Understanding overimitation in social interaction:

From joint actions to teaching

Nejra Rizvanović

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Primary supervisor: Natalie Sebanz

Secondary supervisor: Ildikó Király

Advisor/Mentor: Shaheed Azaad

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Declaration of Authorship

I hereby declare that this submission is my own work and, to the best of my knowledge, contains no materials previously published or written by another person, or which have been accepted for the award of any other degree or diploma at Central European University or any other educational institution, except where due acknowledgment is made in the form of bibliographical reference.

The present thesis includes work that has appeared or will appear in the following articles:

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Nejra Rizvanović

Abstract

Humans learn not only by observing individuals, but also by watching people collaborate toward shared goals. While research in social learning and action understanding has in large part focused on how individuals imitate individual actions and goals, comparatively little is known about how observing *joint actions*—social interactions involving coordination and shared goals—influences imitation. This thesis explored whether the well-established tendency to overimitate individual actions also applies to joint actions, and how this phenomenon manifests across different domains—from observing others to actively participating in joint activities.

Across three empirical studies, we explored these questions in both adults and children. Study 1 (Chapter 2) investigated whether adults expect higher imitative fidelity from others when actions are performed jointly rather than individually, even when some elements of those actions are causally irrelevant. Results showed that joint actions are indeed expected to be copied more faithfully. Study 2 (Chapter 3) tested 3-6-year-old preschool children's imitation of joint versus individual actions and found that overimitation occurs in both contexts, though not significantly more in joint compared to individual ones. Study 3 (Chapter 4) explored the impact of teaching anticipation on imitation in 4- to 6-year-olds. Results indicate that girls, but not boys, imitate more faithfully when they expect to teach others. Additionally, access to goal-related information—whether for teaching or individual learning—increased imitation fidelity across participants.

Together, these findings deepen our understanding of how joint action contexts shape imitative behavior. They offer a more nuanced understanding of imitative learning in both adults and children, highlighting their flexibility in learning from diverse social contexts and their active involvement in shaping cultural knowledge.

To my family,

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Chapter 1. General Introduction

1.1 Social learning and overimitation

The question of how we learn from others has long intrigued psychologists, with foundational work dating back to the early 19th and 20th centuries (e.g., Baldwin, 1902; Bandura, 1977; Rogers & Williams, 2006; Vygotsky, 1926l; Witmer, 1909). In more recent times, this question has gained traction across disciplines such as anthropology, philosophy, cognitive science, and robotics (e.g., Breazeal et al., 2005; Boyd et al., 2011; Flynn, 2008; Garfield et al., 2016; Hewlett et al., 2011; Lew-Levy et al., 2020; Lyons et al., 2007; Nielsen & Blank, 2011). This cross-disciplinary engagement has deepened our understanding of the cognitive and social processes involved in learning from others. It has also helped clarify the difference between basic learning mechanisms—such as local or stimulus enhancement, frequently observed in non-human animals—and more advanced forms of social learning, such as imitation and emulation, which are more characteristic of human behavior (Call et al., 2005; Carpenter et al., 2005; Horner et al., 2006; Nielsen, 2006).

Humans' strong capacity for cultural learning is often attributed, at least in part, to an early-developing tendency for high-fidelity imitation of others' actions (Lyons et al., 2007; see Hoehl et al., 2019, for a review). Unlike emulation, which focuses on replicating the observable end-goal, imitation involves closely copying not just the goal, but also the specific methods, techniques, or solutions used by the model (Lyons et al., 2007). This inclination to imitate others precisely has been observed in both children and adults, sometimes extending to the imitation of seemingly irrelevant or causally unnecessary actions—a phenomenon named 'overimitation' (Lyons et al., 2007; Whiten, 2016).

While the reasons behind overimitation remain a topic of ongoing debate, imitative behavior continues to serve as an important index of learning—closely replicating a model's actions is generally meant to signal that a behavior or skill has been acquired by the novice learner. Moreover, copying behavior offers valuable insight into how learners parse and interpret the actions they observe, as well as how they use contextual and goal-related information to guide this process (Kiraly, 2009).

1.2 Imitative flexibility and the case of joint actions

The phenomenon of overimitation shows that children often perceive redundant actions (e.g., causally irrelevant actions) as integral to the overarching goal (e.g., Hoehl et al., 2019; Kenward et al., 2012; Keupp et al., 2013). However, despite this tendency, numerous studies have demonstrated that both children and adults are not always indiscriminate imitators; in certain contexts, they may be more selective (Buttelman et al., 2013; Gergely et al., 2002; Nielsen & Blank, 2011; Over & Carpenter, 2012). Therefore, identifying the factors that influence overimitation and shape how learners interpret the relevance of observed actions is crucial for understanding how children acquire cultural skills and knowledge from others.

Importantly, studies show that children can form different representations of the observed actions depending on the context in which the actions were produced, supporting the view that imitation is an interpretive process (Keupp et al., 2013, Keupp et al., 2015; Over & Carpenter, 2009; Rakoczy & Schmidt, 2013; Watson-Jones et al., 2014). Actions that have been marked as unintentional or accidental are routinely omitted by young children (Carpenter et al., 1998; Gardiner et al., 2011; Lyons et al., 2011). Similarly, causally irrelevant actions that are not performed on the target object (i.e., non-contact actions) are more likely to be omitted than those performed on the target object, presumably because the causal link in the former case is harder for naïve learners to infer (Hoehl et al., 2019). Additionally, children tend to imitate more in conventional contexts than in instrumental ones (Clegg & Legare, 2016; Rakoczy & Schmidt, 2013; Watson-Jones et al., 2014; Hermann et al., 2013; Kenward et al., 2011;

Kenward, 2012). For example, when normative language is used to emphasize that an inefficient demonstration serves a social function and represents norms or conventions, children are more likely to copy causally irrelevant actions compared to when those actions are framed in non-normative, instrumental terms (Kenward, 2012; Watson-Jones et al., 2014). This flexibility in learning forms the foundation for acquiring both the essential instrumental as well as social skills which are crucial to becoming a successful member of one's cultural group (Legare et al., 2015).

However, young learners do not learn solely from observing and enacting individual actions. In fact, infants routinely observe others working together and begin to engage in collaborative, joint activities themselves even before their first birthday (Henderson et al., 2013). As infants and toddlers, we participate in simple coordinated activities with our caregivers, such as playing peek-a-boo or rolling a ball back and forth (Rheingold et al., 1976; Ross & Lollis, 1987). As adults, the joint actions we engage in become more complex, requiring greater spatial and temporal precision, along with the ability to monitor, predict, and respond appropriately to others' behavior (Sebanz et al., 2006; Sebanz & Knoblich, 2009). Activities like conversing, tango dancing, playing a duet, cooking together, or raising children are examples of these more complex joint interactions. Importantly, such interactions offer valuable learning opportunities in early childhood, allowing individuals to learn coordinated actions by observing others collaborate and, eventually, by directly engaging in the joint activity themselves.

Although research on children's imitative flexibility demonstrates that imitative learning is shaped by a variety of causal and social factors, there is limited understanding of how social interactions in joint contexts—where individuals coordinate towards shared goals affect learning (McEllin et al., 2018). Indeed, while the cognitive and behavioral mechanisms that allow agents to successfully coordinate with one another have been extensively studied in the field of joint action (Sebanz et al., 2006; Sebanz & Knoblich, 2021), the role that these mechanisms play in cultural learning and social transmission episodes has largely been overlooked (McEllin et al., 2018; but see Charbonneau et al., 2024). Similarly, most studies in the field of social learning and cultural evolution have focused on how learners imitate individual goals and actions, with insufficient focus afforded to the question of how aspects that are unique to joint contexts, such as joint coordination and shared goals, guide the learning process (Charbonneau et al., 2024; McEllin et al., 2018). I address this open question in Chapters 2 and 3.

Exploring the link between joint actions and imitative learning is an important step as it can offer a deeper understanding of children's selectivity and motivations in imitation. Moreover, extending the analysis to include not just individual goals and actions but also joint actions allows us to determine whether the processes involved in learning through observing and imitating joint actions differ from those involved in learning through observing and imitating individual actions. More broadly, this thesis aims to integrate insights and methodological tools from the fields of joint action and social learning, aligning with long-standing perspectives that view cognition as a collaborative process rather than the outcome of individual activity (Rogoff, 1998).

Although direct investigations into the link between joint actions and imitative learning in childhood are limited (but see Fawcett & Liszkowski, 2012; Milward & Sebanz, 2018), related research has provided valuable insights into the processes involved in third-party observation of joint actions during infancy (e.g., Begus et al., 2020; Fawcett & Gredeback, 2013; Henderson & Woodward, 2011; Vizmathy et al., 2024) as well as those involved in joint action participation (e.g., Brownell, 2011; Carpenter & Liebal, 2011; Gräfenhain et al., 2009; Moll & Meltzoff, 2011). These studies provide a necessary foundation for addressing an important open question: namely, how does observing and participating in *joint actions* affect imitative learning?

This open question was addressed via three related studies in the present thesis: third-party judgments of others' imitation of joint actions (Chapter 2), observation and imitation of joint actions (Chapter 3), and imitation of individual actions in the context of teaching (Chapter 4). Specifically, the empirical studies presented in this thesis aimed to answer the following questions:

1) Does observing joint action coordination lead to expectations of high-fidelity copying in adults? (Chapter 2)
2) Does observing joint coordinated actions lead to high-fidelity copying in preschool children? (Chapter 3)
3) Does anticipating teaching lead to high-fidelity copying in preschool children? (Chapter 4)

In the remainder of this introductory chapter, I provide a brief overview of the relevant literature and empirical findings related to the main questions raised above and introduce the key questions and hypotheses that were tested.

1.3 Third-party observation of joint actions

Even before participating in collaborative endeavors, infants seem to understand when others are working together (Begus et al., 2020; Henderson & Woodward, 2011; Henderson et al., 2013), and use this information to guide future learning (Fawcett & Liszkowski, 2012).

Reseach on action understanding suggests that the ability to reason about social goals and actions emerges early in ontogeny, and rests on more fundamental capacities to represent certain social configurations as holistic units belonging together (Papeo & Abassi, 2019). Indeed, even young infants are adept at distinguishing individual from social/dyadic actions, using perceptually minimal cues such as spatial proximity and body orientation in the process. Compared to nonfacing dyads, 22-month-olds infants in this study were faster to recognize dyads as a social unit that were facing one another, and who appeared to engage in reciprocal action (Papeo & Abassi, 2019). The authors concluded that the observed visual sensitivity to stimuli with high social value, such as facing dyads, may reflect an adaptation geared toward rapid and reliable recognition of social interaction, which is vital for learning about and from joint acts. Moreover, in the first year of life, infants recognize adults' violations of expected interaction sequences in face-to-face dyadic social interaction (Adamson & Frick 2003), suggesting that they expect facing dyads to interact socially.

