A methodology for distinguishing copying and reconstruction in cultural transmission episodes

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Abstract

Information transmission between individuals through social learning is a foundational component of cultural evolution. However, how this transmission occurs is still debated. The copying account draws parallels with biological mechanisms for genetic inheritance, arguing that learners copy what they observe as they see it. On the other hand, the reconstruction account argues that learners recreate only what is relevant and reconstruct it using pragmatic inference, environmental and contextual cues. Distinguishing these two accounts empirically using typical transmission chain studies is difficult because they generate overlapping predictions. In this study we present an innovative methodological approach that generates different predictions of these accounts by manipulating the task context between model and learner in a transmission episode. We provide an empirical proof-of-concept showing that, when a model introduces embedded signals to their actions that are not intended to be transmitted, learners' reproductions are more consistent with a process of reconstruction than copying.

Keywords: cultural transmission; copying; reconstruction; pedagogy;

Introduction

Social learning, the process of transmitting skills, ideas, and actions from one individual to another, plays a key role in stabilizing cultural traditions from one generation to the next (Hoppitt & Laland, 2013). The process by which it does so, however, is hotly debated within the field of cultural evolution (Acerbi & Mesoudi, 2015; Claidière et al., 2014; Henrich & Boyd, 2002; Morin, 2016b, 2016a; Sperber, 1996). On one side, there are those who argue that social learning is mostly a copying process akin to mechanisms of genetic inheritance where social learners faithfully replicate the information required to learn and produce some behaviour and that cultural stability is a result of the preservation of this information (Henrich, 2016; Laland, 2017; Mesoudi, 2011; Richerson & Boyd, 2005). We term this the *copying* account, and place it in contrast to the *reconstruction* account, which claims that social learners pick out only the information they deem relevant and reconstruct the missing parts by using pragmatic inferences, contextual information, and other constructive processes (Morin, 2016a; Sperber, 2006; Sperber & Hirschfeld, 2004). In the latter case, cultural stability arises because social learners tend to share the same constructive processes and common background knowledge.

We must first outline some crucial terminology that relates to the content of social learning in transmission episodes, and that is to differentiate between features of behaviours that are *integral*, and features that are *incidental*. Imagine a novice tennis player trying to learn how to serve a ball by watching his coach produce the action. Her movements as she throws the ball into the air and hits it with her racket are integral features of the to-be-learned behaviour, as these are the actions that must be reproduced to serve a ball. On the other hand, if the coach pauses to adjust her hat or tie her shoes, these are incidental to the action and the learner can readily recognise that such an action is not part of the to-be-learned behaviour. Neither copying nor reconstruction processes incorporate transparently incidental features into their reproductions. Where these two processes differ, however, is in how they treat integral information.

The copying account draws on the early emergence of the field of cultural evolution as inspired by the Darwinian theory of biological evolution, and this is strongly reflected in its emphasis on the faithful transmission of cultural traits (Cavalli-Sforza & Feldman, 1981; Mesoudi, 2011; Richerson & Boyd, 2005). According to this account, cultural transmission can be taken to follow a strict copying process where a learner observes a model produce a behaviour and copies it faithfully, closely replicating the integral features of the behaviour in a 'Xerox' fashion. Models of copying in cultural evolution recognise that such transmission is noisy, however, and account for this by assuming a degree of random variation in learned behaviour, or copying errors (e.g. Henrich, 2004). This high-fidelity replication is argued to be the driving force of stability in cultural traditions, while innovations and changes across generations are the result of accumulated random copying errors (Charbonneau, 2019).

