Journal of Experimental Child Psychology 213 (2022) 105271

Contents lists available at ScienceDirect

Journal of Experimental Child Psychology

journal homepage: www.elsevier.com/locate/jecp

Spreading the game: An experimental study on the link between children's overimitation and their adoption, transmission, and modification of conventional information

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ARTICLE INFO

Article history:
Received 10 November 2020
Revised 22 July 2021

Keywords:
Overimitation
Cultural Transmission
Social Learning
Imitation
Innovation
Preschoolers

ABSTRACT

Overimitation is hypothesized to foster the spread of conventional information within populations. The current study tested this claim by assigning 5-year-old children ($N = 64$) to one of two study populations based on their overimitation (overimitators [OIs] vs. non-overimitators [non-OIs]). Children were presented with conventional information in the form of novel games lacking instrumental outcomes, and we observed children's adoption, transmission, and modification of this information across two study phases. Results reveal little variation across study populations in the number of game elements that were adopted and transmitted. However, OIs were more likely to use normative language than non-OIs when transmitting game information to their peers. Furthermore, non-OIs modified the games more frequently in the initial study phase, suggesting an inverse relationship between children's overimitation and their tendency to modify

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https://doi.org/10.1016/j.jecp.2021.105271

conventional information. These findings indicate subtle yet coherent links between children's overimitation and their tendency to transmit and modify conventional information.

Introduction

The human capacity to adopt, transmit, and modify information from others is unmatched by any other species. To survive and reproduce, humans rely on skills, ideas, and behaviors that no individuals would ever come up with all by themselves—they are learned socially. Childhood marks a crucial period in this process because young children need to learn immense amounts from others. Importantly, they do not rely only on learning instrumental behaviors and skills such as using tools and contributing to subsistence. Learning about the specific rituals and conventions that characterize their social groups and ensure social cohesion is just as important (Legare & Nielsen, 2020; Nielsen, 2018). The tendencies to adopt, transmit, and modify socially transmitted information set the stage for the immense diversity of instrumental skills (i.e., technology, tools) and conventions (i.e., rituals) that characterize and enrich the human species (Legare, 2017, 2019; Legare & Nielsen, 2015).

It has been argued that these tendencies critically rely on two mechanisms: innovation and imitation (Legare, 2017; Legare & Nielsen, 2015). Imitation—copying others' actions—allows individuals to use the information provided by others while avoiding costly trial-and-error learning. As such, imitation ensures the spread of social information, rendering this mechanism essential for both the adoption and transmission of social information between individuals. Imitation is complemented by innovation—the process in which novel behaviors are invented or modified (Carr, Kendal, & Flynn, 2016). The capacity for innovation is considered vital because it enables individuals to approach novel challenges and to master recurrent ones with increasing efficiency (Neldner et al., 2019; Pellegrini, Dupuis, & Smith, 2007). Some empirical findings paint the picture of imitation and innovation being psychological antagonists. Social learning through imitation reduces individual exploration and therefore innovation (Bonawitz et al., 2011). Furthermore, receiving instructions comprising conventional cues actuates children's imitation while, at the same time, it inhibits their tendency to innovate (Legare, Wen, Herrmann, & Whitehouse, 2015). Individual exploration, on the other hand, reduces subsequent imitation (Wood, Kendal, & Flynn, 2013). However, other research posits that imitation and innovation show conceptual overlaps (Carr et al., 2016; Legare & Nielsen, 2015; Subiaul, Krajkowski, Price, & Etz, 2015; Subiaul & Stanton, 2020). Innovation in which individuals create novel solutions in the absence of social support is rare in young children because they are typically accompanied by adults and older peers with more expertise (Carr et al., 2016). Instead, innovation may first emerge when children aim to modify social information toward higher efficiency (Subiaul et al., 2015; Subiaul & Stanton, 2020) or, more generally, deviate from this information. Thus, one may speculate that the development of innovative capacities in young children critically relies on their capacity to imitate (Carr et al., 2016).

Whereas some of these studies indicate that children switch between innovation and imitation depending on situational factors, recent research suggests that their tendency for either strategy may be rooted in more stable inter-individual differences (Rawlings, Flynn, & Kendal, 2017, 2021; Yu & Kushnir, 2019). For example, highly extroverted toddlers are particularly inclined to imitate others (Hilbrink, Sakkalou, Ellis-Davies, Fowler, & Gattis, 2013), whereas innovators are suggested to stand out in their creativity and openness to experience (Bateson, 2013; Rawlings et al., 2017). In a recent study, Rawlings and colleagues (2021) found personality traits to predict 7- to 11-year-olds' reliance on social learning and innovation. On a population level, a prevalent disposition to imitate others' actions may have profound effects on the spread of behaviors between individuals. Imitation leads to a reliable and stable set of behaviors until modifications are gradually woven in. Once an individual comes up with a previously unknown behavior that is useful or rewarding for others, imitation enables the spread of such information from one individual to another (Tennie, Call, & Tomasello, 2009).

It is important to note that the vast majority of research on children's imitation and innovation focused on contexts in which children learn to achieve instrumental outcomes such as receiving rewards and performing well. For example, children are observed when imitating others' actions (Horner & Whiten, 2005; Lyons, Young, & Keil, 2007) or regarding their capacities to innovate or modify tools to obtain rewards (Carr et al., 2016; Neldner et al., 2019). It is evident that learning to achieve such instrumental outcomes, using both imitation and innovation, presents a central task in child enculturation. However, given the key role of conventions to foster homogeneity and social cohesion within groups (Legare & Nielsen, 2020; Nielsen, 2018; Watson-Jones & Legare, 2016; Wen, Willard, Caughy, & Legare, 2020), a thorough account of cumulative culture—including the transmission and accumulation of artifacts and practices in human groups (Boyd & Richerson, 1988; Tomasello, Kruger, & Ratner, 1993)—also requires an understanding of how conventional information spreads between children. To move forward in this agenda, it is crucial to assess how children adopt, transmit, and modify conventional information.

Overimitation—copying of actions regardless of their functional relevance for achieving an instrumental goal (Horner & Whiten, 2005; Lyons, Damrosch, Lin, Macris, & Keil, 2011; Lyons et al., 2007)—is of particular interest in this regard. In a typical study design, children are confronted with a puzzle box from which to obtain an instrumental outcome (i.e., material rewards). Before doing so, they observe a model performing one or more causally irrelevant actions before obtaining the reward. At test, children are evaluated on whether they copy these irrelevant actions (i.e., overimitation) or skip them to obtain the reward more efficiently (i.e., emulation) (see Hoehl et al., 2019, for a review). In fact, a significant proportion of children tend to overimitate in such contexts, a tendency that has gained considerable scientific attention during recent years given the assumed role of this tendency in the spread of conventional information. Accordingly, the tendency to overimitate supports the adoption and transmission of conventional behaviors within populations as individuals converge on behaviors lacking any obvious instrumental purpose (Legare & Watson-Jones, 2015).

Indeed, research suggests that overimitation is actuated in the absence of instrumental goals. For example, young preschoolers engaged in more overimitation when the model's actions were goal demoted (i.e., not leading to an instrumental outcome or end state; Nielsen, Tomaselli, & Kapitány, 2018). Other work replicates and extends this finding, emphasizing that goal demotion and increased inefficiency encourage preschoolers to copy goal-irrelevant actions (March, Rigby Dames, Caldwell, Doherty, & Rafetseder, 2020). Furthermore, overimitation is particularly pronounced in contexts implying social conventions (Clegg & Legare, 2016; Kenward, 2012; Keupp, Behne, & Rakoczy, 2013) or in which the child is observed by the model (Marsh, Ropar, & Hamilton, 2019; Nielsen & Blank, 2011; Stengelin, Hepach, & Haun, 2019). Taken together, these studies suggest overimitation as an essential phenomenon in the adoption and transmission of conventional information.

Besides goal demotion and conventional markers, the extent to which personality traits predict whether or not a child will engage in overimitation has been discussed (Fenstermacher & Saudino, 2016; Hilbrink et al., 2013; Wagner et al., 2020; Yu & Kushnir, 2019). For example, Yu and Kushnir (2019) documented systematic inter-individual variation in 2-year-old toddlers' tendencies for *faithful imitation* (e.g., overimitation) and *goal emulation* (e.g., copying the goal of an action) across a variety of tasks. Further studies confirmed inter-individual variation in the imitation of socially transmitted information being linked to personality traits and developmental outcomes (Hilbrink et al., 2013; Rawlings et al., 2021; Wagner et al., 2020).

However, the consequences of such variation for the spread of conventions within social groups remain poorly understood. Such links may be evident with regard to the adoption and transmission of conventional information. Theoretical accounts linking overimitation and cumulative culture ascribe overimitation a key role in the adoption and transmission of conventional information within populations (Legare & Nielsen, 2015; Nielsen, 2018). However, empirical evidence in support of such notions is still lacking. One may speculate that a tendency to overimitate should align with a lowered tendency to modify conventional information, suggesting a behavioral conservatism of overimitators. If so, then individuals tending to overimitate might be predisposed to adopt and transmit conventional information within their group, whereas individuals lacking the tendency to overimitate might be predisposed to modify (and advance) such information from time to time.

To test these assumptions, we investigated whether and how inter-individual differences in children's tendency to overimitate influence the adoption, transmission, and modification of conventional information within groups. To this end, we introduced a novel paradigm building on previous work simulating diffusion chains (Caldwell & Millen, 2008a, 2008b; Caldwell et al., 2019) in which we observed the spread of conventional information across two artificial study generations comprised of peers. In a pre-phase, we presented children with two overimitation tasks to assign them to two mutually exclusive study populations. If children engaged in overimitation throughout both tasks, they were assigned as overimitators (OIs). Those who did not show any overimitation in the pre-phase were assigned as non-overimitators (non-OIs). Children who showed overimitation in only one of the two tasks were considered ambiguous and did not partake in subsequent study phases. We chose this approach to artificially compose two study populations that, based on their initial behaviors, differed systematically in their overimitation within an experimental setting. It is important to note that such a categoric assignment does not resemble the rich inter-individual variation in children's natural tendency to overimitate (Hilbrink et al., 2013; Wagner et al., 2020). Instead, the current approach aimed at assigning children at two ends of a spectrum.