Furthermore, research in developmental psychology shows that humans are able to encode social goals and represent complex action sequences involving multiple steps, from very early on (Henderson & Woodward, 2011; Krogh-Jespersen et al., 2020; Woodward & Sommerville, 2000). For instance, Henderson & Woodward (2011) found that 14-month-old infants could successfully identify when two individuals were working together to attain a common goal but only when their actions were complementary—that is, causally related, and crucial for the attainment of the joint goal. Similarly, Fawcett & Gredebäck (2013) found that, in an ambiguous context where the demonstrated actions could be construed as both individual and collaborative, infants used social context to infer a joint goal. Specifically, infants anticipated one agent to place her block in the joint goal location when they observed this agent interacting with another prior to the demonstration.

Besides being adept at recognizing when others are working together, young toddlers also use this information to guide their future behavior (and inform learning). In a study by Fawcett & Liszkowski (2012) on early understanding of collaborative action, the authors examined whether toddlers' understanding of joint activities is guided by their representations of co-actors' individual goals on acting on the object or by an understanding of the common goal-structure underlying the joint activity. They tested toddlers' object-directed imitation across three observation conditions: joint action, individual action (2 models performing individual, parallel actions), and solitary action. In the joint action condition, the two models took turns performing an equal number of actions after which they also acted simultaneously on the target object while making eye contact and addressing each other by saying "Ok, now together!". In contrast, in the individual action condition, the two models took turns performing all actions on their own and never looked at each other during the performance but only at the object and the infant. Finally, in the solitary action condition, one model performed all the actions alone. Their findings supported the hypothesis that, compared to individual and solitary action, after observing joint action, participants were significantly more likely to both initiate joint action by inviting an adult partner to engage, and to replicate the joint activity as a whole. These findings suggest that observers are sensitive to social context when interpreting others' goals and use this information to reproduce others' joint activity through observation. Furthermore, it suggests that observing and engaging in joint actions may be important for the stabilization of cultural traditions (Fawcett & Liszkowski, 2012).

Although work with adults in this domain is scarce, preliminary work in developmental psychology suggests that from a very early age, observing learners also use information about action efficiency in a flexible way to support their understanding of collaboration (Begus et al., 2020; Vizmathy et al., 2024). Whereas observers expect individual agents to act according to the principle of rationality and be as efficient as possible when pursuing goals (e.g., Csibra et al., 2003; Gergely et al., 2002, Liu et al., 2019; Scott & Baillargeon, 2013; Skerry et al., 2013), these expectations of rationality are suspended in a joint context where two agents are coordinating to reach a shared goal (e.g., Begus et al., 2020). One possibility is that the need to coordinate with another person in a joint context may provide the basis for re-evaluating expectations of individual action efficiency normally applied in individual contexts. Taken together, this evidence offers insight into how the principle of rationality—guiding the representation of individual goals and behaviors—is flexibly re-assessed and applied to dyadic interactions (see also Mascaro & Csibra, 2022).

Overall, these findings suggest that humans use a myriad of perceptual and contextual cues that help them to go beyond the analysis of individual goals and actions, and to learn about other forms of social interaction, such as joint actions (Hamann et al., 2012; Henderson & Woodward, 2011; Warneken et al., 2006; Warneken & Tomasello, 2007).

1.4 Teaching in the context of overimitation

Transmission of information is essential to social learning, and a direct consequence of that—namely, the ability to preserve and accumulate valuable insights over time—plays a crucial role in our species' success and cultural complexity (Burdett et al., 2018; Kline, 2015). In addition to observation and imitation, active teaching—where experts transmit information and practical skills to less knowledgeable individuals (Ziv, 2005; Strauss et al., 2015)—is considered one of the key social learning strategies that has contributed to our species' unparalleled cultural advances (Dean et al., 2012). As a rapid, non-selective strategy, teaching serves as an important route to learning complex and opaque knowledge—such as rituals and cultural conventions—that are central to human social life but difficult for novice learners to acquire independently through trial-and-error (Csibra & Gergely, 2009). As such, it plays a key role in understanding how cultures change and evolve over time.

Compared to other, non-pedagogical forms of social learning such as incidental observation or learning by testimonial reports, novice learners show an increased receptivity to information presented pedagogically and are more likely to imitate it (Bonawitz et al., 2011; Butler & Tomasello, 2016; Csibra & Gergely, 2009; Csibra & Gergely, 2011; Gweon & Schulz, 2019; Moll, 2018; Qiu & Moll, 2022). Teaching contexts, often marked by cues like eye contact, direct address, contingent responses, pointing, or exaggerated movements, enhance learning by guiding the learner's attention to key aspects of the task (Csibra & Gergely, 2009; Csibra & Gergely, 2011). Research shows that when information is presented in a communicative context, children come to expect it to represent shared, generic knowledge, leading them to preferentially imitate it (Gergely et al., 2007). For example, when a goal is demonstrated ostensively, such as through gestures or direct address, infants (Brugger et al., 2007; Nielsen, 2006) and toddlers (Carpenter et al., 2005; Southgate et al., 2009) are more likely to copy the actions, even if the actions are cognitively opaque (i.e., when the link between the actions and their ultimate purpose is unclear) (Gergely et al., 2002; Király et al., 2013) or inefficient (i.e., when there is a more efficient action alternative available; Király et al., 2013).

However, most studies that investigate the role of active teaching focus on how child learners effectively exploit *others'* pedagogical communication by relying on behavioral cues produced by them (Bonawitz et al., 2011; Csibra & Gergely, 2009; Csibra & Gergely, 2011; Gergely et al., 2007). While highly informative, experimental foci such as these fail to capture children's understanding of teaching and their active role in transmitting information as children are cast in the passive role of recipients of information. Exploring how children understand the teaching process and how this shapes their transmission of information can provide deeper insights into the development of this ability and emphasize children's active role in shaping and curating cultural knowledge (Qiu & Moll, 2022). I address this open question in Chapter 4.

1.5 Key hypotheses and overview of studies

In summary, the primary aim of this thesis was to explore how the joint context influences imitative behavior, and the expectations associated with it. To that end, the study reported in Chapter 2 examined how adults evaluate others' imitation of individual and joint actions that include causally irrelevant elements. The study described in Chapter 3 investigated how preschool-aged children (3-6 years old) imitate both individual and joint actions with causally irrelevant components, and how factors such as shared goals and action coordination influence imitation. Finally, Chapter 4 explored how 4- to 6-year-olds imitate an adult's demonstration when they anticipate the need to teach or pass on the behavior to others.

Overall, we hypothesized that observers would have different expectations for causally irrelevant actions demonstrated by a single individual versus actions demonstrated by two people jointly, and that these expectations would shape how they themselves imitate such actions. Specifically, we predicted that observing causally irrelevant actions in a joint context would create stronger expectations that such actions are normative, as they are socially stipulated, coordinated, and can be said to represent shared/common knowledge (e.g., aimed at a joint goal). As a result, causally irrelevant actions performed in a joint context would be encoded as part of the overarching goal to act together, resulting in greater expectation that they should be imitated faithfully by others (Chapter 2). This may be due to suspending individual efficiency expectations when there is a need to coordinate with another person (e.g., Begus et al., 2020; Vizmathy et al., 2024) or because of a stronger bias for interpreting causally irrelevant actions as socially relevant in a joint context—i.e., relevant for the social goal of acting together—rather than instrumentally relevant—i.e., relevant with respect to the instrumental outcome of the task (Clegg & Legare, 2016; Kenward et al., 2011; Kenward, 2012; Keupp et al., 2013; Legare et al., 2015; Moraru et al., 2016).

Moreover, causally irrelevant actions would also be *imitated/enacted* more faithfully when performed jointly versus alone (Chapter 3). This prediction is supported by prior research, which shows that coordinated actions performed by multiple individuals increase imitative fidelity in 4- to 6-year-old children (Herrmann et al., 2013), and that observers do not expect individuals to act efficiently when their actions are geared toward a joint goal (Begus et al., 2020; Vizmathy et al., 2024). However, we anticipated that a joint context—unlike a parallel but individual context studied by Herrmann et al. (2013)—would further increase imitative fidelity due to the added requirement to coordinate with a partner during imitation.

Finally, in Chapter 4 (Study 3) I investigated whether anticipating teaching would lead children to interpret an adult's demonstration in normative terms, resulting in faithful imitation, compared to when learning the behavior for themselves. The rationale behind this was that if children are informed they will soon need to teach the behavior to someone else, emphasizing this role should prompt them to interpret the demonstrated actions in conventional terms—viewing them as conveying culturally shared and socially relevant knowledge. As a result, they should imitate the behavior with greater fidelity than when they observe the demonstration without any intention to teach.

In the General Discussion section, I interpret our findings in the context of existing theories of overimitation, including normative and affiliative frameworks. Additionally, I discuss limitations of the current thesis and suggest potential directions for future research.

Chapter 2. Does observing joint action generate expectations of overimitation in adults?

This chapter is based on Rizvanović, N., Azaad, S., & Sebanz, N. (in preparation). Observing Joint Actions Elicits Expectations of Faithful Imitation in Adults.

2.1 Introduction

Collaborative activities in which two or more individuals coordinate their actions around a shared goal play a vital role in everyday human social life (Tomasello et al., 1993; Tomasello et al., 1999). As infants, young children, and even adults, we acquire various skills and behaviors not just by watching individuals act independently, but also by seeing others collaborate towards common goals (Rogoff, 1990; Tomasello, 2009). Observing and imitating these interactions provides a crucial pathway to understanding and taking part in the shared practices of one's culture, such as rituals and social conventions (Herrmann et al., 2013; Legare & Nielsen, 2015). Moreover, the tendency to faithfully replicate the shared practices of one's culture ensures that even behaviors that are characterized by opaque cause-and-effect relationships are passed down and preserved over time (Csibra & Gergely, 2006; Lyons et al., 2011; Nielsen & Tomaselli, 2010).

Despite the growing body of evidence documenting the importance of joint activities in sociocognitive development (Radziszewska & Rogoff, 1988; Sommerville & Hammond, 2007), and their role in cultural transmission (Rogoff, 1990; Tomasello et al., 1999), little is known about how observers learn from joint activities via imitation and how the individual features present in such activities—such as action coordination and joint goals—guide the learning process. Likewise, it remains unclear how third-party observers interpret others' joint activities and what expectations they hold about how these should be imitated. Gaining insight into this issue is essential for understanding which aspects of shared practices drive faithful transmission of cultural information.

Given the central role of interpersonal coordination in social behaviors such as rituals and cultural conventions (Legare & Watson-Jones, 2015; Watson-Jones & Legare, 2016; Wen et al., 2016; Whitehouse & Lanman, 2014), and the established links between these behaviors and imitative learning (e.g., Herrmann et al., 2013; Legare et al., 2015; Watson-Jones et al., 2014), further investigation into these questions is an important avenue for future research.