While cultural transmission can be considered a highly faithful copying process analogous to genetic inheritance (Dennett, 2017; Laland, 2017; Mesoudi, 2011), the copying process is usually approached with much more nuance. This account proposes high-fidelity imitation as a prototypical preservative learning process. However, imitation is not 'blind' copying as with genetic inheritance. Rather, research in cognitive and developmental psychology shows that when imitating learners select which features of a behaviour they learn (Gergely et al., 2002; Legare et al., 2015), that imitation is often context-sensitive (Over & Carpenter, 2012, 2013), and that it operates at multiple degrees of abstraction (Csibra, 2008). For example, take a novice tennis player trying to learn how to serve a ball by watching his coach produce the action. As the coach prepares to show him the serve, she pauses and adjusts her hat to keep the sun from her eyes. If cultural transmission were truly analogous to genetic transmission, the learner would also pause to adjust his hat before he reproduces the behaviour even if it has suddenly become cloudy, as he copies everything that he has seen. Instead, the learner can understand that certain features of the observed behaviour (the actions of preparing and serving the ball) are *integral* to the to-be-learned information, while other features (such as adjusting one's hat) are *incidental* and not supposed to be learned. Copying these incidental features would be over-imitation, as a learner misidentifies non-integral features as integral and so incorporates them into their action representation. Differences between a model and a learner's productions that appear only on incidental features are therefore not relevant to cultural transmission, while differences on integral dimensions of a behaviour are driven by random copying errors (Charbonneau, 2019).

In contrast to the copying account, the reconstruction account argues that a learner's goal is not to copy faithfully the behaviour of the model but instead to use pragmatic inferences, contextual cues, background knowledge, and other constructive processes and resources in order to learn what they deem relevant in the behaviour (i.e. the integral features) and to adapt it to satisfy different goals in different contexts (Morin, 2016a; Sperber, 1996, 2006; Sperber & Hirschfeld, 2004). In contrast to copying, which is a content-neutral transmission mechanism (it does not matter what is being transmitted as everything is replicated in the same way), reconstruction is content-sensitive, as the content of information will affect the inferential processes (ibid., see also Claidière & André, 2012; Sterelny, 2017). These pragmatic inferential processes are argued to be the driving force of stability in cultural traditions, as people will tend to reconstruct information in similar ways due to shared biases. Furthermore, learners will identify only those integral features that are relevant to them in a given context—other features of the to-be-produced action are then reconstructed inferentially. Reconstruction therefore predicts that when learners introduce variations they do so non-randomly. The observed variation arises from convergent transformations in line with content-sensitive reconstructive processes, as opposed to random copying errors (Claidière et al., 2018).

Distinguishing these two accounts empirically is difficult, because although they posit different underlying mechanisms, they also predict similar patterns of behaviour with regard to the transmission of integral information features. One strategy is to use transmission chains experiments (Mesoudi & Whiten, 2008; Miton & Charbonneau, 2018) and measure whether the information transmitted systematically converges in some direction—reconstruction—or whether it transforms in a random manner—copying (e.g. Mesoudi & Whiten, 2004; Miton et al., 2015). However, problems arise when transmitted information is highly stable across transmission episodes. While such stability may appear to reflect high-fidelity copying, this is not sufficient evidence against reconstruction, as a reconstructive process could well yield the same results if a model carried the same integral content that a learner would reconstruct. In such cases, reconstruction becomes indistinguishable from copying and leads to the same predictions: learners should reproduce the integral information features they observe and not reproduce more incidental features.

This ambiguity is a problem for understanding the transmission and stabilisation of cultural phenomena, especially given that it is likely that both processes are at play under different social learning conditions. Understanding how and when transmission uses a copying process and when it is more reconstructive can shed light on the underlying cognitive mechanisms of social learning and have important implications when scaling back up to the level of cultural phenomena. An empirical approach that can distinguish between these two learning processes is therefore of paramount importance.

Methodological Framework

We exploit a core prediction of the reconstruction account: that learners will adapt what they learn to their current task demands or context. By changing the production context between model and learner, therefore, it is possible to experimentally induce systematic deviations in the behaviours of both, and to predict the transformations that would be expected under the two accounts. Critically, these systematic context-driven distortions are incidental features of a behaviour, in that they are not part of the core to-be-learned representation. However, rather than being discrete separate actions that can be easily omitted from a reproduction, these incidental features are embedded within integral information features.

Consider the tennis coach and student again. The novice can learn by observing his coach perform actions repeatedly, but the coach can in turn modify her behaviour to help scaffold her student's learning. For example, when demonstrating a serve, she can slow down and exaggerate different parts of her movements in order to highlight hidden or non-obvious structures in the information. Exaggerations and intentionally slowing down are incidental action features in this case—they are not integral to serving a tennis ball, and not part of the to-be-learned information. However, these features are embedded within integral action features—the sequence of movements required to prepare and pitch the serve—which means it is not possible to simply omit them from a learner's reproduction. Such embedded action features are common in teaching (McEllin et al., 2018), coordination

(Vesper & Richardson, 2014), and sensorimotor communication (Dockendorff et al., 2019; Pezzulo et al., 2013, 2019), and can result in changes to the dynamic profiles of movements in order to structure and communicate information.