In Study Phase 1, we assessed whether both study populations (OIs and non-OIs) would differ in their adoption, transmission, and modification of conventional information. In this study phase, both study populations received identical instructions on how to play one of two novel games (Game A or Game B) via video recordings. Thereafter, children could set up and play by themselves (game adoption) before they were asked to explain the game to another child through a video message (game transmission). We also assessed whether children modified or added new game actions during game adoption and game transmission (game modification). In Study Phase 2, children watched the video instructions from unknown peers of their study population that were recorded in Study Phase 1 (either OIs or non-OIs). In this study phase, children were introduced to a novel game in which they did not engage in Study Phase 1 (i.e., Game A in Study Phase 1 and Game B in Study Phase 2 or vice versa). As in Study Phase 1, children could first play themselves (game adoption) before they were asked to instruct a peer on how to play the game (game transmission). We assessed to what extent game elements deviated from the original instructions given in Study Phase 1 as a proxy for the spread of conventional information across two study generations. All children took part in both phases of the study, which allowed us to assess whether differences between study populations would accumulate over time. Note that the current paradigm does not represent a classic diffusion chain study but followed two predefined groups of children across sequences comprising two study generations.

For each study phase, we coded the fidelity with which children followed the instructions by adopting (a) the materials and (b) the actions of the game. We also coded whether children transmitted (c) which materials to use and (d) which actions to perform when transmitting the game for their peers via video. During game transmission, we also coded children's use of normative language (e.g., signalized by keywords such as "one must/ought to do") (see also Göckeritz, Schmidt, & Tomasello, 2014, and Method of the current article). As a proxy for children's modification of conventional information, we coded whether children would introduce novel actions or objects to the game procedure. It is important to note that the diffusion sequence design of the current study does not inform us whether children modified conventional information intentionally. Because children in Study Phase 2 only had access to their peers' transmission video but not the initial game instructions, these children may have deviated from the initial game unintentionally. Thus, we refer to both intentional and unintentional deviations accumulating across study phases as "game modifications" (see also the "Coding" section below).

We preregistered the current study design and hypotheses on the Open Science Framework (https://osf.io/b26xw/?view_only=ff06a8f970db4a09ac35eaf6e06d9a55). We predicted that conventional information (i.e., rules and materials of the games) would be both adopted (Hypothesis 1) and transmitted (Hypothesis 2) at higher rates among OIs as compared with non-OIs. Given the normative function that has been assumed to drive overimitation (Keupp et al., 2013), we further hypothesized that OIs would transmit conventional information by using normative language at higher rates than their non-OI counterparts (Hypothesis 2b). Furthermore, we predicted that the differences between OIs and non-OIs in both adoption and transmission would become more prevalent throughout the two study phases (e.g., increase from Study Phase 1 to Study Phase 2) as a result of an accumulation of differences between study populations (Hypothesis 3). Finally, because innovation has been discussed as a complementary mechanism to imitation (Legare & Nielsen, 2015), we assumed that OIs would modify less when adopting and transmitting the game (Hypothesis 4) as compared with non-OIs.

Method

Participants

We tested a sample of 149 5-year-old children (M_{age} = 5.23 years, SD = 0.15, range = 5.00–5.51) in the pre-study phase to assess their overimitation. We chose to test children at this age because the preschool years mark an essential time for young children to consolidate their social learning strategies, including the use of overimitation (see Hoehl et al., 2019, for a review). In addition, children's innovation undergoes significant development throughout this age range (Neldner et al., 2019; Subiaul et al., 2015). Thus, children of this age are equipped with sufficient cognitive flexibility to voluntarily modify conventional information in the current study. Piloting revealed that children at this age were capable of engaging in and transmitting the games without being closely supervised by the experimenter. We aimed at parsing children into two distinct and mutually exclusive study populations varying in their tendency to show overimitation (OIs vs. non-OIs). Thus, we consulted participants until these study population sizes could be composed: 32 OIs (16 girls) and 32 non-OIs (16 girls) (see also preregistration). Children were excluded from subsequent study phases if they showed overimitation in only one of the two tasks, such that we could not clearly classify them as either OI or non-OI (n = 33), if testing was interrupted or they refused to be recorded (n = 10), or if the study population they would have been assigned to was already complete (n = 42). We recruited participants from an online database to which they were assigned following their parents' written consent. Children were tested in quiet rooms in their daycare centers after they assented to participate in the study.

We recruited participants from a mid-sized German city with about 600,000 inhabitants. Although we did not individually assess children's socioeconomic backgrounds, child participants in studies conducted in urban Germany are typically from mixed to high socioeconomic backgrounds. Parents in Germany and other Western industrialized societies typically emphasize their children's psychological autonomy up from an early age (Kärtner et al., 2016). Children receive high levels of direct child-centered pedagogy and are used to dyadic settings such as the procedure of the current study. Previous studies have typically documented high rates of overimitation among children from this particular population (Schleihauf, Pauen, & Hoehl, 2019; Stengelin, Hepach, & Haun, 2019, 2020). Furthermore, children commonly receive and process information given via technical devices, such as TVs and computers, both at home and in their daycare environment, allowing us to present and record the game introductions via video.

The ethics committee at the Leipzig Research Center for Early Child Development approved the study procedure. The current study was noninvasive and strictly adhered to the legal requirements for psychological research in Germany. Informed written consent was obtained from all parents before the study took place. Children's participation was strictly voluntary.

Design

Fig. 1 depicts the design of the study. In the pre-test phase, we assigned children to one of two study populations (OIs or non-OIs) depending on their overimitation in two tasks: the Tupper task and the Zipper task (see below). Children were assigned as OIs if they overimitated in both tasks, and they were assigned as non-OIs if they showed no overimitation at all.

To investigate the spread of conventional information within OIs and non-OIs, we designed two different games that could be imitated, transmitted, and modified across two study phases. In Study Phase 1, half the children received an instruction on how to play Game A and the other half received

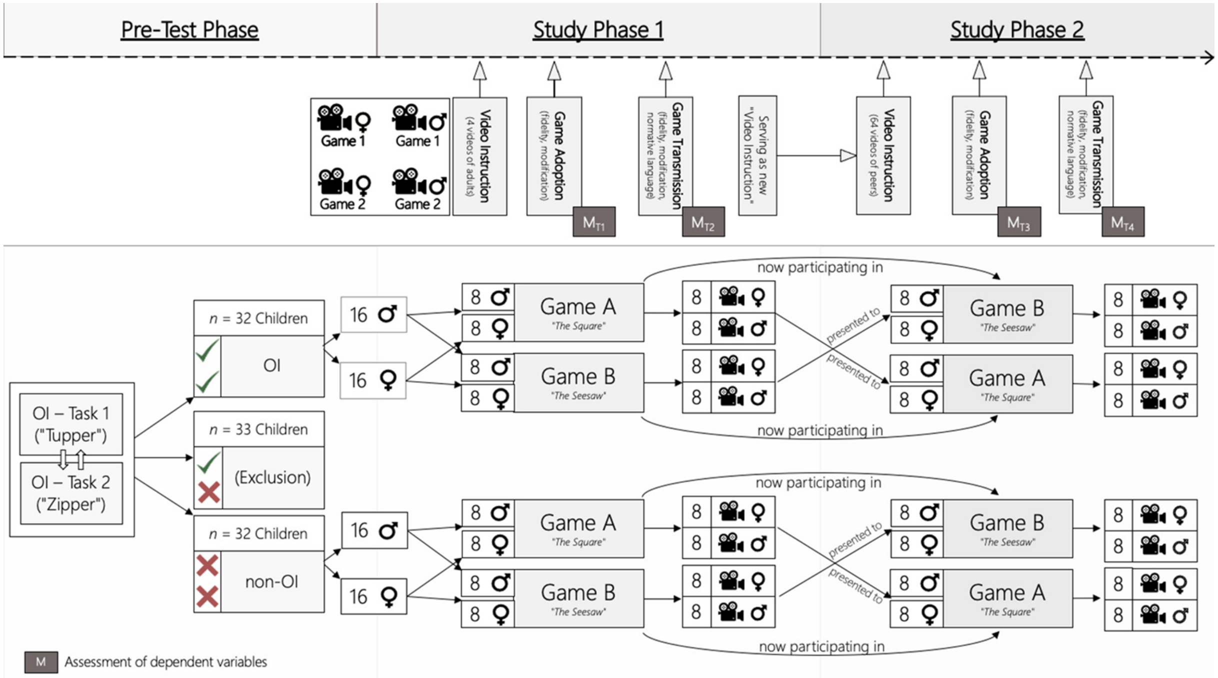

Fig. 1. Study design. The pre-study (pre-test) tasks and Study Phase 1 took place on the same day, whereas Study Phase 2 was conducted some weeks later. For the pre-study phase, the ticks depict the presence of overimitation, whereas the crosses symbolize the absence of overimitation. Information in Study Phase 1 was transmitted from adult to child via video instruction, and information in Study Phase 2 was transmitted from child to child, again via video instruction. Children's game adoption, game transmission, and game modification were assessed as outcomes in both study phases. OI, overimitator; non-OI, non-overimitator.

an instruction on how to play Game B (the assignment was counterbalanced regarding children's assigned study population and their sex). For OIs, this approach resulted in eight sequences of girls and eight sequences of boys receiving Game A as information in Study Phase 1 and in 8 girls and 8 boys receiving Game B as information in this study phase. The same applied to non-OIs. In Study Phase 1, children saw a video instruction of the respective game given by a same-sex adult. After having the opportunity to play the game themselves (game adoption; Study Phase 1), children were recorded while introducing the game to another peer (game transmission; Study Phase 1). Study Phase 2 was assessed some months after Study Phase 1 (M_{delay} = 100 days, range = 29–155). Here, children saw a video in which an unknown same-sex member of their study population explained to them the respective other game, which they had not have played in Study Phase 1. It should be noted that children were not aware that their peer was affiliated with the same study population. Again, children could play themselves (game adoption; Study Phase 2) and were then asked to record a video instruction for a peer (game transmission; Study Phase 2). In total, we assessed 32 diffusion pairs per study population.

Materials and procedure

Setting

Testing took place in a quiet room in the children's daycare centers. We discretely set up a video camera to record children's behaviors throughout the study and used a second video camera to record children's game transmission. The detailed procedure can be found in the online supplementary material (Table S1).