While research examining the link between joint action observation and imitative learning has been limited (with notable exceptions like Fawcett & Liszkowski, 2012; Milward & Sebanz, 2018), both fields have yielded significant insights independently. Whereas the literature on joint action has shed light on the sociocognitive mechanisms involved in successful social interaction (Sebanz et al., 2003; Sebanz et al., 2006; Sebanz & Knoblich, 2021; Vesper et al., 2010), the literature on imitative learning has enhanced our understanding of the factors influencing learners' motivation to copy another's actions faithfully (Hoehl et al., 2019; Horner & Whiten, 2005; Kenward et al., 2011; Lyons et al., 2007; Nielsen & Blank, 2011; Over & Carpenter, 2012). Nevertheless, a lack of synthesis between the two fields has left important open questions: for instance, what role do the coordination mechanisms that are involved in social interaction play in cultural learning and social transmission? (for discussions on the topic see Charbonneau et al., 2024; McEllin et al., 2018). Similarly, how do we reason about and what do we learn by observing others' joint activities, and does this differ from the way we reason about and learn from others' individual actions?

Here, we attempted to answer these open questions by probing third-party observers' expectations regarding transmission fidelity of shared practices by novice learners. Specifically, we asked how the presence of joint goals and joint coordination guides expectations of imitative fidelity in adults, and whether, compared to individual activities, observers expect joint coordinated actions to be passed on and replicated more faithfully by novice learners.

In the following, I summarize key findings on joint action observation and imitative learning of coordinated activities in child and adult populations, highlighting existing limitations and outstanding questions that the current study aimed to address.

2.2 Observing and imitating joint actions

In the field of social learning and cultural evolution, most studies investigating how we learn from others have focused on single-model demonstrations (with notable exceptions like Fawcett & Liszkowski, 2012; Milward & Sebanz, 2018) and on understanding how reasoning about individual goals affects learning and transmission of new behaviors and skills (McEllin et al., 2018). These have found that learners are able to make different predictions about the observed behavior based on what goal is emphasized by the learning context—for instance, imitating more when learning about cultural conventions than when learning about instrumental, non-social skills (Clegg & Legare, 2016; Kenward, 2012; Keupp et al., 2015; Watson-Jones et al., 2014).

Moreover, research in this field shows that, among other factors (see Hoehl et al., 2019, for a review), learners imitate models' actions selectively based on features such as their sex (Dunham et al., 2011; Schleihauf et al., 2019) and group membership (Kinzler et al., 2011). Moreover, they readily adapt their imitative strategy depending on the presence of the model (Nielsen & Blank, 2011). For instance, they choose to imitate an inefficient solution when the model that demonstrated that solution is present but readily omit unnecessary actions in presence of an efficient model (Nielsen & Blank, 2011). It has been argued, therefore, that beyond acquiring practical skills, imitation fulfills key social functions, such as fostering affiliation with the model (Over & Carpenter, 2012) by conveying mutual understanding and shared intent (Uzgiris, 1981)—aspects that are essential for participating in joint activities and for integrating successfully into one's cultural group. Importantly, the capacity to interpret others' actions based on their goals (Clegg & Legare, 2016; Csibra et al., 2003; Gergely et al., 2002; Kenward, 2012; Keupp et al., 2015; Kiraly et al., 2013; Loucks et al., 2017; Watson-Jones et al., 2014) which enables flexible imitation, may also serve as the basis for understanding other types of behavior, such as joint actions.

Research extending beyond single model demonstrations has largely focused on scenarios where two individuals perform synchronous but parallel actions and without a salient end-goal (e.g., Herrmann et al., 2013), thereby limiting the applicability and interpretability of the findings to other forms of joint actions distinguished by tight coordination, complementary roles and clear end-goals that are achieved jointly (Bratman, 1992; Butterfill, 2011).

Nevertheless, research concerned with the effect of multiple demonstrators on imitative fidelity has yielded important insights into which features present in such scenarios play a role in the inferences observers make about what they see, and how these inferences guide their expectations about which aspects of the demonstrated action are important to copy.

Specifically, the study by Herrmann et al. (2013) has shown that observing two models performing actions synchronously increases imitative fidelity in child learners and does so to a greater extent than observing asynchronous actions demonstrated twice by a single individual or once by two models in succession. Still, given that actions performed by the two models in Herrmann et al. (2013) could, in theory, be conceived of as individual in nature as they were performed on separate objects and in parallel (i.e., they were geared towards individual outcomes), it is possible that reasoning about these may be different than reasoning about joint actions where agents coordinate around shared goals—i.e., where agents' coordination is a result of their intention to achieve an outcome jointly. Whereas observing *parallel/individual synchronous* actions may trigger a ritualistic interpretation of the behavior and so result in an expectation of faithful copying (Herrmann et al., 2013), reasoning about *joint coordinated* actions may evoke a normative interpretation of the observed behavior and lead observers to expect such actions to be more resistant to change and thus reproduced more faithfully. Indeed, according to the work of Rakoczy and colleagues (e.g., Rakoczy et al., 2008; Rakoczy & Schmidt, 2013), the understanding of social activities is shaped by normative rules and conventions in childhood, evidenced by the fact that children routinely protest their partner's mistake during a joint game (Rakozcy et al., 2008; Rakoczy & Schmidt, 2013). In other words, children conceived of the joint activity as representing culturally shared behavior (e.g., "everyone does it this way") that should be reproduced faithfully.

Joint coordination may also serve as a cue to joint commitment and in this way boost expectations of faithful copying in third-party observers. In fact, studies with adults report that merely observing others coordinating can evoke the perception of a common goal (Ip, Chiu, & Wan, 2006) and increase observers' perception of the agents' commitment to the joint action (Michael et al., 2016). In a study by Michael et al. (2016), adult observers judged agents involved in highly coordinated joint actions as less likely to abandon the activity in favor of an attractive outside option, compared to dyads acting in less coordinated ways. Similarly, in a study by Gräfenhain et al. (2009), children recognized the commitment inherent in joint actions. Specifically, they attempted to re-engage a partner who disengaged from the shared activity and more frequently signaled their own need to leave when they had previously made a mutual commitment to act together. Given that joint actions are understood to involve a level of commitment from both partners and to convey socially constituted information, it is possible that observers would expect such actions to be imitated with higher fidelity.

Thus, in our study, we investigated whether observing others' joint actions would elicit expectations of faithful imitation because of a normative interpretation of the joint behavior. Although faithful copying is already common in the context of individual action observation and driven by various social and contextual factors (e.g., Horner & Whiten, 2011; Lyons et al., 2007; Nielsen & Tomaselli, 2010; see Hoehl et al., 2019, for a review), we were interested in exploring the added effects potentially brought about by the joint context (e.g., through joint coordination and shared goals).

Finally, our task manipulation involved agents performing both causally relevant and causally irrelevant actions, either together or individually—a setup commonly used in studies on overimitation to better understand the conditions that motivate learners to imitate behaviors without an obvious instrumental function. While the causally relevant actions in our study directly contributed to achieving the end goal (e.g., opening a puzzle box to retrieve a reward), the causally irrelevant actions did not and could therefore be omitted. This setup allowed us to test the strength of observers' expectations regarding the fidelity of others' imitation, extending beyond merely replicating functional behaviors. Moreover, it allowed us to examine whether opaque or inefficient actions would be interpreted differently in individual and joint contexts.

Supporting evidence from developmental psychology suggests that observers indeed use cues of action efficiency as a framework for understanding others' goals (Csibra et al., 2003; Gergely et al., 2002; Jara-Ettinger et al., 2016) and evaluate efficiency differently depending on context (Begus et al., 2020). For instance, while inefficient actions aimed at achieving individual goals have been found to disrupt the attribution of the agent's goal in observers (e.g., Csibra et al., 2003; Gergely et al., 2002), observing inefficient actions performed in a joint context facilitated the attribution of a joint goal (Begus et al., 2020), suggesting that expectations of efficiency are suspended in contexts where agents are coordinating towards a shared outcome.

Similarly, it has been argued that observing actions characterized by ritualistic features such as causal opacity, redundancy, repetition and goal demotion (Legare & Herrmann, 2013), evokes an interpretation of observed actions based on cultural convention rather than on the acquisition of instrumental skills (Herrmann et al., 2013). Furthermore, ritualistic actions performed by multiple individuals (Herrmann et al., 2013) or in conventional contexts (Kenward et al., 2011; Kenward, 2012; Keupp et al., 2013) tend to increase imitative fidelity, presumably because observers interpret these actions as socially rather than instrumentally significant. Thus, if causally irrelevant (opaque) actions are considered by observers as essential steps within the joint task where the goal is for agents to act together and coordinate effectively, then observers should be more likely to interpret these actions based on cultural convention rather than on the efficient acquisition of instrumental skills.

2.3 The present study

The present study employed a 2 (Social Condition: Solo vs. Joint) x 2 (Coordination: Coordinated, Not coordinated) x 2 (Goal-relevance: Relevant, Irrelevant) design. Participants viewed videos depicting an action sequence featuring a goal-irrelevant step. Of interest was whether Social Condition and Coordination impacted participants' 1) expectations that others would imitate the goal-irrelevant step (i.e., overimitation), and 2) their self-reported likelihood of overimitating.

We hypothesized that if observing jointly performed action sequences creates an expectation that all the action steps in the sequence are socially- (as well as goal-) relevant because they are geared towards shared goals, then the participants should expect novice dyads to reproduce the original demonstration faithfully—that is, they should rate the reproduction likelihood of the irrelevant step higher in the joint compared to the solo observation conditions.

Moreover, we hypothesized that this tendency would be reflected in both participants' judgments of others' imitation and their own self-assessment of how they would imitate in the same context. Following the same rationale, if participants in the solo observation conditions encode the demonstration in an instrumentally efficient way, they should expect less imitative fidelity for others and self, because they expect individual agents to reach their goal (of opening the box) as efficiently as possible (after Gergely & Csibra, 2003). Similarly, if participants assume that coordinating in order to perform the inefficient step is costly and therefore only performed when necessary (e.g., when communicating relevant/shared social knowledge), participants should expect more imitation of the extra step when it is performed in a coordinated way compared to when it is not.

2.4 Method

2.4.1 Participants

The required sample size was determined through an a priori power analysis conducted based on pilot data using G*Power (version 3.1.9.2; Faul, Erdfelder, Buchner, & Lang, 2009). The analysis, based on a mixed within-between subjects design, assumed an expected effect size of $f \geq 0.21$, a significance level of $p < .05$ (two-tailed), and a statistical power of $1-\beta = 0.80$. Results indicated that a sample size of 173 participants was required.

We recruited a total of 174 participants via Prolific.com. We excluded data from three participants who failed our attention check, resulting in a final sample of $N = 171$ (35 females; aged 18-59, $M_{age} = 37.4$ years, $SD_{age} = 9.87$ years) English-speaking adults living in the United Kingdom and the United States. Participants received a small monetary payment for completing the study based on Prolific's suggested payment quota. The experiment was approved by the Psychological Research Ethics Board (PREBO) in Austria.

2.4.2 Materials and procedure

Stimuli

Figure 2.1 Illustration of the study apparatus depicting its integral features, as well as the wooden stick used to perform the causally irrelevant action. The integral features include: a top sliding door, behind which there is an opening (one on each side of the box); and a bottom sliding door behind which is an opening (one on each side of the box).