By manipulating the context under which the model and learner produce behaviours such that the model introduces embedded action modifications while the learner need not, we can distinguish between predictions made by the two accounts. If learners are copying when observing an input with embedded (but incidental) modifications, given that a learner cannot simply drop these modifications from their reproduction, they will replicate the actions they observe faithfully and introduce only random copying errors. As such, when the tennis novice comes to serve the ball he will slow down and exaggerate his movements in the same way as his coach. If learners are reconstructing, however, they should identify these modifications but, realising that they are not relevant to the current context, will use pragmatic inference to reconstruct only the core, integral information without the incidental modifications. Under this account, the tennis novice will produce a tennis serve that is more similar to how the coach would serve a ball if she were actually serving in a tennis match.

The primary goal of this paper is to present this methodological framework as a tool for distinguishing copying from reconstruction in cultural transmission. Given that most laboratory empirical work favours copying, a striking way to demonstrate the usefulness of this approach would be to show evidence for reconstruction in a situation where we would most expect to see it. The pedagogical context, where a model actively demonstrates their actions for a learner who understands the model's pedagogical intention, is such a case. While there is some debate as to the degree to which teaching and demonstration are actually common cultural practices (Kline, 2015; Lancy, 2015), such debates are incidental to our current aim. If our framework can distinguish copying from reconstruction under task instructions that favour reconstruction then it can also be applied to cases where we would not make strong predictions in favour of one account over the other.

With such applications in mind, we also test the framework in a more ambiguous case: when the model is not demonstrating but performing the action for aesthetic purposes. We tested two learning conditions in our empirical validation study: one where the model demonstrated the action (Demonstration), and one where he performed it for an audience (Performance). In both situations, learners were allowed to see a context-free production at the beginning of the study and were explicitly informed of the intention of the model that they learned from, which may prime greater use of reconstruction than copying. However, when learning from a Performance, the modifications in the model's behaviour were not the result of a communicative intention with a mutual prescribed repertoire and participants had much more perceptual exposure to the Performance than the Original (unmodified) behaviour, which favour copying. As such, while we expected that participants may be biased towards reconstructing over copying when learning from a Demonstration, whether participants copy or reconstruct when learning from a Performance is a more ambiguous case that demonstrates how our framework can yield insights into the mechanisms at play in episodes of social learning.

Empirical Proof of Concept

In order to contrast the copying and reconstruction accounts of observational social learning, we designed a single-generation transmission task using a short piece of music as the to-be-learned information. Music is an ecologically valid cultural item that can be transmitted and produced under different social and intentional contexts (D'Ausilio et al., 2015). Importantly, we chose to use music because this is a type of information that is fundamentally composed of two integral dimensions: the melody and the rhythm. Rhythm, or the temporal features, is integral to the production but temporal distortions, such as exaggerating long or short pauses, can be used to effectively structure the information. As such, task instructions can be used to embed distortions of an integral property of the information.

In our proof-of-concept, we had participants learn to play a piece of music by watching a video of a model playing it under one of two contexts—either a Performance or a Demonstration. Using two contexts allowed us to examine the learning process across two distinct incidental patterns of non-random variation of the rhythm (an integral feature).

Methods

Participants

We recruited right-handed fluent English-speaking non-musicians who reported no history of neurological impairments or diagnoses, and normal or corrected-to-normal vision. We recruited 32 participants in total (16M; 16F; Mage=27y).

Stimuli

Melody. The melody that participants had to learn was constructed using four notes from a pentatonic scale (C,E,G,A) and consisted of 12 hits. The melody was designed such that a natural rhythmic structure emerged of chunking the first six notes into sets of three and the final six notes into pairs (i.e. 3-3-2-2-2). This rhythmic structure – its distortion during performance and demonstration and its replication during learning – became the basis of our experimental investigation.

Model videos. Stimuli were collected by recording a musician (a male guitar player) using the same apparatus as participants used (see below). The musician was instructed on the piece he was to play and was given a chance to practice it. Once he had learned the sequence and was happy to reproduce it, he was instructed to play the piece through ten times to practice. We selected a single example of these (rep 7) as the Original sequence.

