in populations until beneficial modifications occur" (Vale, Flynn & Kendal, 2012, p. 223). Currently, however, it is unclear whether teaching is a necessary ingredient for cumulative culture to accrue (Zwirner & Thornton, 2015). The aim of our study is to investigate how different variants of teaching (interactive vs. non-interactive) affect cumulative cultural transmission of skills in a complex joint task (collaborative cooking) in a laboratory setting.

Cultural transmission in the laboratory

Transmission chains are a method used to study cultural evolution in the laboratory. Bartlett's (1932) seminal serial reproduction design allowed studying how content changes when transmitted from individuals of one generation to the next. Although Bartlett's method is more focused on constructive remembering of information originally provided to the first generation of participants and not on the accumulation of such information, it has largely inspired modern laboratory research on cumulative cultural evolution (e.g., Caldwell, Atkinson, & Renner, 2016; Mesoudi & Whiten, 2008) or the evolution of language and other communication systems (e.g. Fay, Arbib, & Garrod, 2013; Kirby, Cornish, & Smith, 2008). However, the method in its standard form prescribes one-way transmission without receiver feedback and has thus been criticized for neglecting the interactive processes germane to conversational remembering (Edwards & Middleton, 1987). Indeed, recent work has shown that giving participants the opportunity to freely interact during transmission improves transmission quality (Tan & Fay, 2011).

Cultural transmission of manual tasks

In a series of experimental studies using transmission chains, individuals built paper airplanes or towers made of spaghetti and modeling clay (Caldwell & Millen, 2008). For the paper plane task, successive generations had access to different types of social information: (i) information about actions (new generations observed what previous generations did); (ii) information about results (new generations observed final products and their performance measured in flying distance); and (iii) information

generated through teaching (new and old generations interacted about the completed task). These three types of social information were designed to enable imitation (information about actions); emulation (information about results) and instructed learning (information generated through teaching). The results indicated that cumulative learning was found in all three conditions (imitation, emulation and teaching). Such findings seem to challenge widespread claims about the necessity of social transmission for cumulative cultural evolution (e.g. Boyd & Richerson, 1994).

Building paper airplanes is arguably an artificial task likely to be confounded by prior experience. Zwirner and Thornton (2015) extended these findings using a more realistic basket construction task. They found that teaching increased the accumulation of improvements over generations, but that it was not necessary for them to occur, further supporting the hypothesis that imitation and teaching are not "fundamental prerequisites for cumulative culture" (Zwirner & Thornton, 2015, p. 7).

Cultural transmission and social interaction

A recent study examined the influence of social interaction in transmission chains (Tan & Fay, 2011). In an interactive condition, chains of participants interacted freely with one another to transmit narrative information from one generation to the next. In a non-interactive condition, receivers of the information had to listen to audio-recordings of narrations produced by senders (previous generation) and then recorded their own accounts of what they had listened to, which were passed on to a new generation of receivers for the same procedure. Transmission was more accurate in the interactive condition than in the non-interactive condition, and was due to the effect of receivers' behavior, including backchannels or clarification questions. The authors suggested that the motivation or ability to interact during information transmission may contribute to the emergence of cumulative culture.

Our experiment

In Tan and Fay (2011), it could be the case that benefits of the interactive transmission of information are related to the nature of the task (information transfer) rather than to general mechanisms of cultural transmission. Hence, it is unclear whether interactivity plays a role in transmitting manual skills. Our experiment thus investigated the interactive context in which the cultural transmission of manual skills occurs. That is, we studied whether the teaching behaviors of senders who have experience with a skill is affected by the presence or absence of receivers from a subsequent generation. The experiment consisted in the cultural transmission of memories and skills collected from a collaborative cooking task (ravioli-making) via transmission chains. Chains of three generations (G1-G2-G3) of pairs of participants made ravioli and transmitted their experience to a pair in the next generation. This occurred under two conditions (interactive condition vs. non-interactive condition). In the interactive condition, transmissions occurred in face-to-face conversations, whereas in the non-interactive condition they were video-recorded as instructions to the next generation. All transmissions were video-recorded in order to analyze both verbal and embodied features of information transfer (e.g., gestures that depict an action), which may be particularly important for the transmission of manual skills.