Pre-study phase: Overimitation tasks

Both overimitation tasks were presented in a counterbalanced task order across children. In each task, the experimenter demonstrated both goal-irrelevant and goal-relevant action steps when retrieving a sticker from a device. In the Tupper task (applied from Stengelin et al., 2020; see Fig. 2A), the experimenter first tapped a rod on each of the four locks of a transparent box (goal-irrelevant action). She then lifted the cover of the box with her hands (goal-relevant action) and retrieved one of two rewards (sticker). Afterward, the experimenter instructed the child, "Now you can take the other sticker," and the child was given the opportunity to retrieve the sticker. The materials used for the Zipper task consisted of a transparent plastic zipper bag, a light switch, and a piece of wood, which were firmly connected (see Fig. 2B). The experimenter started the demonstration by pushing the light switch (goal-irrelevant action). She then moved the zipper by hand to open the

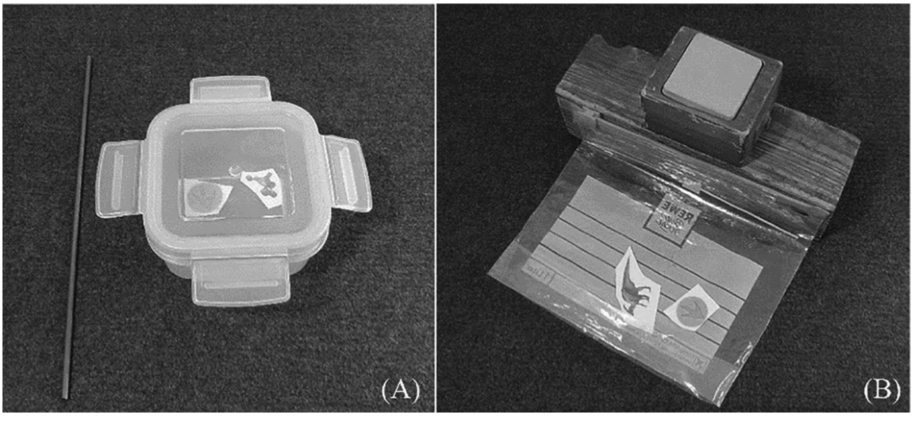

Fig. 2. Overimitator (OI) tasks—the Tupper task (A) and the Zipper task (B). In each task, a sticker was removed by the experimenter using goal-irrelevant and goal-relevant actions. The box/zipper was closed again before the child was given a turn to obtain the second sticker.

bag (goal-relevant action) and retrieved one of two rewards (sticker). Again, the child was instructed to obtain the remaining sticker afterward.

Based on children's behaviors in both overimitation tasks, the experimenter immediately assigned them to the study populations. Children who overimitated in both tasks (e.g., by tapping one or more of the locks in the Tupper task, by pressing the light switch in the Zipper task) were classified as OIs, whereas those who showed no overimitation across tasks were classified as non-OIs. Those who showed overimitation in just one of the two tasks were not tested further but received the stickers as compensation for their participation.

Initial game instructions

Both OIs and non-OIs received one of two initial game instructions based on their study population and sex. We introduced two different games of equal demands: the *square* and the *seesaw.* These games were designed as a child-appropriate operationalization of conventional information and did not have a discrete end state, and one could neither win nor lose. In the original adult demonstration, five objects were needed to engage in each game and were available alongside five distractor objects not included in the instruction videos (see below). The instructions included normative sentences typically containing variants of the German pronoun "man" (i.e., "one"), which is a very common way to emphasize the normativity of an utterance in German (i.e., "Wenn *man* am Holzklotz vorbei kommt sagt *man* 'Pit'" [When *one* passes the wooden block, *one* says 'Pit']). Both games were presented alternately and were counterbalanced across study populations and sexes.

Study Phase 1

The experimenter explained that she brought a game of a friend (either Game A or Game B, matched to the child's sex). She said that her friend had recorded a video of a game that she wanted to show the child and asked the child to watch it carefully (see supplementary material for instruction videos and procedural details).

Game A: The square. Five items were used in this game: a blue skipping rope, a game board with lines drawn on it, a little green wooden wheel, two wooden sticks (blue and red), and a blue wooden block. An additional five distractor objects were available alongside the other objects and were not used in the initial demonstration: a small roll of black tape, a chestnut, two small twinkling balls, a red toy building block, and 8-shaped colored cardboard (Fig. 3A; see also supplementary Material [Tables S4 and S5]). On-screen, the adult model stated which object he or she would choose before demonstrating the game. The model explained that the blue stick needed to be inserted into the green wooden wheel. The wheel then needed to be moved with the stick alongside the game board following the marked lines to form a circular shape without going back and forth. When passing the blue wooden

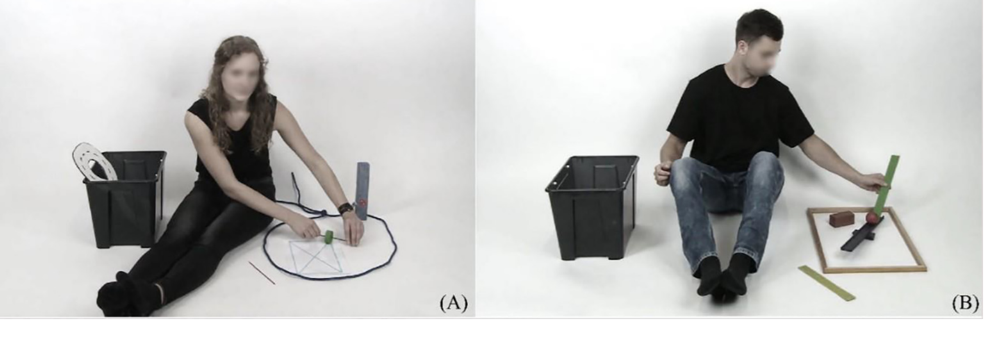

Fig. 3. Snapshots of the initial video instructions. Video instructions were recorded with same-sex adults for Game A (the square [Picture A]) and for Game B (the seesaw [Picture B]). The arrangement of objects is depicted for each game. The black baskets contained an additional five objects that were accessible for children but not used in the video instructions.

block, one was supposed to say "Pit." After reaching the initial position, one needed to replace the blue stick with the red stick before going through the same procedure again. On-screen, the model repeated all actions once more. In total, the video included verbal instructions on how to play the game for two complete rounds in total, followed by two demonstrations lacking verbal instructions.

Game B: The seesaw. Again, five items were needed to play the game: a picture frame, a seesaw, a red wooden ball, a set of two wooden bars (yellow and green), and a brown wooden block. An additional five distractor objects were available but were not used in the demonstration: a small roll of pink tape, a stone, two small plastic balls with bells, a blue toy building block, and a short red rope (Fig. 3B; see also supplementary material [Tables S4 and S5]). As with the other game, the rules to play the game were explained and demonstrated on-screen. Accordingly, the red wooden ball needed to be moved along the seesaw by pushing it with one of the yellow bars. Next, one would return with the ball to the starting position, forming a circular movement by moving in one direction. When passing the brown wooden block with the ball, one was supposed to say "Tak." After returning to the starting position, the yellow bar needed to be replaced with the green bar. Then all actions were repeated. As in Game A, the video instruction included verbal utterances on how to play the game for two rounds, followed by two demonstrations without verbal statements.

Study Phase 1: Game adoption. After watching the video instructions, a black plastic box containing all objects belonging to the demonstrated game and five distractor objects was provided to the child, who then could play himself or herself. Importantly, the experimenter left open what or how the child could play, leaving it to the child whether to focus on adoption or modification. The experimenter asked the child to let her know when the child was finished. When the child played longer than 5 min, the experimenter kindly interrupted the child and went on to record the game transmission.

Study Phase 1: Game transmission. After assessing the child's game adoption, the experimenter told the child that she planned to visit another kindergarten the next day. She stated that it would be great if the child could record a video demonstrating the game so that another child in the other kindergarten could play the game as well. If the child agreed, all objects were put back in the basket. Next, the experimenter set up the second video camera with which the child's video instruction could be recorded. The child could freely demonstrate and explain the game. Videos were recorded until the child said he or she was done or, at the latest, after 3 min. At the end of Study Phase 1, children received the stickers they had retrieved in the pre-study phase as well as an additional sticker they could choose at the end of the testing as compensation for their participation.

Study Phase 2

Study Phase 2 was always conducted on another date than Study Phase 1. The procedure was mostly similar to the protocol of Study Phase 1. The experimenter asked the child whether he or she could remember what had happened in the initial study phase. Each child's memory was refreshed by shortly bringing up either the wheel and the square-shaped board (Game A) or the seesaw and the ball (Game B). This time, each child was told that the experimenter had already visited another kindergarten where a peer (unknown to the test child) had shown her an alternative game. Each child received another child's video instruction recorded in Study Phase 1. The video instructions of a same-sex child were randomly assigned to children within the respective group (OI–male, OI–female, non-OI–male, or non-OI–female), also considering the game played in Study Phase 1 (each child played a novel game in Study Phase 2). Game adoption, transmission, and modification were assessed as in Study Phase 1. Because there was no further study phase, the transmission videos of Study Phase 2 were used only for coding and not as instruction videos. At the end of Study Phase 2, children received stickers as compensation for their participation.

Coding

We coded the following dependent measures separately for both study phases: game adoption, game transmission (including children's normative language), and game type modification.

Overimitation tasks

The overimitation tasks were coded live by the experimenter to immediately allocate participants to the study populations (the accuracy of this allocation was double-checked during video coding). In the Tupper task, overimitation was coded as such if children tapped the locks of the Tupper box before retrieving the sticker. In the Zipper task, overimitation was coded as such if children pushed the light switch before retrieving the sticker from the plastic bag.

Game adoption and transmission

To assess children's game adoption and transmission, we evaluated both aspects by relating children's actions to those initially demonstrated by the adult model. Actions are further referred to as either identical to or deviant from the initial video. We designed both Game A (the square) and Game B (the seesaw) to apply an identical coding system on both game adoption and game transmission. Doing so enabled us to relate both variables in the statistical analyses. Children received a maximum score of 11 points on this scale (henceforth *fidelity* score) when they adopted or transmitted all rules (6 points) and object choices (5 points) as modeled by the adult in either study phase. The objects of both games were comparable in their function for each game (see supplementary material [Tables S4 and S5 and Fig. S20]).

We coded children's actions regarding movements, action switching, and sound production. Children could receive 2 points per category when showing the respective behavior. That is, they could receive 1 point for performing the action using the right method, 1 point for moving the object in the correct form (Category 1: movement), 1 point for switching to the action at the right time/location, 1 point for switching to the next action in the same manner as initially instructed (Category 2: action switching), 1 point for making a sound at the initially instructed location, and 1 point for making the same sound as initially instructed (Category 3: sound).

Game transmission: Normative language

The use of normative language was coded during game transmission. In line with the suggestions of Göckeritz and colleagues (2014), children's utterances were coded as normative language if a normative understanding of actions and choices was emphasized by the use of normative utterances (e.g., "One must do it like this," "This goes here!"). For example, 17 children (12 non-OIs and 5 OIs) made use of the German word "man" (i.e., "one"; see above) in Study Phase 1, whereas 8 children used this wording in Study Phase 2 (all non-OIs). These utterances (among others) were coded as normative. An utterance was not classified as such if children were speaking in the first person (e.g., "I do this!"). We created a normative language score for which children obtained 1 point for each utterance comprising normative language (regardless of whether utterances referred to actions displayed in the initial instructions or game modifications). In addition, we also coded for children's tendency to speak in general. This variable was added following a suggestion of an anonymous reviewer and thus was not preregistered prior to data acquisition. In this way, we evaluated whether potential differences in normative language across study populations would be indicative of variation in normative language particularly or whether this would reflect differences in language use irrespective of the normative domain. We transcribed children's utterances in the game transmission phases word for word and counted the number of words. We then coded how many of these words were included in normative utterances as compared with utterances lacking normative language.