A series of videos was taken of the model playing the piece under different conditions: Performance and Demonstration. In Performance videos, the model was asked to perform the

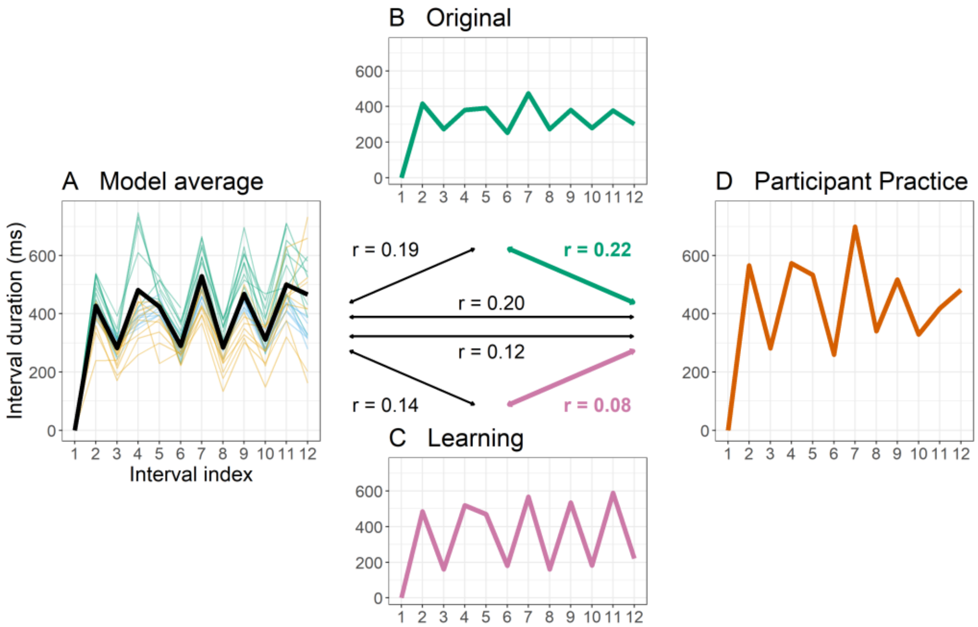

Figure 1. A grand average of all the model's ITI sequences across all videos that were not shown to participants covering all three production contexts (Original, green; Performance, orange; Demonstration, blue; far left plot). This grand average (black line) was then used to calculate semipartial correlations, or the residual relationship between a learner's production (red, far right) and either the Original (green, top) or Learning sequences (purple, bottom) while controlling for baseline similarity in the productions. The Learning sequence presented here is the model's Performance. Coefficients in bold are interpreted as similarity metrics, and were the dependent variable used for analysis.

piece for an audience. He knew that this video would be shown to people later on whose task would be to rate his performance in terms of style. This instruction created a performative context, which has an intentional component (to be stylish or aesthetic in a production), and a social component (the video will be watched by an audience). In Demonstration videos, the model was told to demonstrate the piece for somebody else to learn, and he knew that his video would be later shown to people who would have to learn to play the piece from watching him. This instruction created a pedagogical context, whereby the model intentionally introduced a series of modifications to the piece (e.g. slowing down and exaggerating the spatial and velocity profiles of his movements, in line with McEllin et al., 2018) that serve a social communicative goal: to scaffold information for the learner and facilitate learning. In this, as in the Performance video, there is an intentional component (to be pedagogical) and a social component (the video will be watched by a learner).

The model produced ten of these videos each. From the performance and demonstration videos collected of the model we selected a single example of each (Performance 8, Demonstration 9). All model example videos were selected after visually examining the ITIs and trajectories of these movements as illustrating obvious contextual modifications.

Apparatus. We used four Millenium MPS-400 Tom pads connected to a ddrum DDTi trigger interface to record responses, which participants produced with a wooden drum stick with a foam tip. Auditory feedback, metronome beats, and data recording was handled with a custom Max MSP patch that also recorded video and audio of the model and participants as they played the piece. Each drum produced a different MIDI tone, the pitch of which corresponded to a note from a pentatonic scale. Tones lasted for 250ms and the volume scaled to the force with which participants hit the drum.