In line with Caldwell and Millen's (2008) studies using manual tasks, we expect that performance will improve over generations due to the accumulation of learned improvements. We further expect interactive transmissions to allow receivers of information to ask questions and request clarifications (Tan & Fay, 2011), and thus, to stimulate senders to talk and gesture more. This in turn may lead to a better transmission of skills. As a result, we also expect interactive transmissions to lead to better performance than non-interactive transmissions. Finally, we expect longer transmissions from senders to lead to subsequent higher performance in receivers when compared to performances following shorter transmission.

Thus, the hypotheses we tested were:
H1) Performance improves over generations;
H2) During transmissions (G1-G2; G2-G3), senders gesture more (H2a) and speak more (H2b) in the interactive condition than in the non-interactive condition;
H3) Performance improves more in the interactive condition than in the non-interactive condition;
H4) Performance is predicted by the number of words and the duration of gestures in the preceding transmission session.

Method

Participants

Participants (n = 246; 117 men) were recruited from the student population of the University of Neuchâtel (Age M= 23.2; SD= 4.07). They were fluent speakers of French, and reported having limited previous cooking experience. They had previous practice of simple skills like combining and heating ingredients but did not master more complex skills (e.g. preparing pie from scratch). Participants received 25 CHF compensation each for half an hour of their time along with an incentive of 0.25 CHF in total for each produced ravioli of good quality. There were 41 chains (20 in the interactive condition and 21 in the non-interactive condition). Pairs of participants were randomly assigned to different conditions (interactive vs. non-interactive) and generations (G1-G3) in the chains.

Task

The task consisted of two kinds of sessions, *performance* sessions and *transmission* sessions (Fig. 1). In performance sessions, participants from each generation prepared ravioli together in pairs. Their goal was to produce as many good-quality ravioli as possible in 10 minutes. Each pair had at their disposal a ball of 150 grams of dough; 200 grams of filling made of ricotta cheese, concentrated tomato paste and salt; a 24-hole ravioli mold with zigzag sealing for easy release; a pasta maker; a rolling pin; a cutting board; 2 pizza cutters; 2 knives; 4 teaspoons; 2 kitchen cloths and kitchen paper; 250 grams of flour; and a stopwatch. Immediately after the time was up, the ravioli were evaluated by the experimenter. Transmission sessions occurred immediately after each performance session (except for the last one, see Fig. 1). Pairs who had just completed the task explained to next-generation pairs how to prepare the ravioli. These sessions were unstructured and did not have time constraints (they typically lasted 2-8 minutes).

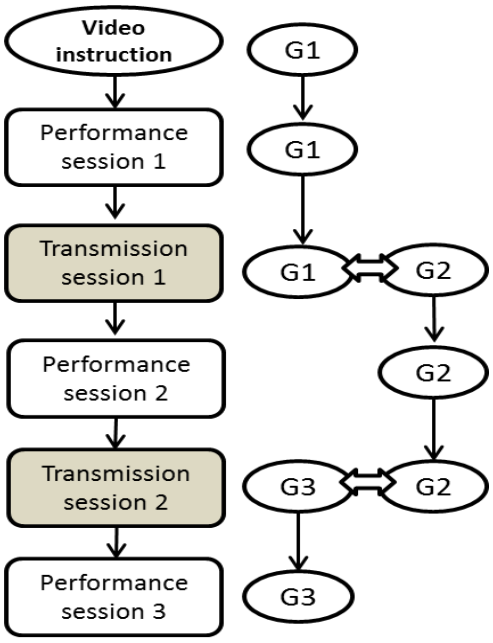

Figure 1. Sequence of sessions in the experiment and groups involved in each session.