If OIs were more inclined to speak generally than non-OIs, we would expect to find significant differences between the groups in spoken words within and outside of normative utterances. In contrast, if OIs and non-OIs differed only in their reliance on normative language, we would expect to document population-level differences exclusively for normative utterances but not for non-normative utterances.

Game modification

We coded deviations from the initial game instructions for both study phases. The most commonly stated components in definitions of modification as an innovative act are the novelty of action, idea, artifact, or material together with an intended implementation or spread of such (West & Farr, 1990). Therefore, we created a game modification score that was based on the novelty of an action by applying the following categories: the choice of novel objects (i.e., objects not used by the model), the new arrangement of the objects (i.e., not introduced by the model), and novel behaviors (i.e., not performed initially by the model). Accordingly, children could receive a game modification score from 0 to 3. We based this coding on a study by Nielsen, Tomaselli, Mushin, and Whiten (2014), who assessed innovation in the context of tool modifications. To distinguish innovative modification from exploration and erroneous imitation, we conceived the behaviors as intentional modifications only if at least one of the following conditions was fulfilled: children showed the same (novel) behavior during game adoption and game transmission, children emphasized the novelty using verbal utterances, or children played the game identically to the initial instruction beforehand, indicating that they intentionally modified the rule at some point. As noted above, the diffusion-sequence design does not allow one to infer whether children assessed in Study Phase 2 deviated from the initial instructions intentionally. Instead, we assessed whether deviations from the initial game instructions provided in Study Phase 1 accumulated across both study generations. Thus, game modification scores obtained in Study Phase 2 provide information on how sequences of 2 children transmitted and modified the initial game instructions. More details on our coding procedures are reported in the supplementary material (Tables S6 and S7) along with the frequencies of the conditions according to which children's behaviors were scored as modifications (Table S8).

Reliability coding

The overimitation tasks (in addition to the initial live coding), both fidelity scores (adoption and transmission), the normative language score, and the game modification score were coded from tape by the experimenter (the third author). In addition, a research assistant who was blind to the study design and hypotheses coded 25% of the data (16 children). We estimated inter-rater reliability using a two-way mixed, absolute agreement, single-measures intraclass correlation coefficient (ICC; Hallgren, 2012; Koo & Li, 2016). ICCs were calculated in R Version 3.4.3 (R Core Team, 2015) using the package *irr* (Gamer, Lemon, Fellows, & Singh, 2019). The ICC for overimitation was 1, indicating perfect inter-rater agreement (Cicchetti, 1994). The average inter-rater reliability for both fidelity scores (game adoption and game transmission in Study Phases 1 and 2) was .98 and thus was excellent. The ICC for our coding of children's use of normative language during game transmission in both study phases was .92 and thus was excellent. The average inter-rater reliability for game modification scores revealed good agreement with an ICC of .81 (see also supplementary material [Table S9]).

Statistics and data analysis

Game adoption and transmission

We tested our hypotheses applying a logistic generalized linear mixed model fitted via maximum likelihood (GLMM; Baayen, Davidson, & Bates, 2008) using the package *lme4* and the function *glmer* (Bates, Mächler, Bolker, & Walker, 2014) in R Version 3.4.3 (R Core Team, 2015). We aimed to predict the fidelity with which children adopted and transmitted the games (response variables) by their inter-individual tendency to overimitate in the prior overimitation tasks (predictor variable). Game imitation and game transmission fidelity were combined into one outcome variable (*fidelity score*). We added the predictor *fidelity type* to the model, indicating whether this outcome reflected children's game adoption or game transmission. Children could receive fidelity scores from 0 to 11, with higher scores indicating better alignment between original game instructions and child behaviors. Response variables that have lower and upper bounds can be transformed into a binary variable by scoring each awarded point as 1 and each point not awarded as 0. Thus, we analyzed these data with a binary response term and a binomial error structure. To do so, we implemented a matrix comprising two columns with the sum of awarded and not-awarded points per individual and phase as the response.

We then generated a full model comprising the fixed effects of study population (OIs or non-OIs), fidelity type (adoption or transmission), study phase (1 or 2), and their interactions. We also included sex as a control variable to account for the potential effects of sex on overimitation (Frick, Clément, & Gruber, 2017; Schleihauf et al., 2019). Diverging from our preregistration, we did not include the type of game (the square or the seesaw) as an independent variable in our model because a preliminary analysis of game type as a single predictor of game fidelity revealed no significant effect of game type

(χ^2 = 0.341, df = 1, p = .559, Nagelkerke's R^2 = .001). We did so to reduce model complexity and to overcome converging issues for subsequent analyses. Individual identity was included as a random effect to account for within-participant variation. Furthermore, we included the random slope of fidelity type and study phase within individual identity as well as the respective correlations to account for repeated measures within participants. Assumption checks confirmed this approach (see supplementary material [Table S10]). To avoid an increased Type I error rate due to multiple testing, we first tested the statistical significance of the full model compared with a null model lacking the predictors of interest but comprising sex as a control fixed effect, the random effect of participant, and the random slope for game fidelity type and study phase within participants (Forstmeier & Schielzeth, 2011). To do so, we used a likelihood ratio test (Dobson, 2002). The full model provided a better fit to the data than a null model (χ^2 = 34.937, df = 7, p < .001, Nagelkerke's R^2 = .129). To determine the effects of the predictors (study population, game fidelity type, study phase, and their interactions), we further compared the full model with the respective reduced models lacking the predictor of interest with likelihood ratio tests.

Game transmission: Normative language

We aimed to predict whether OIs would use conventional language more frequently than non-OIs. Therefore, we fitted two models for both codings of normative language (normative language score and number of words included in normative verbal utterance). We fitted one additional model for the number of words included in non-normative verbal utterance to control whether potential variation between OIs and non-OIs would apply to normative language specifically or to language use more generally. For all three models, we fitted a negative binomial error distribution, which is commonly used for count response variables including a high number of zeros with the function *glmmTMB* (Magnusson et al., 2017). We included the fixed effects study population, study phase, their interaction, and the control factor sex in each model. We did not include the type of game (the square or the seesaw) because preliminary analysis did not reveal an effect of this variable (normative language score model: χ^2 = 0.010, df = 1, p = .919, Nagelkerke's R^2 = .001; normative word number model: χ^2 = 0.264, df = 1, p = .607, Nagelkerke's R^2 = .002; non-normative word number model: χ^2 < 0.001, df = 1, p = .985, Nagelkerke's R^2 < .001). Individual identity was included as a random intercept to account for within-participant variation. A random slope of study phase within individual identity could not be added because we had only one observation per generation. Assumption checks for these three models are reported in the supplementary material (Table S11). For all models, we first performed a full–null model comparison. For the normative language score model (χ^2 = 10.786, df = 3, p = .013, Nagelkerke's R^2 = .090) and the normative word number model (χ^2 = 10.843, df = 3, p = .013, Nagelkerke's R^2 = .084), the full model explained more variation in the data than the null model. For the non-normative word number model, the full model did not explain more variation in the data than the null model (χ^2 = 4.704, df = 3, p = .195, Nagelkerke's R^2 = .036). For both models yielding a significant full–null model difference, we compared the full models with reduced models lacking the predictors of interest to estimate the effects of study population and study phase.

Game modification

We assessed whether children's tendency to overimitate would predict their innovative modification of conventional information, with the hypothesis that OIs would be less likely to modify conventional information than non-OIs. Due to the lower bound (0) and upper bound (3) of the modification score, we again analyzed these data with a response matrix and a binomial error structure using the function *glmer.* We first generated a full model using the function *glmer,* which entailed the fixed effects fidelity type, study population, study phase, and all possible interactions. Furthermore, we again included sex as a control factor. We did not include the type of game (the square or the seesaw) as an independent variable in our model because a preliminary analysis of game type as a single predictor of modification revealed no statistically significant effect (χ^2 = 2.23, df = 1, p = .135, Nagelkerke's R^2 = .010). The random effect individual identity was included as a random effect together with the random slopes of fidelity type and study phase. We also included the correlations of the random effects. Assumption checks are reported in the supplementary material (Tables S12 and S13). The full model provided a better fit to the data than the null model (χ^2 = 17.767, df = 7, p = .013, Nagelk-

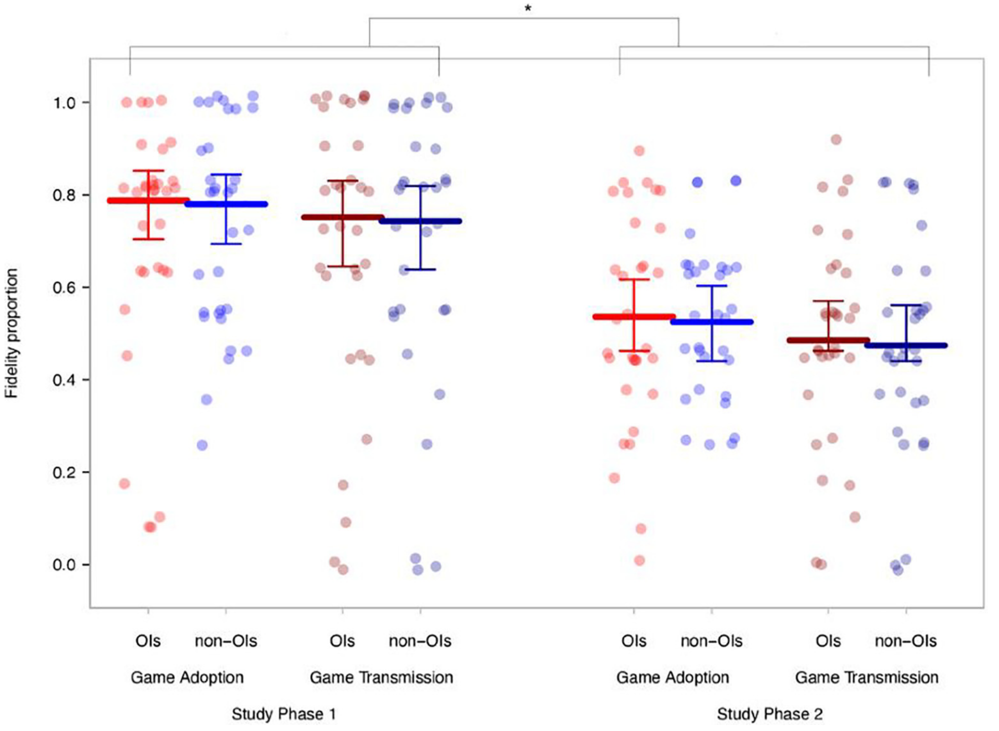

Fig. 4. Game adoption and transmission fidelity as a function of all predictors. Data points are jittered to improve visibility. Horizontal lines represent the respective point estimates predicted by the model. Estimates are centered for the factor sex. Error bars represent 95% confidence intervals retrieved with 1000 bootstraps. OIs, overimitators; non-OIs, non-overimitators; *p < .05.

erke's R^2 = .079). Again, we compared the full model with the respective reduced models lacking the predictor of interest. Because we found an interaction effect of study population and study phase, we performed additional post hoc analyses of both study phases separately. Therefore, we fitted a model with the predictor study population and the random intercept individual identity for both study phases.