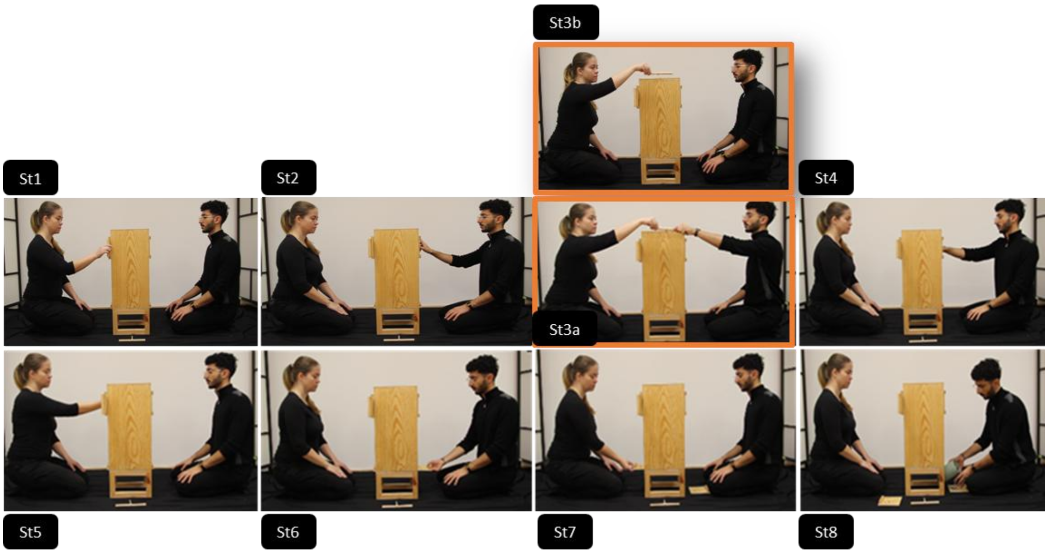

Figure 2.2 Illustration of the joint demonstration condition and actions performed by the models. The models retrieved the hidden object from the puzzle box by taking turns in (a) opening the top sliding doors (St1, St2); (b) grabbing the T-shaped stick and moving it to tap the top of the box either together (St3a) or alone (St3b); (c) reaching into a round opening to remove the hook that kept the object suspended on a loop inside the box (St4, St5), (d) opening

the bottom sliding doors which revealed the object (St6, St7), and (e) retrieving the toy (St8). While acting together, the models performed the causally irrelevant action on the same T-shaped stick (St3a).

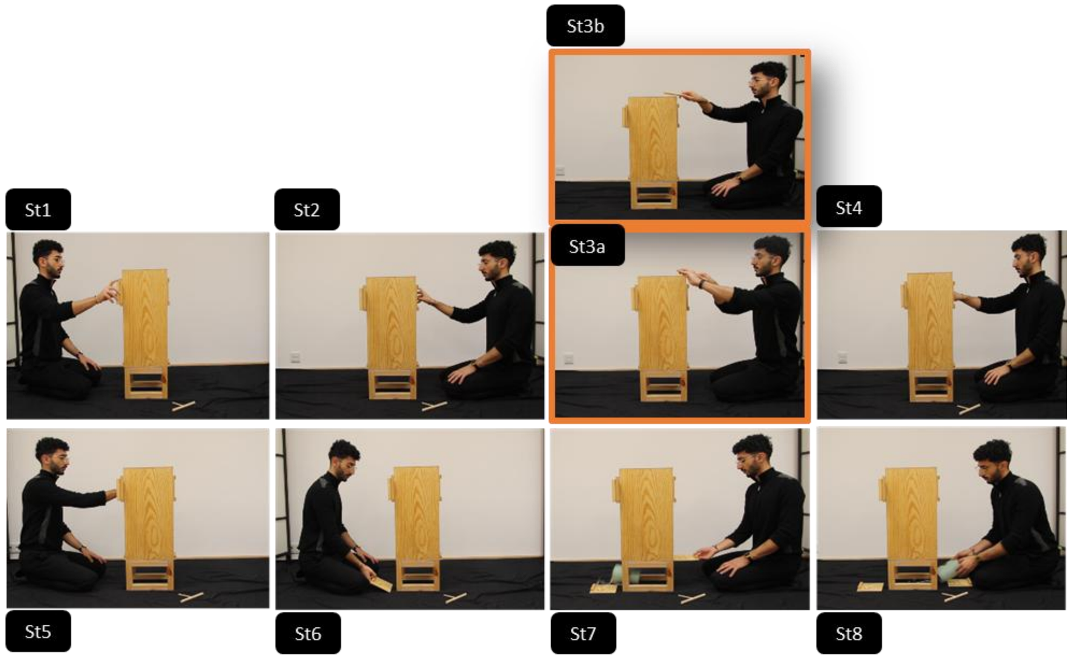

Figure 2.3 Illustration of the individual demonstration condition and actions performed by the models. The model retrieved the hidden object from the puzzle box by (a) opening the top sliding doors (St1, St2); (b) grabbing the T-shaped stick and moving it to tap the top of the box either bimanually (St3a) or unimanually (St3b); (c) reaching into a round opening to remove the hook that kept the object suspended on a loop inside the box (St4, St5), (d) opening the bottom sliding doors which revealed the object (St6, St7), and (e) retrieving the toy (St8).

We recorded videos of actors interacting with a 30x70cm wooden puzzle box (see Figure 2.1 for an illustration of the apparatus). Actors performed a total of 8 action steps to retrieve a hidden object from within the box. The relevant steps included: 1) opening the top sliding doors, 2) detaching the hooks from the loops, and 3) opening the bottom sliding doors. Opening the top sliding doors freed access to the loops on which the hidden object was suspended by a string. Detaching the hooks thus allowed the object to fall to the bottom of the box and, once the bottom sliding doors were removed, to retrieve the object. Critically, step 3 was ostensibly irrelevant to this goal—actors picked up and touched the box with a t-shaped stick (Figure 2.1).

In total, we recorded four videos. In the two *joint* videos, an actor sat on either side of the box and took turns performing the relevant steps. In the two *solo* videos, a single depicted actor moved from one side of the box to the other to perform each relevant step. The irrelevant step differed according to the coordination condition. In the joint-*uncoordinated* video, a single actor performed the irrelevant step alone using one hand. In the joint *coordinated* condition, both actors jointly grasped the t-shaped object and performed the irrelevant step together. The actor in the solo-*uncoordinated* video performed the irrelevant step identically to that in the joint-*uncoordinated* video. In the solo-*coordinated* video, the actor performed the irrelevant action using both hands to grasp the t-shaped object. Videos featured sound which served as feedback for various steps (e.g., the object falling after the rope is unhooked).

We extracted 8 still images from videos depicting each action step for participant judgements.

Procedure

Participants were assigned to one of four experimental conditions: solo uncoordinated (n=42), solo coordinated (n=43), joint uncoordinated (n=42), joint coordinated (n=44). The experimental session began with an *action observation* phase. First, we showed participants images of the box (Figure 2.1). Next, participants read "In the following, you will watch a short video clip of people/a person opening a puzzle box to retrieve a hidden object." Participants watched this video twice.

Next, participants were shown an image depicting a novice agent or a novice dyad sitting by the box facing forward and toward the participant, along with a text that described the following scenario:

> [**SOLO**]: This is Alex. He has seen the same video as you and will now, for the first time, try to open the puzzle box to retrieve the hidden object.

[**JOINT**]: This is Sophie and Alex. They have seen the same video as you and will now, for the first time, try to open the puzzle box to retrieve the hidden object.

Participants were then presented with stills depicting individual action steps performed by the model(s) of the original demonstration (Figure 2.2 and Figure 2.3) and asked to rate the likelihood that the respective steps will be reproduced by the novice agent or dyad, using a 1-5 slider scale (1=highly unlikely; 5=highly likely). Specifically, participants saw the following text on the screen:

[**SOLO**]: Do you think Alex, pictured below, will perform this action step?

[**JOINT**]: Do you think Sophie and Alex, pictured below, will perform this action step?

Finally, participants were asked to indicate the likelihood that they will perform the individual action steps using the same 1-5 slider scale, and prompted with the following text:

[**SOLO**]: Now, imagine that you are about to open the box for the first time to retrieve the hidden object. Will you perform this action step?

[**JOINT**]: Now, imagine that you and your friend are about to open the box for the first time to retrieve the hidden object. Will you and/or your friend perform this action step?

Participants' judgments of step necessity were assessed using the question: *"How necessary do you think it was to perform this action step in order to open the box and retrieve the hidden object?"* This question was designed to determine whether participants recognized step 3 as causally irrelevant among all the others and to examine whether their necessity judgments were influenced by social context and action coordination.

Lastly, we administered an attention check by asking participants "Were the people in the video wearing black or grey?".

The experiment was created using PsychoPy (Version 2022.2.4).

2.5 Results

We discarded data from three participants for failing our attention check. The data were analyzed using RStudio (Version 4.3.0) and JASP (Version 0.16.4.0). Processed data will be available online upon submission of the study.

2.5.1 Necessity judgements

A 2 (Social Condition: Solo vs. Joint) x 2 (Coordination: Coordinated, Not coordinated) x 2 (Goal-relevance: Relevant, Irrelevant) ANOVA was conducted on participants' necessity ratings, with Relevance as a within-subject factor, and Social Condition and Coordination as between-subject factors.

As expected, we found a main effect of Relevance - relevant steps were judged more necessary overall than irrelevant steps, $F(1, 167) = 746.61$, $p < .001$, $\eta^2_p = .82$. Additionally, there was a main effect of Social Condition, with actions performed in the solo condition rated as more necessary overall than those in the joint condition, $F(1, 167) = 6.94$, $p = .009$, $\eta^2_p = .04$.

There was a significant interaction between Relevance and Social Condition, $F(1, 167) = 4.85$, $p = .029$, $\eta^2_p = .028$. Follow-up analysis of simple main effects revealed that the difference between solo and joint conditions was significant only for the irrelevant step, $F(1) = 7.46$, $p = .007$. See Table 2.1 and Figure 2.4.

The three-way interaction between Relevance, Social Condition, and Coordination was marginally significant, $F(1) = 3.72$, $p = .055$, $\eta^2_p = .02$. This reflected that the two-way interaction between Relevance and Social Condition was significant for coordinated $F(1) = 11.48$, $p < .001$, but not for uncoordinated conditions $F(1) = 0.24$, $p = .629$. No other significant interactions or main effects were observed (*ps >.09*).