Procedure

Participants signed consent forms upon their arrival. G1 pairs watched a 3 min 47 sec video tutorial that was recorded for the study (Fig. 1). It provided information about the steps to be followed to prepare ravioli in pairs. They then completed Performance session 1, followed by Transmission session 1 (together with G2 pairs). Then, G2 pairs completed Performance session 2. During this time, G1 pairs were paid, debriefed and allowed to leave. After having completed Performance session 2, G2 pairs participated in Transmission session 2 (together with G3 pairs). Then, G3 pairs completed Performance session 3. During this time, G2 pairs were paid, debriefed and allowed to leave. After performance session 3, G3 pairs were paid, debriefed and allowed to leave.

Measures

All sessions were videotaped and transcribed. Information transmission (teaching) was measured by the total number of words uttered by senders as well as the total duration of their manual gestures (iconic and pointing gestures) in the transmissions. Performance was measured as the quantity of "good" ravioli each pair produced. The criteria that experimenters considered to count ravioli as good exemplars were that they should contain enough filling and they should be perfectly sealed.

Results

Descriptive results appear in Tables 1 (performance) and 2 (transmission).

Table 1. Performance (*M, SD*) by condition and generation

	Interactive	Non-interactive
G1	8.70 (10.70)	10.67 (9.36)
G2	10.65 (11.51)	10.33 (9.24)
G3	14.80 (10.75)	12.57 (8.81)

Table 2. Transmission variables (*M, SD*) by condition and transmission

	Interactive	Non-interactive
	Sender words	
G1G2	872.45 (290.22)	545.14 (222.655)
G2G3	924.15 (447.53)	480.19 (196.16)
	Sender gestures	
G1G2	196.19 (69.93)	152.40 (76.00)
G2G3	216.80 (98.52)	117.27 (57.64)

Note. G1G2: Transmission session 1. G2-G3: Transmission session 2.

We tested our hypotheses using random intercept mixed-model regression (in R 3.4, packages lme4 and lmerTest). We included chains as clustering variables.

H1: Performance improves over generations.

To test H1, we included condition and the linear trend of generation as predictors of performance. Performance improved marginally (linear trend: $B = 2.79$, $SE = 1.41$, $t = 1.98$, $p = 0.051$). Condition was not a significant predictor of performance ($B = -0.19$, $SE = 2.13$, $t = -0.09$, $p = 0.92$). Thus, H1 is marginally supported.

H2: During transmissions (G1-G2; G2-G3), senders gesture more (H2a) and speak more (H2b) in the interactive condition than in the non-interactive condition.

To test H2, we included condition as a predictor of sender's gestures (H2a) and words (H2b), controlling in each model for transmission session. The interactive condition was the reference category. H2a was supported ($B = -71.04$, $SE = 20.59$, $t = -3.48$, $p = 0.001$). H2b was also supported ($B = -385.63$, $SE = 81.16$, $t = -4.75$, $p < .001$). Transmission (reference category: first transmission) was not related to the dependent variables (for sender's gestures: $B = -7.94$, $SE = 12.90$, $t = -0.615$, $p = 0.54$; for senders' words: $B = -8.05$, $SE = 49.06$; $t = -0.16$, $p = 0.87$). Overall, H2 is supported.

H3: Performance improves more in the interactive condition than in the non-interactive condition.

To test H3, we included the condition, the linear trend of generation and their interaction term as predictors of performance. The performance of groups in the interactive condition improved across generations (linear trend: $B = 4.31$, $SE = 2.03$, $t = 2.12$, $p = 0.04$). Groups in the non-interactive condition do not improve less than groups in the interactive condition, as shown by the non-significant condition x linear trend of generation interaction ($B = -2.97$, $SE = 2.84$, $t = -1.04$, $p = 0.30$). Thus, H3 is not supported.