Results

Game adoption and transmission

For children's game fidelity, the full–reduced model comparisons indicated a statistically significant effect of study phase (χ^2 = 30.296, df = 1, p < .001, Nagelkerke's R^2 = .113). Descriptive and visual data inspection analyses (see Fig. 4; see also supplemenatary material [Tables S14 and S15]) revealed that the children adopted and transmitted the initially presented game rules more in Study Phase 1 than in Study Phase 2 ($M_{\text{Study Phase 1}}$ = 7.77, SD = 3.00; $M_{\text{Study Phase 2}}$ = 6.67, SD = 2.91). No other predictor reached statistical significance (see supplementary material [Table S15]). Children did not significantly differ in adopting and transmitting game rules depending on their study population (χ^2 = 0.043, df = 1, p = .835, Nagelkerke's R^2 < .001), and their game adoption fidelity did not differ significantly from their game transmission fidelity (χ^2 = 2.677, df = 1, p = .102, Nagelkerke's R^2 = .011).

Game transmission: Normative speech

For the original normative language score, we found a significant main effect of study population (χ^2 = 6.462, *df* = 1, *p* = .011, Nagelkerke's R^2 = .055) and a marginal effect of study phase (χ^2 = 3.295, *df* = 1, *p* = .069, Nagelkerke's R^2 = .028). OIs produced more normative utterances than non-OIs, and children produced more normative utterances in Study Phase 1 than in Study Phase 2 (see Fig. 5A; see also supplementary material [Tables S16 and S17]). This pattern was confirmed when we analyzed the number of words within normative utterances (study population: χ^2 = 6.349, *df* = 1, *p* = .012, Nagelkerke's R^2 = .050; study phase: χ^2 = 3.014, *df* = 1, *p* = .082, Nagelkerke's R^2 = .02) (see Fig. 6). No other predictors reached statistical significance (see supplementary material [Tables S18 and S19]). No such pattern was evident when analyzing the number of words used outside of normative utterances (study population: χ^2 = 1.359, *df* = 1, *p* = .224, Nagelkerke's R^2 = .010; study phase: χ^2 = 2.414, *df* = 1, *p* = .120, Nagelkerke's R^2 = .0188) (see Fig. 5B; see also supplementary material [Table S19]). Taken together, these analyses suggest that OIs produced more normative utterances than non-OIs while showing no evidence that such population-level differences were grounded in a more general tendency to use words in the absence of normative communication.

Game modification

Full–reduced model comparisons revealed a statistically significant interaction of study phase and study population (χ^2 = 4.810, *df* = 1, *p* = .028, Nagelkerke's R^2 = .022) (see Fig. 6; see also supplementary material [Tables S20 and S21]). Children's modifications varied across study phases depending on their assigned study population. Post hoc analysis revealed that in Study Phase 1 OIs modified the game at significantly lower rates than non-OIs (χ^2 = 4.252, *df* = 1, *p* = .039, Nagelkerke's R^2 = .041) (see supplementary material [Table S22]). No such difference was found for Study Phase 2 (χ^2 = 0.617, *df* = 1, *p* = .432, Nagelkerke's R^2 = .005) (see Table S22).

Discussion

The current study assessed potential effects of inter-individual variation in young children's tendency to overimitate on their adoption, transmission, and modification of conventional information. To this end, we assigned children to one of two study populations (OIs or non-OIs) based on their overimitation across two tasks. Next, we assessed the spread of conventional information within these two study populations by simulating the transmission of conventional information across two study phases. In doing so, we assessed children's adoption and transmission (including their use of normative language) of game instructions as well as deviations from the initial game instructions (i.e., game modification).

In contrast to our hypotheses, we found no evidence that OIs would differ from non-OIs in the amount of game elements they adopted and transmitted to their peers. Thus, these findings oppose claims on the significance of overimitation on the spread of conventional information within populations (Legare & Nielsen, 2015). In line with our hypotheses, OIs were more likely than non-OIs to use normative language when transmitting game information to their peers. Accordingly, children's overimitation and their tendency to use normative language might emanate from a shared disposition varying across individuals (Kenward, Karlsson, & Persson, 2011; Keupp et al., 2013). We also found systematic differences between OIs and non-OIs in children's tendency to modify conventional information. In Study Phase 1, non-OIs were more inclined to modify and add actions or objects to the initial game rules and transmitted these modifications to their peers. Considering the innovative value of such game modifications (see also Carr et al., 2016), this finding supports theoretical claims on imitation and innovation as interdependent drivers of cumulative culture (Legare & Nielsen, 2015; Rawlings et al., 2017). Whereas such accounts have mostly focused on the spread of instrumental behaviors and skills within populations, the current findings extend such work by linking children's overimitation to the spread of conventional information within populations. In the following, we first examine each of these results individually before turning to a more general discussion of the current findings.

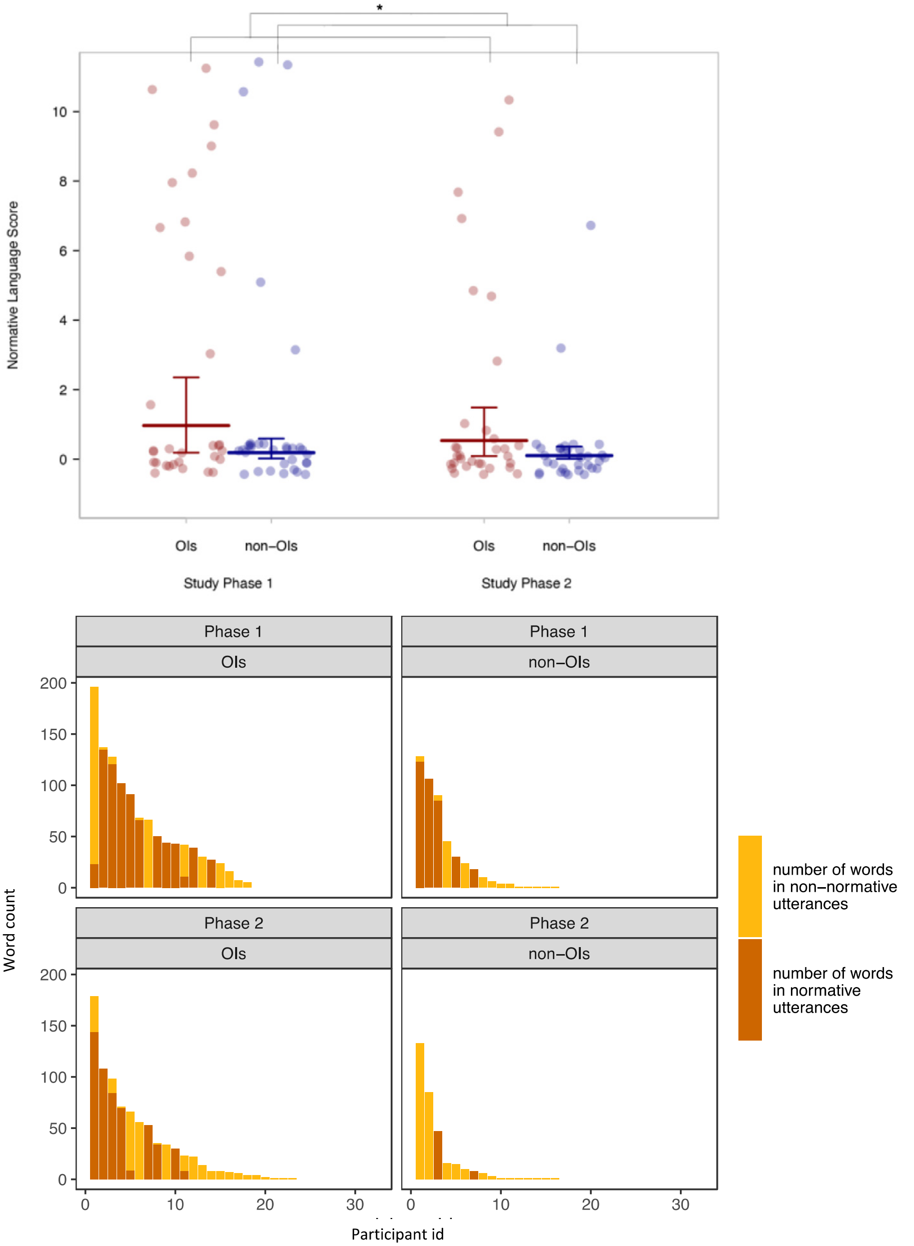

Fig. 5. Analyses of normative language use across study populations. Upper panel: Normative language scores across study phases. Bold lines represent the respective point estimates that are centered for the factor sex. Error bars represent 95% confidence intervals retrieved with 1000 bootstraps. Lower panel: Numbers of words in non-normative and normative utterances as a function of study population and study phase. Data are plotted for each participant (32 children per cell). OIs, overimitators; non-OIs, non-overimitators; *p < .05.