Drums were positioned in front of the participant in a semi-circular arrangement. They were positioned on stands measuring 80cm high and 30cm apart (measured from centre to centre). Crucially, the drums were in the same position for the learners as for the model videos.

Design & Procedure

There were two between-subject learning contexts: participants either learned by watching the selected model's Performance or the Demonstration. Participants came into the lab with the experimental setup and sat in a chair in front of the drum set. They were told that they would be learning to play a short piece of music on the drums in front of them. They were told that they would first watch a video of a musician playing the piece they were about to learn so as to familiarise themselves with the task. They watched the Original video twice without playing it back.

Then participants were told that they would now learn to play the piece they just watched by watching a different video of the same musician playing the same piece but under a different context (Performance or Demonstration). They were told the context of the video they were learning from using the same wording as the instructions given to the model.

Participants would watch the learning video and then play it back as best they could, and they did this repeatedly until they could do the whole sequence ten times consecutively without an error (hitting the correct drums in the correct order). During their production we recorded MIDI output from the drums.

Data Analysis

The MIDI output from Max 7 included the drum ID, force, onset, and offset of each drum hit. There were ten of these for each participant, one per practice trial. Data were first checked for double taps where the drumstick bounced on the drum, registering as two taps when there was only one. Strings of full inter-tap interval (ITI) sequences were then analysed using semipartial correlations (SPCs).

ITIs were calculated by subtracting the onset of a given note from the offset of the previous note. This generated a vector of eleven ITIs for each sequence that reflected the rhythmic structure of the piece (long ITIs reflect pausing at the end of rhythmic chunks). Strings of ITIs were generated for each practice trial for each participant and were compared against two of the three model videos (the Original video and whichever of the Performance and Demonstration videos participants had learned from watching, or the Learning video). We calculated similarity between sequences using semipartial correlations (SPCs), as described in Figure 1, and use this as a measure of similarity between two productions. In order to compare these coefficients, we used a grand average of all videos that the model made during stimulus generation minus the videos shown to participants. This grand average was used this to control for the baseline similarity that one would expect to see between two ITI sequences of the same piece of music. SPC coefficients therefore show the residual relationship after controlling for the fact that they are two productions of the same melody. Note that these coefficients are calculated only as a metric of similarity between two productions—rather than interpreting these coefficients on their own, we are interested specifically in comparing these metrics in relation to different model inputs. SPCs were calculated using the *spcor.test* function in the R package *ppcor* (Kim, 2015).

Results

When learning from a video that included incidental context-driven action modifications—exaggerated pauses—embedded on an integral feature—the rhythm of the piece—the question was which sequence their reproductions would be most similar to. The predictions of the two accounts were clear. If participants were copying the videos they learned from, they should be more similar to the Learning sequence than to the Original. If participants were using a reconstruction process, however, their reproductions should not include these incidental embedded cues and should instead be more similar to the Original video.

Similarity measures are shown in Figure 2. Positive SPC coefficients indicate that two sequences of ITIs are more similar to each other than would be expected of any two random productions of the same piece. These results indicate significantly more positive SPC coefficients for the Original video than the Learning, both when participants learn from Performance ($t(15)=3.88$, $p=.001$) and Demonstration ($t(15)=2.96$, $p=.010$). These results are consistent with the reconstruction account as the productions of the learners show evidence of convergent transformation of the rhythm back to the model's Original production and away from the sequence they learned from watching.