The marginal improvement in performance in the test of H1 is probably driven by the interactive condition, as the magnitude of the negative interaction term in the test of H3 is close to the main effect.

H4: Performance is predicted by the number of words and the duration of gestures in the preceding transmission session.

To test H4, we simultaneously included the number of words uttered by senders and their gestures during the transmission preceding the task as predictors of performance (we did not predict the performance of G1), controlling for condition and generation. H4 was not supported (for senders' words: $B = 0.01$, $SE = 0.06$, $t = 0.15$, $p = 0.87$; for senders' gestures: $B = 0.03$, $SE = 0.02$, $t = 1.41$, $p = 0.16$). Neither Condition ($B = 1.43$, $SE = 2.70$, $t = 0.53$, $p = 0.60$) nor Generation ($B = 3.44$, $SE = 2.04$, $t = 1.68$, $p = 0.10$) were related to performance.

Discussion

We investigated whether the interactive context in which cultural transmission occurred affected the transmission process and its outcomes. We observed that senders behaved differently depending on the presence or absence of listeners (longer transmissions in terms of talk and gesture). However, such differences did not affect the subsequent performance of the receivers (see Table 1). That is, performance improved over generations (albeit marginally) regardless of interactivity, further supporting previous findings (e.g. Caldwell & Millen, 2008; Zwirner & Thornton, 2015) and research on cumulative learning in humans (e.g. Boyd & Richerson, 1994). However, in contrast to the manual tasks previously employed (e.g. paper airplanes, spaghetti towers, and baskets), our collaborative cooking task presented some particularities. Some materials that the participants had the possibility to use (e.g. ravioli mold; pasta maker and rolling pin) may have operated as cultural affordances (e.g. Ramstead, Veissière, & Kirmayer 2016) already encapsulating relevant information for the successful completion of the task. Material culture, as transmitted by cooking utensils, has played a central role in the evolution of human cognition (Malafouris, 2013). Future studies on cultural transmission in the laboratory should begin to take into consideration the importance of such cultural affordances if they want to better understand the actual ecologies of teaching and learning.

Tan and Fay (2011) showed that "that interaction between senders an receivers promotes more accurate recall and transmission of cultural information" (p. 405). Our analyses did not deal with verbal protocols and the amount of information accurate recalled over generations. However, based on this previous evidence we expected to find more increased performance in the interactive condition compared to in the non-interactive condition. In other words, if more accurate information were produced in interactive chains (as previous evidence suggests), it could lead to an increase in performance over generations in the interactive condition. Against our expectations, in our study, this was not the case. We did not find an effect of the number of words and duration of gestures produced by senders on performance of receivers over transmission chains (see Table 2). Although, senders spoke and gestured more in the interactive condition than in the non-interactive condition (see Table 2), this did not affect receivers' performance. This result suggests that there is no clear correspondence between the quantity of information transmitted over generations and performance.

In our analyses we did not examine the content of the information transmitted over generations or how it was recalled during performance. A possible theme for further investigation related to our current results is whether better or worse performing generations transmit more useful information over chains. It may well be the case that worse performing generations communicate more useful information to next generations if they focus their accounts on the errors they committed during performance.

In contrast to Tan and Fay (2011), our findings showed that in complex joint tasks having the possibility of asking questions and requesting clarifications (interactive condition) did not bring benefits. This could be related to the nature of the task participants were asked to perform. Whereas in Tan and Fay (2011) participants simply relayed information received from previous generations, in our study participants had the opportunity to perform the task before transmitting information to the next generation. This involved access to the

tools provided as well as the opportunity to test different strategies and solve problems. Throughout human evolution, "the social environment, not just individual minds, has become increasingly organized to support the flow of information across the generations" (Sterelny, 2012, p. 27). Looking at the multiple ways in which interactive contexts, task specificity, and cultural affordances affect the transmission of everyday skills (e.g. cooking) is an important step towards better understanding the mechanisms of cultural transmission.

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