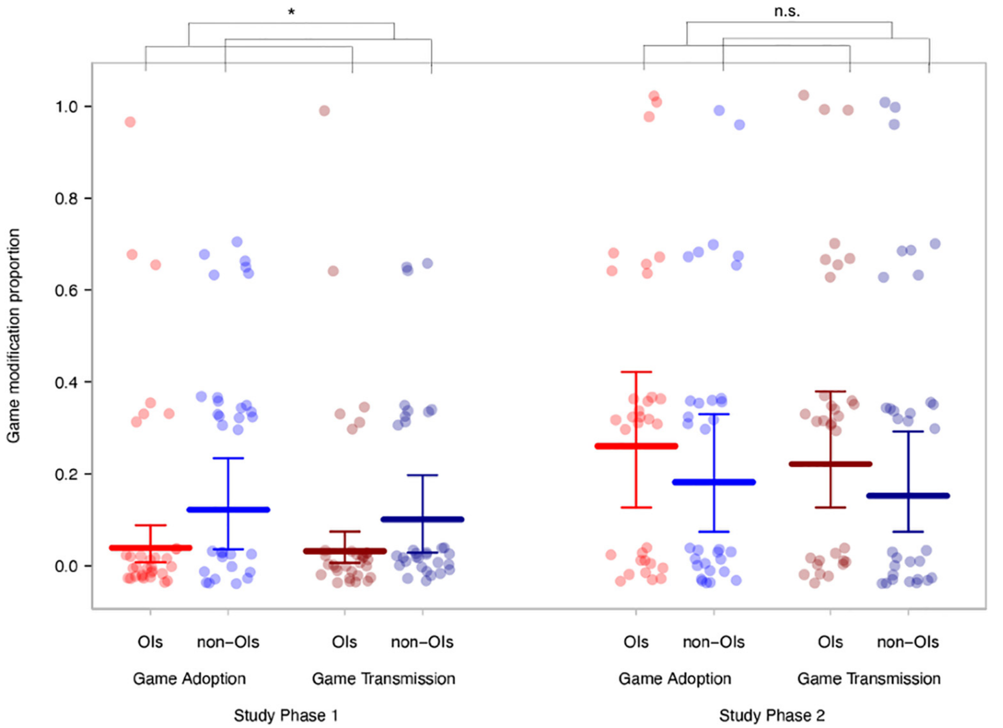

Fig. 6. Game modification scores as a function of all predictors. Data points are jittered to improve visibility. Bold lines represent the respective point estimates retrieved from the model. Estimates are centered for the factor sex. Error bars represent 95% confidence intervals retrieved with 1000 bootstraps. OIs, overimitators; non-OIs, non-overimitators. n.s., nonsignificant; *$p < .05$.

Game adoption and game transmission

We found no support for the hypothesis that conventional information would spread selectively among OIs compared with non-OIs. In addition, OIs were not particularly prone to adopt conventional information when playing the game, and they were not more inclined to transmit such information than their non-OI counterparts.

One explanation for the absence of significant population-level differences in the current study holds that children's tendency to overimitate (or not) in the pre-study phase did not reflect stable dispositional variation in overimitation. Accordingly, children's overimitation in a given setting might be mostly determined by situational constraints. Indeed, such factors play a role in children's overimitation. For example, children are known to overimitate selectively when being observed by others (Nielsen & Blank, 2011; Stengelin et al., 2019) or when they are confronted with adult models rather than peer models (Wood, Kendal, & Flynn, 2012). However, we assigned children as OIs or non-OIs within an experimentally controlled procedure to ensure that situational factors could not drive children's assignment to study populations. Furthermore, we assigned children to study populations only if they had acted consistently across two overimitation tasks. Children displaying more nuanced overimitation by copying causally irrelevant actions in only one of the two tasks were not assigned to study populations to ensure sufficient variation between OIs and non-OIs. Thus, it is important to note that we did not investigate the full spectrum of inter-individual variation in overimitation.

Notably, previous research on children's social learning strategies identified systematic and stable variation across individuals. For example, Yu and Kushnir (2019) found that "individual differences in children's imitation transcend immediate contextual influences" (p. 5), suggesting high-fidelity imitation as a stable trait-like disposition during early ages. This notion aligns with prior work documenting links between children's social learning strategies (i.e., overimitation) and stable personality traits such as extraversion (Hilbrink et al., 2013; see also Flynn & Whiten, 2012).

It is important to note that these studies assessed inter-individual variation in toddlers' learning strategies, thereby focusing on participants of markedly younger ages than those studied here. Although cross-sectional research has indicated that children's learning strategies, including their overimitation, are subject to developmental change (McGuigan, Makinson, & Whiten, 2011; van Leeuwen et al., 2018), the relative stability of children's preferred learning strategies has, to our knowledge, yet to be investigated. Thus, we emphasize that longitudinal research is needed to assess the inter-individual stability of overimitation across childhood and how such variation is linked to developmental outcomes. However, because we found effects of study population on children's normative language use and their tendency to modify game information in Study Phase 1, we find it most plausible that our assignment of children as OIs or non-OIs captured systematic variation in overimitation across individuals.

Another explanation holds that children's overimitation primarily affects their adoption and transmission of goal-related instrumental actions rather than of conventional information lacking instrumental outcomes. Children's overimitation is typically assessed in experimental contexts where children are tasked to obtain rewards or objects from puzzle boxes (Hoehl et al., 2019). The presence of such goals is crucial because it gives children the choice between ignoring causally irrelevant actions while pursuing the instrumental goal (i.e., emulation) and copying all actions instead (i.e., overimitation). Thus, the absence of instrumental goals in situations comprising conventional information may restrain the range of alternative learning strategies to be used, such that children converge on imitating any behavior modeled by others (Carpenter, Call, & Tomasello, 2005). If so, children who would typically emulate in the presence of instrumental goals might shift toward copying causally irrelevant actions if such goals are absent. As such, inter-individual variation in children's overimitation may be meaningful only to predict the adoption and transmission of conventional information in the presence of instrumental goals. This notion is in line with recent work documenting higher rates of overimitation in contexts where instrumental goals are demoted or absent (March et al., 2020; Nielsen et al., 2018; Taniguchi & Sanefuji, 2021).

Children's capacity to flexibly choose between social learning strategies depending on situational affordances thus may be important to consider when assessing whether social learning strategies in instrumental settings transcend to conventional settings. In their study, Yu and Kushnir (2019) allowed for conceptual overlaps between the factors *goal emulation* and *faithful imitation* on an inter-individual level when using oblique factor rotation. Critically, both factors reflect a tendency to learn socially rather than individually (Rawlings et al., 2017). For example, children's imitation in a puppet theater task lacking any instrumental goal was linked to their scores on both the factors *goal emulation* and *faithful imitation.* In the presence of an instrumental goal, children's copying of causally irrelevant actions was linked only to the factor faithful imitation. Thus, one may assume that population-level variation in children's overimitation may yield more pronounced effects on the spread of instrumental behaviors and skills. In the absence thereof, inter-individual variation may be of little relevance because children uniformly take a "ritual stance" to adopt and transmit conventional information regardless of individual learning dispositions.

Normative language

It is plausible that population-level differences in children's social learning were detected only in more subtle forms such as their use of normative language when transmitting game rules. OIs more readily used normative language when transmitting information to their peers compared with non-OIs. Thus, children's overimitation and their tendency to transmit information through normative utterances might share a conceptual overlap such as a disposition to conceive and emphasize behaviors as normative. Prior research has linked children's tendency to imitate faithfully with their normative reasoning (Clegg & Legare, 2016; Kenward et al., 2011; Keupp et al., 2013). In line with this notion, both phenomena undergo significant development during the early preschool years. At around 3 years of age, children's sensitivity to group-related social norms is honed (Plötner, Over, Carpenter, &

Tomasello, 2015). At the same age, their overimitation becomes increasingly frequent (Clay, Over, & Tennie, 2018; Clegg & Legare, 2016; Legare et al., 2015; McGuigan & Whiten, 2009; Watson-Jones et al., 2014). Based on our findings, one may speculate that children who are equipped with a normative stance (including their reliance on normative language) are also predisposed to overimitate others' actions.

Developmental research has also shown that normative language facilitates social learning in children (Clegg & Legare, 2016; Legare & Nielsen, 2015; Legare et al., 2015). In the current study, such wording did not lead to conventional information being adopted and transmitted more persistently among OIs than among non-OIs. Again, one may speculate whether the tendency to use normative language among non-OIs may affect the adoption and transmission of instrumental actions. Conventional information, such as the game rules in the current study, might not require the use of normative language because they are treated as conventional anyway (Rakoczy, Warneken, & Tomasello, 2008).

It is important to note that we assessed the adoption and transmission of information across only two study phases, limiting the detection of population-level effects unfolding across multiple generations. We did so because we focused on the spread of information in study populations varying in a key disposition (i.e., children's tendency to overimitate). Assessing more study phases in the current context would have implied doubling the number of initial games and participants, exceeding the capacities of the current study project. Future studies may introduce more fine-grained proxies for game adoption and transmission or may assess the spread of conventional or instrumental information across multiple generations in order to gain sufficient power for observing such potential links. Such work may help to better explain whether and how an increased reliance on normative language among OIs affects the spread of information in human populations.

Game modification

Consistent with the idea that OIs are more likely to conceive of others' behaviors as normative, they were more reluctant to modify such game rules in the first phase of our study. Whereas children's tendency to modify socially learned information has mostly been discussed in the context of instrumental actions (i.e., innovation of tool use; Carr et al., 2016; McGuigan et al., 2017; Neldner et al., 2019), the current study taps into another important perspective on the modification of conventional information in children. Whereas modification and innovation in instrumental contexts often incorporate the notion that they are aimed toward more efficiency, such a functional and directional aspect is evidently lacking in the modification of conventional information.

Nonetheless, we argue that the interplay of imitation and innovation as the psychological drivers of cumulative culture (Legare & Nielsen, 2015) is not restrained to the spread of instrumental actions. Instead, related processes may also take place in the spread of conventional information. Individuals favoring strategies other than mere overimitation may be essential in this cumulative process by being prone to modify learned behaviors and potentially innovate new ones. For example, children tending to emulate (i.e., copying the goal rather than the means of a demonstrated action) may be more likely to deviate from conventional information in order to create novel behaviors than those tending to overimitate under similar circumstances. This notion is in line with previous work highlighting conceptual overlaps between emulation and innovation (Carr et al., 2016). Focusing on others' goals rather than their actions and attaining such goals flexibly may lead to the use of emulation and modification/innovation as learning strategies at the same time. As such, the proportion of emulators versus (over)imitators in a given population may be essential to the accumulation of behaviors and information. In line with this assumption, Stengelin and colleagues (2020) documented similar proportions of children showing overimitation versus children showing no overimitation among two diverse societies (rural Hai||om, Namibia vs. urban Leipzig, Germany). The extent to which interindividual variation in children's overimitation within human populations holds a function for the adoption, transmission, and modification of conventional information is a question that demands further scientific exploration.

Interestingly, game modification was the only dependent variable for which we found diverging results for Study Phases 1 and 2. OIs and non-OIs differed in their tendencies to modify game elements only in Study Phase 1, where they had received the initial instructions from an adult. Here, children's game modifications were assessed with reference to the initial game instructions comprising experimentally controlled content. No such difference was found in Study Phase 2, where children received diverse instructions from their peers that already deviated from the initial game instructions. Initially, we expected that differences between study populations should accumulate from Study Phase 1 to Study Phase 2, but it appears that our study design had the opposite effect; initial differences between study populations may have washed out between study phases based on procedural variation across both study phases.