Table 2.1 Descriptive statistics for step necessity ratings by condition

Goal Relevance	Social Condition	Coordination Condition	N	Mean	SD
Irrelevant	Joint	Coordination	43	1.350	0.675
		No coordination	41	1.523	1.018
	Solo	Coordination	43	2.157	1.428
		No coordination	44	1.639	1.157
Relevant	Joint	Coordination	43	4.147	0.604
		No coordination	41	4.208	0.615
	Solo	Coordination	43	4.187	0.502
		No coordination	44	4.274	0.575

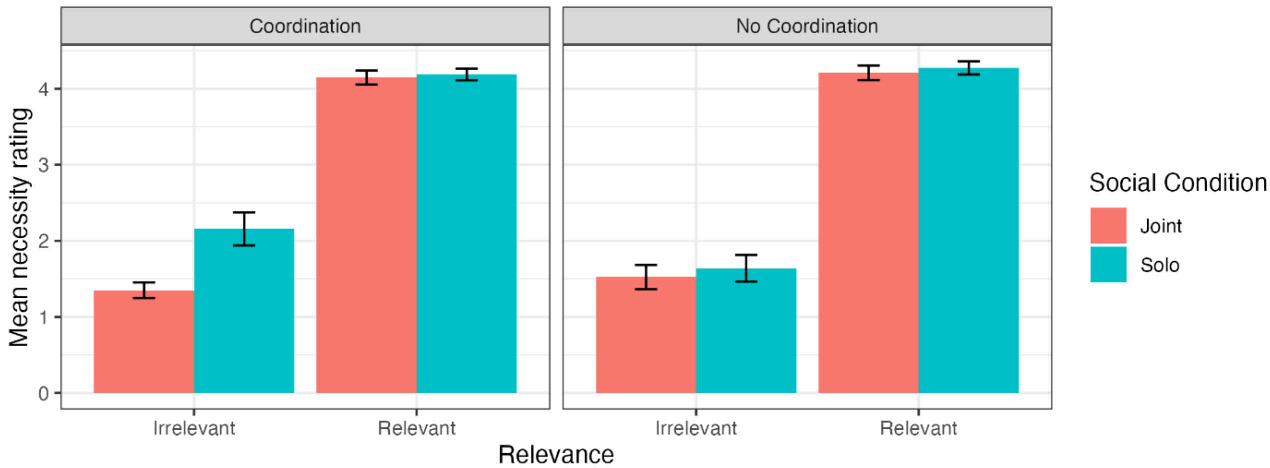

Figure 2.4 Mean step necessity ratings by condition, displayed separately for Coordination (left) and No Coordination (right). Error bars represent 95% CI.

2.5.2 Judgments of expected imitative fidelity for others and self

In this analysis, we investigated whether social context and action coordination influenced participants' expectations regarding others' imitative fidelity (i.e., how closely others would replicate the original demonstration) and their self-reported likelihood of imitating the demonstration faithfully themselves.

We excluded responses from participants who were unable to differentiate between relevant and irrelevant action steps. We did so by focusing exclusively on the subset of participants who rated the irrelevant step (Step 3) 2.5 or lower on the slider scale—and who also rated the relevant steps 3.5 or higher in terms of necessity ($N = 120$).

This decision was motivated by two key considerations. First, most participants correctly identified step 3 as causally irrelevant, as evidenced by the main effect of Relevance ($p < .001$). Second, our primary interest was in examining whether social context and action coordination influence expectations of imitative fidelity when participants can accurately infer the causal relationship between action steps and the end goal. Such an approach offers stronger evidence and insight into how social context, rather than causal confusion, shapes interpretations of the observed behavior.

We entered judgement data into a 2 (Social Condition: Solo vs. Joint) x 2 (Coordination: Coordinated, Not coordinated) x 2 (Goal-relevance: Relevant, Irrelevant) x 2 (Judgement: Self vs. Other) ANOVA with Goal-relevance and Judgement as within-subjects factors. This produced a main effect of Goal-relevance—relevant steps were judged as more likely to be imitated, $F(1, 116) = 218.01$, $p < .001$, $\eta^2_p = 0.65$. See Table 2.2 and Figure 2.5. We found a two-way interaction between Judgement and Social Condition, $F(1, 116) = 6.81$, $p = .010$, $\eta^2_p = 0.055$. Simple main effects revealed an effect of Social Condition for other judgements, $F(1) = 5.60$, $p = .018$, but not for self judgements, $F(1) = 0.02$, $p = .884$. That is, people judged solo steps to be less likely to be reproduced for other judgements, but not self judgements.

Finally, we found a two-way interaction between Goal-relevance and Judgement, $F(1, 116) = 5.83$, $p = .017$, $\eta^2_p = 0.048$. Simple main effects revealed that the effect of relevance was significant for both judgement types ($p < .001$), but larger for self judgements. No other significant interactions or main effects were observed (*ps* >.24).

Table 2.2 Descriptive statistics for Self and Other judgments across conditions

Goal-relevance	Judgment	Social Condition	Coordination Condition	N	Mean	SD
Relevant	Self	Joint	Coordination	33	4.435	0.502
			No coordination	30	4.324	0.812
		Solo	Coordination	23	4.482	0.441
			No coordination	34	4.468	0.540
	Other	Joint	Coordination	33	4.242	0.595
			No coordination	30	4.281	0.560
		Solo	Coordination	23	4.136	0.614
			No coordination	34	4.173	0.558
Irrelevant	Self	Joint	Coordination	33	2.764	1.542
			No coordination	30	2.345	1.297
		Solo	Coordination	23	2.581	1.662
			No coordination	34	2.431	1.611
	Other	Joint	Coordination	33	2.980	1.288
			No coordination	30	2.728	1.282
		Solo	Coordination	23	2.328	1.085
			No coordination	34	2.358	1.258

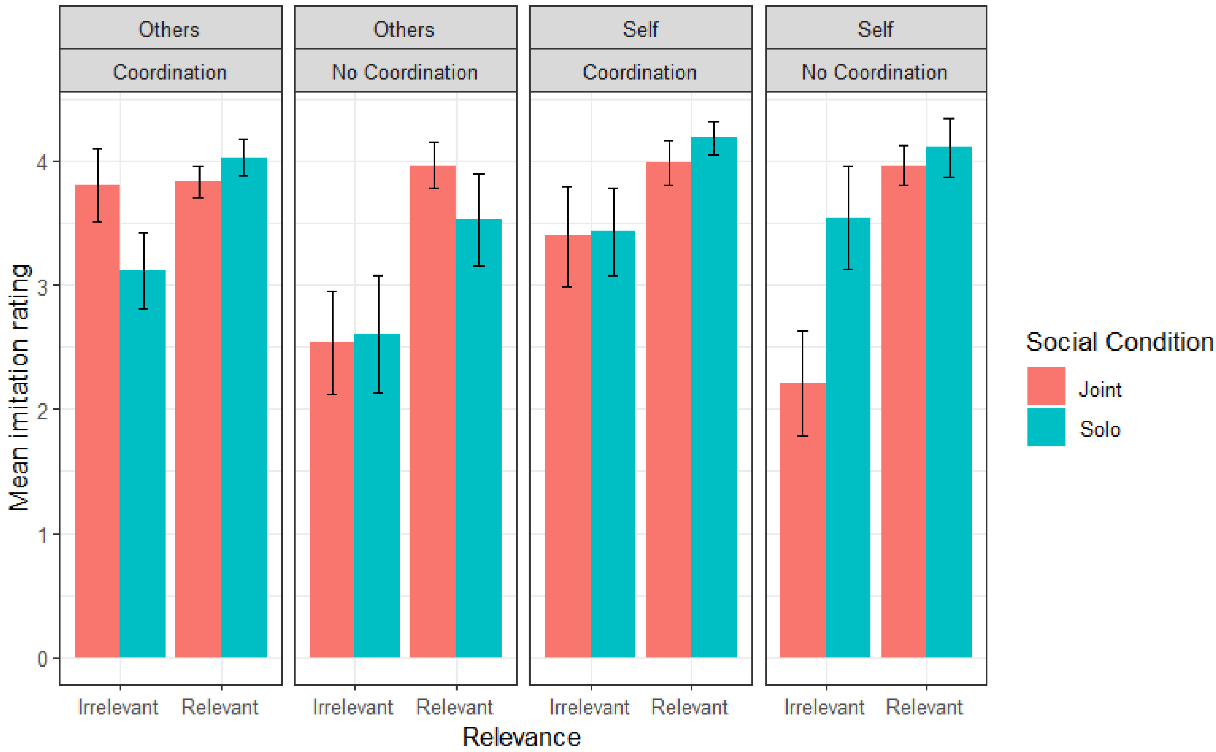

Figure 2.5 Mean imitation ratings by condition, displayed separately for Coordination vs. No Coordination, and for Others vs. Self. Error bars represent 95% CI.

2.6 Discussion

From an early age, humans show a unique drive and ability to work together and coordinate toward shared goals (Melis, 2013; Tomasello, 2009). Most previous studies have focused on exploring the cognitive and behavioral mechanisms that allow agents to successfully coordinate with one another (Sebanz et al., 2006; Sebanz & Knoblich, 2021), with less attention devoted to the question of how these same processes support cultural learning and the spread of knowledge (McEllin et al., 2018; but see Charbonneau et al., 2024). Here, we examined whether social context (individual vs. joint) and the type and degree of coordination (between people and within an individual) involved in the performance of an action influence third-party judgments of imitative fidelity in an object-directed task. Our main question was whether seeing an action performed jointly and with coordination leads to stronger expectations that others should reproduce it more faithfully, compared to observing uncoordinated joint, or individual activity.

In line with our predictions, the results indicate that participants expected others to replicate all the actions more faithfully in the joint action conditions than when observing individual actions. However, contrary to our predictions, action coordination did not seem to modulate this effect. In other words, participants did not expect coordinated joint actions to be imitated more faithfully compared to uncoordinated joint actions. Finally, participants' judgments about how they would imitate the activity did not differ based on social context or action coordination.

Moreover, our results show that participants were able to distinguish between causally relevant and irrelevant actions, as reflected in their significantly lower necessity ratings for irrelevant steps across all main analyses. However, even when participants were able to infer the causal relationship between the actions and the goal of opening the box, they still expected others to reproduce the action sequence more faithfully when it was carried out with a partner—an effect which was not limited to irrelevant steps but applied more broadly to all the actions in the action sequence. These findings suggest that the joint context alone served as a strong enough cue to prompt participants to expect more faithful imitation. Taken together, the findings also support the idea that imitation is a rational, interpretive process influenced by contextual signals (Gergely et al., 2002), rather than a blind, automatic response rooted in causal confusion—where learners wrongly infer that irrelevant actions are necessary and imitate them as a result (Lyons et al., 2007).

We see several possible reasons why participants expected more faithful imitation in the joint context. First, observing joint coordinated actions may have evoked a normative interpretation of the observed behavior in third parties and lead observers to expect such actions to be more resistant to change and thus reproduced more faithfully. This interpretation is supported by the work of Rakoczy and colleagues (e.g., Rakoczy et al., 2008; Rakoczy & Schmidt, 2013), who argue that young children's understanding of social activities is influenced by normative rules and cultural conventions. According to their view, joint activities are perceived as reflecting commonly accepted, culturally shared practices—essentially, ways of doing things that are seen as typical or expected within a group (e.g., "everyone does it this way").