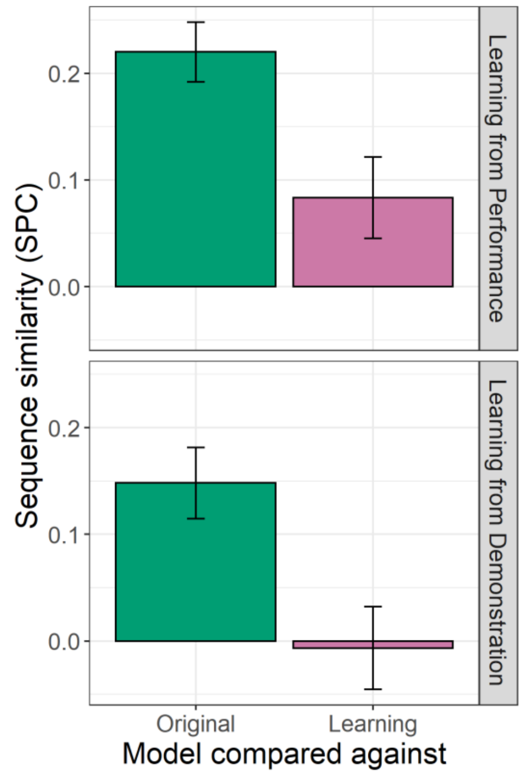

Figure 2. Average sequence similarity metric, calculated using semi-partial correlations (SPCs), for successful practice reproductions of participants. Bars show similarity to Original (green) and Learning (pink) models in subjects who learned from Performance (left) and Demonstration models (right). Error bars show ±95% confidence intervals.

Discussion

We present the results of an experimental proof-of-concept using a novel methodological approach for the study of cultural transmission. We find that when varying the task context between a model and a learner in such a way that the model introduces embedded incidental modifications to their actions, learners show non-random deviations, supporting reconstruction. Specifically, learners reproduce integral features of the action (the sequence of notes and the original rhythm of the piece), but do not replicate embedded incidental modifications such as pedagogical or performative signals. This indicates that learners adapt what they have observed and reconstruct towards the original, unmodified actions of the model. These findings are consistent with the predictions of the reconstruction account.

The current paper is not intended to settle the current debate between the copying and the reconstruction accounts of social learning. Instead, our aim is to provide a tool for future work that can differentiate these processes in particular learning episodes. To do this, we used a case where we expected to see evidence of reconstruction, given that participants were able to observe the Original video before practicing. Indeed, how the piece of music would sound outside of a performative or pedagogical context serves as background knowledge. This is not only an ecologically valid manipulation—as students learning a piece of music typically have a chance to listen to it before they learn—, but also highlights another difference between the two processes: background knowledge plays a key role in reconstructive processes, but plays no role in copying. This manipulation therefore helps to further differentiate these two processes.

The framework that we present offers an opportunity for future work examining the role of individual cognitive mechanisms in cultural transmission and cultural evolution. The core of our approach can serve as a useful new tool when designing transmission studies that exploit changes in task context to examine mechanisms of social learning. Our findings also raise interesting questions that are relevant to the study of both cultural evolution and social interactions, such as how learners identify and interpret contextual cues in order to understand transmitted information. For example, although there is a well-established literature showing that observers use action kinematics to decode both instrumental (Becchio et al., 2012, 2018; Cavallo et al., 2016; Koul et al., 2019) and communicative intentions (McEllin et al., 2018; Trujillo et al., 2019), it remains an open question whether people can recognise these embedded signals spontaneously without knowledge of the response alternatives, and whether the same embedded signals can be interpreted differently merely by manipulating instructions.

In this paper, we outline a new methodological approach to studying transmission episodes that can make competing predictions about copying and reconstruction by exploiting incidental action modulations that are embedded in integral dimensions of the behaviour. We present a proof-of-concept using music as a candidate behaviour and temporal exaggerations as the embedded incidental information, but this approach is generalisable to a range of cultural phenomena. For example, other kinds of skill acquisition in the motor domain such as sport or dance can be studied in a similar way, and the use of motion capture to analyse movement kinematics under the logic of this framework would provide compelling insights into the learning mechanisms at play. This methodology can also be adapted for use outside the motor domain—as long as such studies examine complex behaviours that can incorporate context-driven embedded modifications. For example, the study of storytelling and other means of text transmission could benefit from this approach, by identifying how narrators adapt the information according to the current context.

Although the current study supports a reconstruction process over copying, it is very plausible that both processes are at play in different learning episodes. In the case of the tennis novice who observes his teacher's exaggerated dynamics, we might expect reconstruction given that the learner likely has a pre-existing representation of what a tennis serve *should* look like from watching the sport. On the other hand, in cases where the difference between incidental and integral features is more opaque due to a lack of experience, or where the risks of incorrectly dismissing integral features outweigh the costs of reproducing incidental action features, it is very plausible that learners would be more likely to faithfully copy. Crucially, the methodological approach that we propose can distinguish these processes in different transmission episodes and across different types of phenomena and is impartial in that it makes clear and testable predictions about both copying and reconstruction.

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