One crucial difference between the two study phases was that the initial demonstrations in Study Phase 1 were identical for children across both study populations and entailed experimentally controlled pedagogical cues. In Study Phase 2, however, each child received different demonstrations, comprising variation in the information transmitted by peers. As outlined above, it is impossible to tease apart intentional and unintentional modifications for children in the second study phase because children may have simply adopted the modifications transmitted by their predecessors. These demonstrations not only were less structured but also varied substantially between participants with regard to instructional details, the actions demonstrated, and the pedagogical cues being used by the peer demonstrator.

Another reason for this finding may be that our approach to present children with adult models in Study Phase 1 and with peers in Study Phase 2 drove this pattern of results. Previous studies have shown that children are more inclined to adopt and emphasize conventional information from adult models over peer models (Rakoczy, Hamann, Warneken, & Tomasello, 2010) and to copy adults' actions selectively (McGuigan et al., 2011; Wood et al., 2012). Thus, OIs might refrain from modifying conventional information if it is presented by adults but not if such information is given by peers, which may have caused the detection of differences between the two study populations in Study Phase 1 but not in Study Phase 2.

Given the two study phases of the current study, we can only speculate on whether the increased game modification rates in Study Phase 1 (but not in Study Phase 2) were driven by the models' age or other procedural differences across study phases. More targeted research controlling for the informative value of peers' instructions is needed to shed light on how likely children modify conventional information from adults compared with peer models (Kachel, Hepach, Moore, & Tomasello, 2021; Rakoczy et al., 2010).

Furthermore, it is important to note that the current approach of assigning children as OIs and non-OIs does not fully resemble the diversity of social learning tendencies in the real world. This assignment presents an experimental approach to simulate the spread of conventional information under controlled settings. Notably, a significant portion of children ($n = 33$) did not partake in the game adoption and transmission phases of the study because they could not be assigned as OIs or non-OIs. Although assessing these children was beyond the scope of the current study, the tendency to flexibly switch between learning strategies may be highly relevant for the spread and modification of both conventional and instrumental information within populations. Although the current approach focused on the influence of children's predispositions for certain social learning strategies, we want to highlight that the adoption, transmission, and modification of conventional and instrumental information is multifaceted in that it not only relies on individual dispositions (Yu & Kushnir, 2019) but also is shaped by situational constraints (Nielsen & Blank, 2011; Nielsen et al., 2018) and cultural constraints (Berl & Hewlett, 2015; Stengelin et al., 2019). Unraveling the interplay of such factors presents a major challenge moving toward a comprehensive understanding of children's emerging capacities to adopt, transmit, and modify cultural information.

For example, children's social learning strategies rely on various cognitive skills that may vary across individuals and ages. Here, we aimed to parse children into study populations based on their overimitation but not based on more general cognitive domains such as language proficiency and memory capacities. With regard to children's language use, our additional analyses of children's general verbalizations did not indicate significant population-level variation in this domain. Children varied in their use of normative language but not in how much they relied on non-normative language. Thus, this finding resonates with previous work failing to identify significant links between children's social learning and their verbal abilities (Flynn & Whiten, 2012).

To minimize potential effects of children's memory capacities, we assessed children's overimitation in short tasks comprising one causally irrelevant action to be remembered and copied. Such actions were performed on predefined areas on the reward containers (i.e., pressing a light switch or using a tool to tap the lid of the container), rendering it unlikely that memory capacities drove overimitation among these participants (Speidel et al., 2021; see also Stengelin et al., 2020). To our knowledge, only one study has directly assessed the degree to which children's overimitation is linked to their memory capacities. Even though Marsh and colleagues' (2019) study used more complex sequences of irrelevant actions that needed to be remembered, the authors found no evidence that overimitation was linked to children's memory capacities. Thus, we are confident that neither language nor memory capacities drove the current findings on population-level variation in children's normative language use or in their tendency to modify game rules. Yet, we emphasize that a more systematic investigation of not only the social and cognitive correlates of young children's overimitation, but also their social learning strategies more generally, will help to better understand how conventional information is adopted, transmitted, and modified among young children.

Taken together, the findings of the current study document two coherent differences in the spread of conventional information among children who either overimitated an adult model in an experimental setting or refrained from doing so. First, although OIs and non-OIs did not differ in their tendency to adopt and transmit conventional actions, they differed in their use of normative language; OIs were more inclined than non-OIs to use normative language when transmitting conventional information to peers. Second, OIs and non-OIs differed in their tendency to modify conventional information. After receiving initial information from adult models, OIs were less likely than their non-OI counterparts to alter the game rules by adding novel objects or actions to the game. The spread of both instrumental and conventional information is an integral aspect of cumulative culture in human populations. Inter-individual variation in the tendency to overimitate needs to be considered as a determinant of how conventional information is adopted, transmitted, and modified from one individual to the next.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

This work was supported by a PRIME (Postdoctoral Researchers International Mobility Experience) Fellowship from the German Academic Exchange Service (Deutscher Akademischer Auslandsdienst [DAAD]) granted to Hanna Schleihauf. We thank Theo Toppe, Anne Sibilsky, and Jan Engelmann for their helpful comments on earlier versions of the manuscript.

Data availability

The data and scripts for analyses are openly available as online supplementary material https://github.com/HannaSchleihauf/OI.Transover.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jecp.2021.105271.

References

Baayen, R. H., Davidson, D. J., & Bates, D. M. (2008). Mixed-effects modeling with crossed random effects for subjects and items. *Journal of Memory and Language, 59*(4), 390–412.

Bates, D., Mächler, M., Bolker, B., & Walker, S. C. (2014). Fitting linear mixed-effects models using lme4. ArXiv. doi:10.1063/pt.5.028493.

Bateson, P. (2013). *Play, playfulness, creativity and innovation*. Cambridge, UK: Cambridge University Press.
Berl, R. E. W., & Hewlett, B. S. (2015). Cultural variation in the use of overimitation by the Aka and Ngandu of the Congo Basin. *PLoS One, 10*(3), e0120180.
Bonawitz, E., Shafto, P., Gweon, H., Goodman, N. D., Spelke, E., & Schulz, L. (2011). The double-edged sword of pedagogy: Instruction limits spontaneous exploration and discovery. *Cognition, Brain, Behavior, 120*(3), 322–330.
Boyd, R., & Richerson, P. J. (1988). *Culture and the evolutionary process*. Chicago: University of Chicago Press.
Caldwell, C. A., Atkinson, M., Blakey, K. H., Dunstone, J., Kean, D., Mackintosh, G., ... Wilks, C. E. H. (2019). Experimental assessment of capacities for cumulative culture: Review and evaluation of methods. *Wiley Interdisciplinary Reviews: Cognitive Science, 11* e1516.
Caldwell, C. A., & Millen, A. E. (2008a). Experimental models for testing hypotheses about cumulative cultural evolution. *Evolution and Human Behavior, 29*, 165–171.
Caldwell, C. A., & Millen, A. E. (2008b). Studying cumulative cultural evolution in the laboratory. *Philosophical Transactions of the Royal Society B: Biological Sciences, 363*, 3529–3539.
Carpenter, M., Call, J., & Tomasello, M. (2005). Twelve- and 18-month-olds copy actions in terms of goals. *Developmental Science, 8*(1), F13–F20.
Carr, K., Kendal, R. L., & Flynn, E. G. (2016). Eureka!: What is innovation, how does it develop, and who does it? *Child Development, 87*(5), 1505–1519.
Cicchetti, D. V. (1994). Guidelines, criteria, and rules of thumb for evaluating normed and standardized assessment instruments in psychology. *Psychological Assessment, 6*(4), 284–290.
Clay, Z., Over, H., & Tennie, C. (2018). What drives young children to over-imitate? Investigating the effects of age, context, action type, and transitivity. *Journal of Experimental Child Psychology, 166*, 520–534.
Clegg, J. M., & Legare, C. H. (2016). Instrumental and conventional interpretations of behavior are associated with distinct outcomes in early childhood. *Child Development, 87*(2), 527–542.
Dobson, A. J. (2002). *An introduction to generalized linear models*. Boca Raton, FL: Chapman & Hall.
Fenstermacher, S. K., & Saudino, K. J. (2016). Exploring links among imitation, mental development, and temperament. *Infancy, 21*(5), 536–559.
Flynn, E., & Whiten, A. (2012). Experimental "microcultures" in young children: Identifying biographic, cognitive, and social predictors of information transmission. *Child Development, 83*, 911–925.
Forstmeier, W., & Schielzeth, H. (2011). Cryptic multiple hypotheses testing in linear models: Overestimated effect sizes and the winner's curse. *Behavioral Ecology and Sociobiology, 65*(1), 47–55.
Frick, A., Clément, F., & Gruber, T. (2017). Evidence for a sex effect during overimitation: Boys copy irrelevant modelled actions more than girls across cultures. *Royal Society Open Science, 4*(12), 170367. https://doi.org/10.1098/rsos.170367.
Gamer, M., Lemon, J., Fellows, I., & Singh, P. (2019). Various coefficients of interrater reliability and agreement. Retrieved from https://cran.r-project.org/web/packages/irr/irr.pdf.
Göckeritz, S., Schmidt, M. F. H., & Tomasello, M. (2014). Young children's creation and transmission of social norms. *Cognitive Development, 30*, 81–95.
Hallgren, K. A. (2012). Computing inter-rater reliability for observational data: An overview and tutorial. *Tutorials in Quantitative Methods for Psychology, 8*(1), 23–34.
Hilbrink, E. E., Sakkalou, E., Ellis-Davies, K., Fowler, N. C., & Gattis, M. (2013). Selective and faithful imitation at 12 and 15 months. *Developmental Science, 16*, 828–840.
Hoehl, S., Keupp, S., Schleihauf, H., McGuigan, N., Buttelmann, D., & Whiten, A. (2019). "Over-imitation"—A review and appraisal of a decade of research. *Developmental Review, 51*, 90–108.
Horner, V., & Whiten, A. (2005). Causal knowledge and imitation/emulation switching in chimpanzees (*Pan troglodytes*) and children (*Homo sapiens*). *Animal Cognition, 8*(3), 164–181.
Kachel, G., Moore, R., Hepach, R., & Tomasello, M. (2021). Toddlers prefer adults as informants: 2- and 3-year-olds' use of and attention to pointing gestures from peer and adult partners. *Child Development, 92*(4). https://doi.org/10.1111/cdev.13544.
Kärtner, J., Keller, H., Lamm, B., Abels, M., Yovsi, R. D., & Chaudhary, N. (2016). Manifestations of autonomy and relatedness in mothers' accounts of their ethnotheories regarding child care across five cultural communities. *Journal of Cross-Cultural Psychology, 38*, 613–628.
Kenward, B. (2012). Over-imitating preschoolers believe unnecessary actions are normative and enforce their performance by a third party. *Journal of Experimental Child Psychology, 112*(2), 195–207.
Kenward, B., Karlsson, M., & Persson, J. (2011). Over-imitation is better explained by norm learning than by distorted causal learning. *Proceedings of the Royal Society B: Biological Sciences, 278*(1709), 1239–1246.
Keupp, S., Behne, T., & Rakoczy, H. (2013). Why do children overimitate? Normativity is crucial. *Journal of Experimental Child Psychology, 116*(2), 392–406.
Koo, T. K., & Li, M. Y. (2016). A guideline of selecting and reporting intraclass correlation coefficients for reliability research. *Journal of Chiropractic Medicine, 15*(2), 155–163.
Legare, C. H. (2017). Cumulative cultural learning: Development and diversity. *Proceedings of the National Academy of Sciences of the United States of America, 114*(30), 7877–7883.
Legare, C. H. (2019). The development of cumulative cultural learning. *Annual Review of Developmental Psychology, 1*(1), 119–147.
Legare, C. H., & Nielsen, M. (2015). Imitation and innovation: The dual engines of cultural learning. *Trends in Cognitive Sciences, 19*(11), 688–699.
Legare, C. H., & Nielsen, M. (2020). Ritual explained: Interdisciplinary answers to Tinbergen's four questions. *Philosophical Transactions of the Royal Society B: Biological Sciences, 375*, 20190419.
Legare, C. H., & Watson-Jones, R. E. (2015). The evolution and ontogeny of ritual. In D. M. Buss (Ed.), The handbook of evolutionary psychology (2nd ed., Vol. 32, pp. 1–19). Hoboken, NJ: John Wiley.
Legare, C. H., Wen, N. J., Herrmann, P. A., & Whitehouse, H. (2015). Imitative flexibility and the development of cultural learning. *Cognition, Brain, Behavior, 142*, 351–361.