Another possibility is that observing joint actions created a cue to joint commitment and in this way boosted expectations of faithful copying for others. In fact, research with adults shows that merely observing others engage in highly coordinated joint actions can enhance perceptions of the agents' commitment, with observers judging such agents as less likely to abandon the activity for a more attractive alternative (Michael et al., 2016). Similarly, research with children suggests that participation in joint action also creates a sense of joint commitment for the parties involved. For example, in a study by Gräfenhain et al. (2009), children demonstrated an understanding of the commitment involved in joint actions by attempting to re-engage a partner who withdrew from the shared activity and by more often signaling their own need to leave when a mutual commitment had been established. Taken together, these findings suggest that because joint actions involve shared commitment and convey socially constituted information, observers are likely to expect these actions to be imitated with greater fidelity.

Participants may have also held the belief that individual actions should be efficient when geared toward instrumental goals (Csibra, 2003; Gergely et al., 2002; Jara-Ettinger et al., 2016; Liu et al., 2019; Scott & Baillargeon, 2013; Skerry et al., 2013). In contrast, observing a joint action may have led the observers to encode such a demonstration as socially rather than instrumentally relevant (e.g., Kenward et al., 2011). This shift is reflected in the stronger expectation that others should faithfully reproduce the original demonstration when acting with a partner, suggesting that participants interpreted all actions in the joint context as socially relevant, even when they judged some of the actions as unnecessary for achieving the end-goal. Thus, it is likely that the situational constraint of acting jointly and coordinating with a partner served as the basis for re-evaluating the efficiency parameters that apply to and support goal attribution for individual actions, thereby allowing for inefficient behavior to occur within a joint context.

However, when judging the likelihood that they themselves would reproduce the original demonstration, participants did not consider social context or the type and degree of action coordination. Instead, they reported that they were equally likely to imitate in individual and joint conditions, and regardless of coordination. One reason for the observed difference between the solo and joint action conditions for Others, but not for Self, could be that participants interpreted the question about others' joint imitation as asking how an action *should* be performed more generally—implying a more normative judgment—whereas questions about their own imitation may have been interpreted as a question about personal preference.

It's also possible that participants understood the question "How likely are you to imitate step X in this scenario?" in different and subjective ways, making it difficult to draw a clear interpretation of the results. For instance, some participants may have imagined acting with a friend in the joint task while others may have imagined a stranger, potentially biasing their responses in different ways. This ambiguity is further complicated by the fact that in the joint action conditions, the irrelevant step was sometimes performed by only one of the two joint action partners. In such cases, even if a participant indicated they were unlikely to imitate the irrelevant step themselves, it does not necessarily mean they did not expect the step to be carried out by their joint action partner.

Likewise, imagining themselves performing the actions may have led participants to focus on how they would imitate the behavior in private, thereby reducing the need to attribute to it a social or normative interpretation and consequently acting more efficiently. This interpretation is possible given previous research showing that individuals often omit unnecessary steps when reenacting a model's actions in private, even if they had previously included those steps when imitating in front of others (e.g., due to "audience effects"; see Lyons et al., 2007; Marsh et al., 2019; Nielsen & Blank, 2011).

Thus, it is also likely that the online context reduced the normative pressure involved in acting in front of another person or with another person, in that participants' own imitation was assessed in a scenario where they merely had to imagine acting with someone else. Extending the paradigm to test adults' imitative behavior in a live social context may shed light on how, in addition socionormative pressures, the immediate constraint of having to coordinate with another affects the cultural transmission of shared practices and whether the effect is stronger for joint compared to individual actions (see Rizvanović et al., 2025, and Chapter 3, for a similar study with preschool children).

Finally, our results suggest that action coordination did not modulate the observed difference between individual and joint actions when judging others' imitation fidelity. It's important to note, however, that the degree of coordination varied only for a single causally irrelevant action. Throughout the rest of the demonstration, the joint action partners remained coordinated, taking turns to perform the relevant actions on the box. As a result, the entire demonstration may have already been perceived as highly coordinated, regardless of how the irrelevant action was carried out. In other words, it is possible that the coordination associated with the irrelevant action was not rendered sufficiently salient in the current design to effectively assess its influence on transmission fidelity.

Future research on the link between joint action coordination and imitative fidelity should aim to better distinguish between coordination inherent to the joint activity and coordination specific to targeted aspects within that activity. One way to achieve this in the current context would be to include a control condition—such as a parallel action setup (as in e.g., Fawcett & Liszkowski, 2012)—where both partners perform the irrelevant action independently and simultaneously, while still coordinating turn-taking for the relevant actions. This would help clarify whether joint performance of the irrelevant action creates a stronger expectation of faithful imitation compared to simply acting in parallel. Similarly, a control condition in which actors perform all actions in parallel—not just the irrelevant step—could shed light on whether different forms of coordination shape expectations of imitation differently, depending on whether they stem from joint intentionality or merely parallel activity.

An interesting open question is why participants judged the solo irrelevant action as more necessary than the joint irrelevant action, and why they did so despite simultaneously expecting the joint activity overall to be reproduced with greater fidelity. Specifically, when a step was clearly relevant, factors such as social context and action coordination appear to have played little role in judgments of necessity. However, when the step was irrelevant and its purpose opaque, participants seemed to have been more influenced by how the action was performed when evaluating its necessity. One possibility is that, under conditions of uncertainty, participants rely on different cues to assess whether a step is necessary for achieving the instrumental goal, depending on whether they observe individual or joint actions. Future work is needed to replicate and better understand this finding.

Overall, the findings of the study indicate that observers do not expect imitation to occur indiscriminately; rather, they form context-sensitive expectations regarding the fidelity of imitation, influenced by factors such as the social context in which the behavior was originally produced. Specifically, we found that adult observers expect joint actions performed by others to be reproduced more faithfully compared to individual actions, even when they correctly infer that some elements of the joint activity are causally unnecessary. As such, the results offer valuable insight into how joint actions contribute to the cultural transmission of shared practices and provide evidence that a joint context increases expectations of imitative fidelity.

Chapter 3. Effects of joint action observation on children's imitation

This chapter is based on Rizvanović, N., Király, I., & Sebanz, N. (2025). Effects of Joint Action Observation on Children's Imitation. *Behavioral Sciences*, *15*(2), 208.

3.1 Introduction

Young children routinely incorporate actions which are causally irrelevant, inefficient or somehow 'silly' into their imitation (Hoehl et al., 2019; Horner & Whiten, 2005; Lyons et al., 2007). Such high-fidelity copying is an early-emerging form of social learning, appearing between the ages of 18 months and 3 years (Gardiner et al. 2011; Whiten et al., 2009), increasing into childhood (Horner & Whiten 2005; Lyons et al. 2007; McGuigan et al. 2007), and adulthood (McGuigan et al. 2011; Flynn & Smith 2012). Unlike emulation, which prioritizes reproducing the observable, concrete goal without replicating the specific means, imitation entails a full reproduction of the modeled action. This includes both the action's form—i.e., how it was achieved—, and its intended outcome — i.e., what was achieved (Csibra & Gergely, 2006; Whiten et al., 2009). When the modelled action includes causally irrelevant elements (e.g., actions that do not contribute to achieving the end-goal), this behavior is referred to as 'overimitation' (Lyons et al., 2007).

Theorists of cultural evolution have argued that in addition to other social learning mechanisms such as emulation and teaching, the human predilection towards high-fidelity copying may form the bedrock of culture. In fact, as a nonselective copying strategy, it enables rapid acquisition of causally opaque forms of knowledge (i.e., behaviors which lack an obvious instrumental function), such as cultural conventions and rituals, that are readily available during childhood but difficult to acquire through individual practice (Boyd et al., 2011; Lyons et al., 2011; Nielsen & Tomaselli, 2010).

Although overimitation has been studied extensively in contexts where child learners observe and learn novel actions from individual demonstrations, much less is known about how observing and participating in joint actions guides learning (Charbonneau et al., 2024; McEllin et al., 2018). The current research, therefore, aimed to fill this gap by investigating how preschool children interpret unusual, causally irrelevant actions performed in a joint context, and how they imitate them when doing so entails coordination with another person. Specifically, we investigated whether the tendency to overimitate, that has been documented for individual actions (Lyons et al., 2007), extends to joint actions, and whether joint coordination modulates imitative behavior. By exploring these questions, we sought to deepen our understanding of the role of social interaction in early learning and contribute to a growing body of work demonstrating children's imitative flexibility (Legare et al., 2015). From a practical perspective, insights from this work could inform the design of targeted interventions that approach learning as a form of joint, collaborative activity.

Below, I first summarize key findings concerning the processes and cognitive mechanisms that support flexible imitative learning from individual action observation in childhood and outline ways in which these may be applied to learning about and from joint actions. Next, I review research on the development of joint action, and suggest how the key elements that are involved in understanding and participating in joint actions may inform imitation of joint actions.

3.1.1 Processes underlying flexible imitation of actions

Although children have a strong tendency to imitate others faithfully, research reveals they are highly selective imitators who strategically decide when to replicate an outcome (e.g., emulate) and when to replicate the process (e.g., imitate). Indeed, they are able to generate different predictions about observed behaviors based on what they perceive to be the model's goal during the demonstration (Clegg & Legare, 2016; Gergely et al., 2002; Gergely & Jacob, 2012; Király et al., 2013; Over & Carpenter, 2009; Rakoczy & Schmidt, 2013) and adjust their imitative strategies depending on whether they are learning instrumental skills or social and normative conventions (Clegg & Legare, 2016; Rakoczy & Schmidt, 2013).

We argue that it is precisely the flexible nature of imitation, subserved by humans' precocious ability to reason about others' actions in terms of goals (Csibra, 2003), that allows children to understand and learn from various forms of social interaction, such as joint actions—for instance, by enabling them to go beyond reasoning about individual goals, and to learn from and about the complementary nature of coordinated, joint actions (Brownell, 2011; Henderson & Woodward, 2011; Warneken et al., 2006; Warneken & Tomasello, 2007).

Proponents of the *affiliative account* suggest that overimitation occurs because of a deeply engrained social motivation to belong to a social group, expressed in the imitative context through the desire to affiliate with, and act like the model (Over & Carpenter, 2012; Over, 2020). In an experimental demonstration of this by Nielsen and Blank (2011), children's imitative strategy depended on which demonstrator was physically present in the room at the time the child manipulated the puzzle box. In this study, children aged 4-5 years observed two methods of opening a puzzle box—one efficient and the other inefficient. While they were more likely to adopt the inefficient technique if the model demonstrating it was present during imitation, when left alone, they tended to copy the efficient method more (Nielsen & Blank, 2011). Findings from this study suggest that merely invoking a social scenario (e.g., by having the model that demonstrated the action present in the room) leads children to copy that model's course of action despite their knowledge of the efficient strategy. In other words, when the learning context emphasized social goals, and the children felt a strong motivation to affiliate with the model, they often imitated the person, and not the actions.

Crucially, the ability and motivation to faithfully imitate a model's actions are considered fundamental for learning group-specific cultural conventions, such as norms and rituals (Heyes, 2021; Nielsen et al., 2020), that promote group coordination and cooperation (Henrich, 2009; Legare & Nielsen, 2020; Whitehouse, 2021) by signaling group membership (Liberman et al., 2018), in-group preferences (Wen et al., 2016), and fostering group trust (Hobson et al., 2018).