Lyons, D. E., Damrosch, D. H., Lin, J. K., Macris, D. M., & Keil, F. C. (2011). The scope and limits of overimitation in the transmission of artefact culture. *Philosophical Transactions of the Royal Society B: Biological Sciences, 366*(1567), 1158–1167.
Lyons, D. E., Young, A. G., & Keil, F. C. (2007). The hidden structure of overimitation. *Proceedings of the National Academy of Sciences of the United States of America, 104*(50), 19751–19756.
Magnusson, A., Skaug, H. J., Nielsen, A., Berg, C. W., Kristensen, K., Maechler, M., van Bentham, K. J., Bolker, B. M., & Brooks, M. E. (2017). glmmTMB: Generalized Linear Mixed Models using Template Model Builder. *R package version* (1), 3 https://github.com/glmmTMB.
March, J., Rigby Dames, B., Caldwell, C., Doherty, M., & Rafetseder, E. (2020). The role of context in "over-imitation": Evidence of movement-based goal inference in young children. *Journal of Experimental Child Psychology, 190*, 104713. https://doi.org/10.1016/j.jecp.2019.104713.
Marsh, L. E., Ropar, D., & Hamilton, A. F. de C. (2019). Are you watching me? The role of audience and object novelty in overimitation. *Journal of Experimental Child Psychology, 180*, 123–130.
McGuigan, N., Burdett, E., Burgess, V., Dean, L., Lucas, A., Vale, G., & Whiten, A. (2017). Innovation and social transmission in experimental micro-societies: Exploring the scope of cumulative culture in young children. *Philosophical Transactions of the Royal Society B: Biological Sciences, 372*, 20160425.
McGuigan, N., Makinson, J., & Whiten, A. (2011). From over-imitation to super-copying: Adults imitate causally irrelevant aspects of tool use with higher fidelity than young children. *British Journal of Psychology, 102*, 1–18.
McGuigan, N., & Whiten, A. (2009). Emulation and "overemulation" in the social learning of causally opaque versus causally transparent tool use by 23- and 30-month-olds. *Journal of Experimental Child Psychology, 104*(4), 367–381.
Neldner, K., Redshaw, J., Murphy, S., Tomaselli, K., Davis, J., Dixson, B., & Nielsen, M. (2019). Creation across culture: Children's tool innovation is influenced by cultural and developmental factors. *Developmental Psychology, 55*(4), 877–889.
Nielsen, M. (2018). The social glue of cumulative culture and ritual behavior. *Child Development Perspectives, 12*(4), 264–268. https://doi.org/10.1111/cdep.2018.12.issue-410.1111/cdep.12297.
Nielsen, M., & Blank, C. (2011). Imitation in young children: When who gets copied is more important than what gets copied. *Developmental Psychology, 47*(4), 1050–1053.
Nielsen, M., Tomaselli, K., & Kapitány, R. (2018). The influence of goal demotion on children's reproduction of ritual behavior. *Evolution and Human Behavior, 39*(3), 343–348.
Nielsen, M., Tomaselli, K., Mushin, I., & Whiten, A. (2014). Exploring tool innovation: A comparison of Western and Bushman children. *Journal of Experimental Child Psychology, 126*, 384–394.
Pellegrini, A. D., Dupuis, D., & Smith, P. K. (2007). Play in evolution and development. *Developmental Review, 27*(2), 261–276.
Plötner, M., Over, H., Carpenter, M., & Tomasello, M. (2015). The effects of collaboration and minimal-group membership on children's prosocial behavior, liking, affiliation, and trust. *Journal of Experimental Child Psychology, 139*, 161–173.
R Core Team (2015). *R: A language and environment for statistical computing*. Vienna, Austria: R Foundation for Statistical Computing.
Rakoczy, H., Hamann, K., Warneken, F., & Tomasello, M. (2010). Bigger knows better: Young children selectively learn rule games from adults rather than from peers. *British Journal of Developmental Psychology, 28*, 785–798.
Rakoczy, H., Warneken, F., & Tomasello, M. (2008). The sources of normativity: Young children's awareness of the normative structure of games. *Developmental Psychology, 44*(3), 875–881.
Rawlings, B., Flynn, E., & Kendal, R. (2017). To copy or to innovate? The role of personality and social networks in children's learning strategies. *Child Development Perspectives, 11*(1), 39–44.
Rawlings, B. S., Flynn, E. G., & Kendal, R. L. (2021). Personality predicts innovation and social learning in children: Implications for cultural evolution. *Developmental Science*,. https://doi.org/10.1111/desc.13153 e13153.
Schleihauf, H., Pauen, S., & Hoehl, S. (2019). Minimal group formation influences on over-imitation. *Cognitive Development, 50*, 222–236.
Speidel, R., Zimmermann, L., Green, L., Brito, N. H., Subiaul, F., & Barr, R. (2021). Optimizing imitation: Examining cognitive factors leading to imitation, overimitation, and goal emulation in preschoolers. *Journal of Experimental Child Psychology, 203*, 105036. https://doi.org/10.1016/j.jecp.2020.105036.
Stengelin, R., Hepach, R., & Haun, D. B. M. (2019). Being observed increases overimitation in three diverse cultures. *Developmental Psychology, 55*(12), 2630–2636.
Stengelin, R., Hepach, R., & Haun, D. B. M. (2020). Cross-cultural variation in how much, but not whether, children overimitate. *Journal of Experimental Child Psychology, 193*, 104796. https://doi.org/10.1016/j.jecp.2019.104796.
Subiaul, F., Krajkowski, E., Price, E. E., & Etz, A. (2015). Imitation by combination: Preschool age children evidence summative imitation in a novel problem-solving task. *Frontiers in Psychology, 6*. https://doi.org/10.3389/fpsyg.2015.01410, 1410.
Subiaul, F., & Stanton, M. A. (2020). Intuitive invention by summative imitation in children and adults. *Cognition, 202*, 104320. https://doi.org/10.1016/j.cognition.2020.104320.
Taniguchi, Y., & Sanefuji, W. (2021). Irrelevant actions, goal demotion and explicit instruction: A study of overimitation. *Infant and Child Development, 30*. https://doi.org/10.1002/icd.2227 e2227.
Tennie, C., Call, J., & Tomasello, M. (2009). Ratcheting up the ratchet: On the evolution of cumulative culture. *Philosophical Transactions of the Royal Society B: Biological Sciences, 364*, 2405–2415.
Tomasello, M., Kruger, A. C., & Ratner, H. H. (1993). Cultural learning. *Behavioral and Brain Sciences, 16*(3), 495–511.
van Leeuwen, E. J. C., Cohen, E., Collier-Baker, E., Rapold, C. J., Schäfer, M., Schütte, S., & Haun, D. B. M. (2018). The development of human social learning across seven societies. *Nature Communications, 9*, 2076.
Wagner, N. J., Waller, R., Flom, M., Ronfard, S., Fenstermacher, S., & Saudino, K. (2020). Less imitation of arbitrary actions is a specific developmental precursor to callous–unemotional traits in early childhood. *Journal of Child Psychology and Psychiatry, 61*(7), 818–825.
Watson-Jones, R. E., Legare, C. H., & Human, H. W. E. A. (2014). Task-specific effects of ostracism on imitative fidelity in early childhood. *Evolution and Human Behavior, 35*(3), 204–210. https://doi.org/10.1016/j.evolhumbehav.2014.01.004.
Watson-Jones, R. E., & Legare, C. H. (2016). The social functions of group rituals. *Current Directions in Psychological Science, 25*(1), 42–46.

Wen, N., Willard, A. K., Caughy, M., & Legare, C. H. (2020). Watch me, watch you: Ritual participation increases in-group displays and out-group monitoring in children. *Philosophical Transactions of the Royal Society B: Biological Sciences, 375*, 20190437.
West, M., & Farr, J. L. (1990). Innovation at work. In M. A. West & J. L. Farr (Eds.), *Innovation and creativity at work: Psychological and organizational strategies* (pp. 3–13). New York: John Wiley.
Wood, L. A., Kendal, R. L., & Flynn, E. G. (2012). Context-dependent model-based biases in cultural transmission: Children's imitation is affected by model age over model knowledge state. *Evolution and Human Behavior, 33*(4), 387–394.
Wood, L. A., Kendal, R. L., & Flynn, E. G. (2013). Copy me or copy you? The effect of prior experience on social learning. *Cognition, Brain, Behavior, 127*(2), 203–213.
Yu, Y., & Kushnir, T. (2019). The ontogeny of cumulative culture: Individual toddlers vary in faithful imitation and goal emulation. *Developmental Science, 23* e12862.