Relatedly, proponents of the *normative account* suggest that overimitation may result from children interpreting the demonstrated actions as social norms (Hoehl at el., 2019; Keupp et al., 2013). According to this view, children's representation of events is organized in a hierarchical goal-like structure, which renders a certain goal more important in the action parsing process depending on contextual cues, resulting in a flexible occurrence of overimitation (Keupp et al., 2013). For instance, when children determine that bringing about the effect is hierarchically the most important goal, they should choose a course of action suitable for reaching that goal without necessarily copying the same means produced by the model. If, however, they consider that copying the same means produced by the model is the most important goal, they should imitate the means in addition to the end-goal.

Recent findings support the view of overimitation as a function of normative action interpretation. For instance, studies show that starting at around 2 years of age, children can form different representations depending on the context in which the action was produced (Keupp et al., 2013, Keupp et al., 2015; Over & Carpenter, 2009; Rakoczy & Schmidt, 2013; Watson-Jones et al., 2014) and tend to imitate causally-irrelevant actions more in conventional compared to instrumental contexts (Clegg & Legare, 2016; Hermann et al. 2013; Kenward et al., 2011; Kenward, 2012; Rakoczy & Schmidt, 2013; Watson-Jones et al., 2014). When normative language was used to highlight that an inefficient demonstration has a social function and represents norms and conventions, 3-6-year-old children were more likely to copy causally unnecessary actions compared to when such actions were marked in non-normative, instrumental terms (Kenward, 2012; Watson-Jones et al., 2014). A possible reason for why children considered that reproducing the entire action sequence is the most important goal despite being able to discern the causal structure of the task is that the presence of the model and the use of normative language led the children to encode the causally irrelevant actions as socially/normatively rather than instrumentally relevant.

Recent research in developmental psychology with 9- to 14-month-old infants suggests that observers also use information about *action efficiency* in a flexible way to support their understanding of collaborative and cooperative behaviors (Begus et al., 2020; Mascaro & Csibra, 2022; Vizmathy et al., 2024). These build on prior work demonstrating infants' capacity for representing goals of both individual (e.g., Gergely & Csibra, 2003; Henrik & Southgate, 2012; Woodward, 1998) and collaborative actions (Fawcett & Liszkowski, 2012; Henderson & Woodward, 2011; Henderson et al., 2013; Krogh-Jespersen et al., 2020).

Indeed, whereas evidence shows that at 12-months infants expect agents to act according to the principle of rationality and be as efficient as possible when pursuing *individual* goals (e.g., Csibra, 2003; Gergely et al., 2002; Jara-Ettinger et al., 2016; Liu et al., 2019; Scott & Baillargeon, 2013; Skerry et al., 2013), these expectations of efficiency are suspended in a joint context where two agents are coordinating to reach a *shared goal* (Begus et al., 2020; Vizmathy et al., 2024). A possible explanation for this finding comes from research on 'sensorimotor' or movement-based communication in joint action research with adults, showing that inefficient behaviors in form of movement modulations (e.g., speeding up, slowing down, or exaggerating one's movement trajectory) often serve to facilitate coordination in a joint context by increasing predictability of partners' actions (Pezzulo et al., 2013; Vesper & Richardson, 2014). Similarly, research has shown that when engaged in joint actions, adults routinely prioritize joint efficiency over individual efficiency by choosing paths that minimize joint rather than individual costs (Török et al., 2019, 2021).

Given the facilitating role of sensorimotor communication in joint actions, and the demonstrated willingness of joint action partners to forgo individual efficiency when coordinating, deviations in efficiency that are often a result of such signaling may be justified in the context when coordinating with another is necessary to reach the intended goal. In fact, to observers, such deviations from efficiency may serve to support understanding of collaborative actions (e.g., Begus et al., 2020; Vizmathy et al., 2024).

It remains an open question however, whether observing jointly performed causally irrelevant, and therefore inefficient, actions would lead to faithful *copying*—perhaps due to suspending individual efficiency expectations when there is a need to coordinate with a partner (e.g., Begus et al., 2020; Vizmathy et al., 2024) or interpreting such actions as socially rather than instrumentally relevant (Clegg & Legare, 2016; Kenward et al., 2011; Kenward, 2012; Keupp et al., 2013; Legare et al., 2015).

Investigating how observers *imitate* jointly performed inefficient actions could provide further insight into the way they reason about action inefficiency in a joint context—where inefficiency is achieved by performing non-functional, causally irrelevant actions. Additionally, it can specify how the immediate need to coordinate with a partner guides imitative learning, and in this way, offer a more nuanced understanding of the way joint activities influence and shape the transmission of cultural information in childhood.

3.1.2 Imitation of coordinated actions

In imitative learning contexts, interpersonal coordination has also been linked to higher fidelity in childhood. For instance, in a study by Herrmann et al. (2013), 3-6-year-old children observing coordinated actions performed by two models in parallel copied such actions more faithfully compared to asynchronous actions demonstrated twice by a single individual or once by two models in succession. The authors concluded that observing multiple individuals performing the same action in parallel prompted children to interpret the observed action in conventional rather than instrumental terms—that is, children interpreted the actions performed by multiple individuals as reflecting conventional knowledge rather than knowledge about how to perform the action in an instrumentally efficient way (Herrmann et al., 2013).

Following this rationale, it can be argued that to the extent that joint actions are considered to represent culturally shared information because they are brought about through shared intentionality (Bratman, 1992), they should be imitated with greater fidelity compared to actions that are brought about individually. In this way, reasoning about joint actions may be akin to reasoning about social norms and conventions (Rakoczy & Schmidt, 2013).

Although the study by Herrmann et al. (2013) sheds light on the role of interpersonal coordination on imitative fidelity, it is not clear whether children in this study conceived of the coordinated behavior they saw as joint, as the two models performed actions on separate objects in parallel. A more recent study by Milward and Sebanz (2018) explored the effects of joint action observation and participation on imitation of closely coordinated actions in 2.5-6-year-old children. Children either observed two actors performing two different parts of a joint action or participated in the joint action themselves. The authors found that the children were more likely to replicate both parts of the joint action following joint action observation, compared to participation. These findings provide first direct evidence about children's imitation of *coordinated* actions and suggest that it may be easier for children at this stage in development to form joint goal representations when they passively observe a joint action compared to when they are actively involved in the task. Similarly, an investigation into the effects of joint action observation on imitation by Fawcett & Liszkowski (2012) showed that

18-month-old are more likely to recruit a partner and replicate the joint activity after having observed joint actions compared to observing parallel or individual actions.

Overall, this early sensitivity suggests an existing set of cognitive mechanisms that allows observers to go beyond the analysis of individual actions and learn from and about the complementary nature of joint actions (Henderson & Woodward, 2011; Warneken et al., 2006; Warneken & Tomasello, 2007). Furthermore, it suggests that joint actions may be important in the stabilization of cultural traditions, by boosting high fidelity copying for individuals that observe (Milward & Sebanz, 2018) and partake (Fawcett & Liszkowski, 2012) in joint activities.

Although the studies above show that children can recognize joint goals by observing others' coordinated behavior (Milward & Sebanz, 2018), and tend to replicate coordinated behaviors jointly (Fawcett & Liszkowski, 2012), it remains an open question whether observing jointly coordinated behavior also creates an expectation that such actions should be imitated faithfully even if they are not functional in bringing about the desired shared goal (i.e., if they include causally irrelevant actions)? Exploring this question could offer deeper insight into the role of joint actions in stabilizing cultural traditions and enhance our understanding of how children interpret and make sense of others' actions in social and collaborative contexts.

3.2 The present study

In the current study, we examined whether the tendency of young children to copy causally irrelevant actions (i.e., to overimitate) following individual demonstrations (e.g., Lyons et al. 2007) extends to joint demonstrations. Furthermore, we investigated whether observing joint behavior, in which two individuals perform causally irrelevant actions while coordinating to achieve a shared instrumental goal, leads to greater imitation of these actions compared to their performance in an individual, non-coordinated context.

We based our design on previous studies on overimitation that utilize puzzle boxes with embedded causally irrelevant actions to examine how children interpret and imitate these actions under different conditions (Hoehl et al., 2019). However, we modified the apparatus to allow joint manipulation (see Section 2.2. for details on the design of the task apparatus).

While prior studies have incorporated certain elements of joint actions into their designs (e.g., Begus et al., 2020; Herrmann et al., 2013; Milward & Sebanz, 2018), to our knowledge, no study to date has directly investigated the link between joint action observation and overimitation by embedding goal-irrelevant elements into the task, nor aimed to disentangle the relative contributions of joint goals and action coordination within an instrumental, goal-directed task.

To that end, we employed a 2x2 between-subjects design, experimentally varying two factors: the type of action children observed (individual vs. joint) and the presence of action coordination involved in the performance of the causally irrelevant action (present/yes vs. absent/no). This resulted in four experimental conditions to which the children were assigned randomly: Individual Coordination, Individual No coordination, Joint Coordination, and Joint No coordination.

We predicted that observing joint coordinated actions would result in more imitation of the causally irrelevant action compared to observing these actions performed in an individual, non-coordinated context. This may be due to suspending individual efficiency expectations when there is a need to coordinate with another person (e.g., Begus et al., 2020; Vizmathy et al., 2024) or because of a stronger bias for interpreting causally irrelevant actions as socially relevant in a joint context—i.e., relevant for the social goal of acting together—rather than instrumentally relevant—i.e., relevant with respect to the instrumental outcome of the task (Clegg & Legare, 2016; Kenward et al., 2011; Kenward, 2012; Keupp et al., 2013; Legare et al., 2015; Moraru et al., 2016).

It is important to note that although a normative bias begins to emerge early on for *individual* if they are marked in conventional (Clegg & Legare, 2016; Kenward et al., 2011; Kenward, 2012; Legare et al., 2015; Rakoczy & Schmidt, 2013; Watson-Jones et al., 2014) terms, observing *joint* actions may elicit a stronger normative bias because normativity is further emphasized via coordinated action. Thus, if participants are more likely to perceive a performance as normative because it is produced in a joint context (e.g., where cues of conventionality are pronounced by shared goals and joint coordination), they should imitate the causally irrelevant action more in a joint compared to the individual context.

3.3 Method

3.3.1 Participants

A total of 101 children aged 3 to 6 years (M_{age} = 4.7 years, SD_{age} = .829, 49 females) that participated in the study were included in the final analysis. This age range was selected because it marks a developmental period when children can form joint goal representations (Warneken et al., 2012) and when their ability to reason about actions in normative terms matures, driven in part by prolonged exposure to social norms and conventions (Rakoczy & Schmidt, 2013). Several local public kindergartens were contacted via email or in person, and parental consent forms were distributed to those who expressed interest in participating. All children whose parents provided prior consent were tested at their respective kindergartens. Participants were typically developing speakers of German or Hungarian. No additional selection criteria were applied beyond the age range and the ability to understand German or Hungarian.

We based our sample size on a previous imitation study that used a comparable number of participants per condition and tested a similar age range (Schleihauf et al., 2019). The sample size in the study by Schleihauf et al. (2019) was determined through an a priori power analysis conducted using G*Power (version 3.1.9.2; Faul, Erdfelder, Buchner, & Lang, 2009). The analysis was informed by prior research on overimitation (Hoehl et al., 2014), with an expected effect size of $d \geq 0.6$, a significance level of $p < .05$ (two-tailed), and a statistical power of $1-\beta = 0.8$.

The study included four experimental between-subject conditions: Individual Coordination (n = 25), Individual No coordination (n = 25), Joint Coordination (n = 26), and Joint No coordination (n = 25). The final sample comprised 7 three-year-olds, 32 four-year-olds, 45 five-year-olds, and 17 six-year-olds. Thirteen additional participants were recruited but excluded from the final sample because they did not complete the testing either due to shyness (n = 7), restlessness (n = 1), or experimenter error (n = 5). Participants were tested in kindergartens in Vienna, Austria (n = 42, females = 22), and Budapest, Hungary (n = 59, females = 27). Upon completing the study, all children received stickers and a participation certificate as recompense, irrespective of their success at the task. The experiment was approved by the Psychological Research Ethics Board (PREBO) in Austria, and the United Ethical Review Committee for Research in Psychology (EPKEB) in Hungary (approval code: 2021/08_01). We collected written consent from children's parents or primary caretakers. In addition, participants provided verbal consent before taking part in the experiment and signed their name on the consent form either alone or with the help of the experimenter.

All sessions were video recorded with the permission of participants' parents/primary caretakers and coded on the relevant measures. The data was analyzed using 0.16.4.0 version of the JASP data analysis and visualization package.

3.3.2 Materials and procedure

A 30x70x30cm opaque (wooden) puzzle box was used across conditions (see Figure 3.1 for an illustration). The apparatus was constructed specifically for this study (and Study 1), drawing on designs commonly used in imitation research that examine children's understanding and imitation of objects (e.g., Hoehl et al., 2014; Horner & Whiten, 2005; Lyons et al., 2007; Schleihauf et al., 2021). The primary distinction was that, while such apparatuses are typically designed for manipulation by a single individual only, ours was modified to enable additional manipulation by two individuals (i.e., joint action) by incorporating mirrored features.

A hidden object with a sticker inside could be retrieved from the puzzle box by performing a sequence of causally relevant actions in which the performance of a single causally irrelevant action was embedded. The causally relevant actions included (a) opening the top sliding doors, (b) detaching the hooks from the loops inside the puzzle box, and (c) opening the bottom sliding doors. Since the box features were mirrored on both of its sides, there were a total of six causally relevant actions (three on each side). Opening the top sliding doors revealed the loops inside the box, from which the hidden object was suspended by a string. Detaching the hooks caused the object to drop to the bottom of the box, which was hollow but secured by the bottom sliding doors. Once these doors were opened and removed completely, the object fell out of the box and could be retrieved. The causally irrelevant action consisted in moving a T-shaped stick (illustrated below) to touch the top front of the box. All causally relevant actions were performed in the same way by the model(s), while we experimentally varied the presence of individual or joint action coordination when performing the causally irrelevant action.

Figure 3.1 Illustration of the apparatus depicting its integral features, as well as the wooden stick used to perform the causally irrelevant action. The integral features include: a top sliding door, behind which there is an opening (one on each side of the box); and a bottom sliding door atop which is an opening (one on each side of the box).

Design

Participants were randomly assigned to one of the four conditions described in detail in Table 3.1. See also Figure 3.2 and Figure 3.3 for a visual representation.

Table 3.1 Number of models and execution modes by experimental condition

Condition	Number of Models Overall	Number of Models (CIA*)	Mode of Execution
Individual No Coordination	1	1	Unimanually
Individual Coordination	1	1	Bimanually
Joint No coordination	2	1	Unimanually
Joint Coordination	2	2	Jointly (one hand each)

Note. 'Number of Models Overall' refers to the number of individuals involved in the demonstration of the overall action sequence including the relevant action steps, while 'Number of Models (CIA)' refers to the number of individuals involved in the demonstration of the causally irrelevant action. 'Mode of Execution' refers to the manner in which the CIA was performed.

Participants in the *individual observation group* watched a single model performing the causally irrelevant action either unimanually (Individual No coordination condition) or bimanually (Individual Coordination condition). In contrast, participants in the *joint observation group* watched a dyad, where either one member performed the action unimanually (Joint No coordination condition) or both members manipulated the stick together using one hand each (Joint Coordination condition) (See Figure 3.2 and Figure 3.3).

In the individual observation conditions, a single model performed all actions alone, moving from one side of the box to the other. This included performing all six causally relevant actions as well as the causally irrelevant action that was embedded within the action sequence (marked in orange in Figure 3.2). In contrast, in the joint condition, the two members of the dyad alternated manipulating their side of the box while seated, each performing three causally relevant actions. Depending on condition, the causally irrelevant action was performed either by one member unimanually or by both members simultaneously (marked in orange in Figure 3.3). Full demonstration videos and processed data are available at https://osf.io/hsg2n/. Analysis code is available upon request.

This design ensured that the demonstration of the causally irrelevant action was kept perceptually consistent across conditions (i.e., always performed with one or two hands; see Table 3.1 for an overview), allowing any differences in overimitation rates between conditions to be attributed to the social context in which the action was performed.

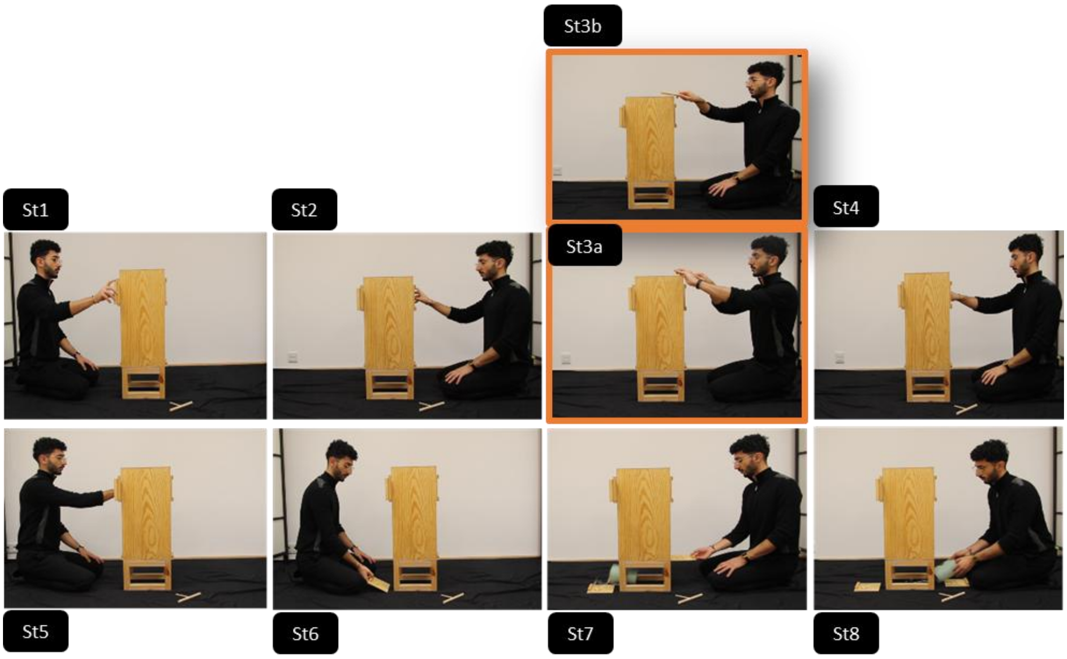

Figure 3.2 Illustration of the individual demonstration condition and actions performed by the model. The model retrieved the hidden object from the puzzle box by (a) opening the top sliding doors (St1, St2); (b) grabbing the T-shaped stick and moving it to tap the top of the box either bimanually (St3a) or unimanually (St3b); (c) reaching into a round opening to remove the hook that held the object suspended on a loop inside the box (St4, St5), (d) opening the bottom sliding doors which revealed the previously hidden object (St6, St7), and (e) retrieving the object (St8).

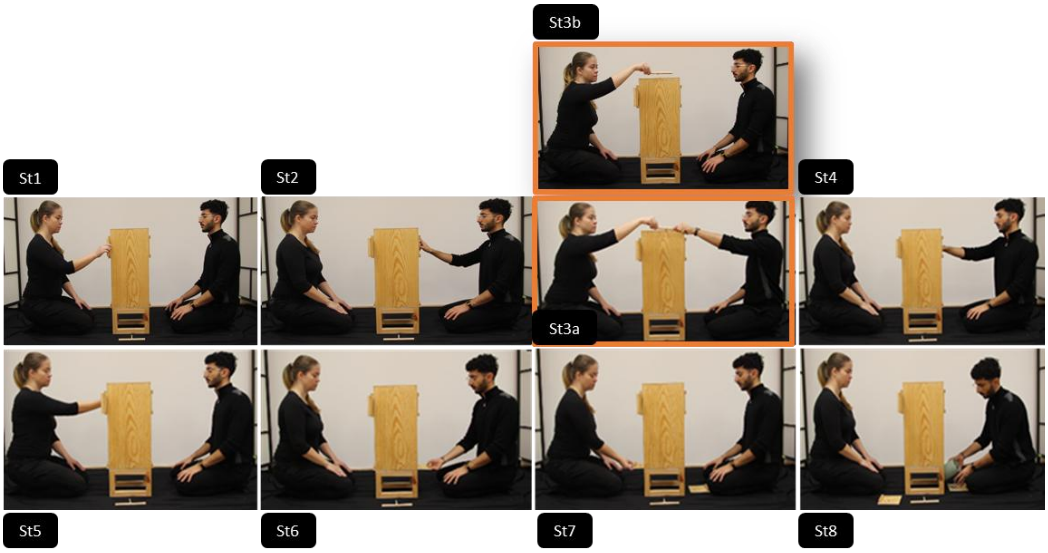

Figure 3.3 Illustration of the joint demonstration condition and actions performed by the model. The models retrieved the hidden object from the puzzle box by taking turns in (a) opening the top sliding doors (St1, St2); (b) grabbing the T-shaped stick with one hand and moving it to tap the top of the box either together (St3a) or alone (St3b); (c) reaching into a

round opening to remove the hook that held the object suspended on a loop inside the box (St4, St5), (d) opening the bottom sliding doors which revealed the previously hidden object (St6, St7), and (e) retrieving the object (St8). While acting together, the models performed the causally irrelevant action on the same T-shaped stick (St3a).

Procedure

Prior to taking part in the study, participants provided verbal consent and proceeded to sign the consent form either on their own, or with the help of the experimenter. Then, they were encouraged to explore the puzzle box on their own for a maximum of two minutes. After the child signaled that they were done exploring the box, or after the two minutes had elapsed, they were led to and seated in a chair which was positioned centrally at 1.5 meters facing the box. Participants then observed the model(s) demonstrate how to open the puzzle box to retrieve the hidden object, after which they were invited to operate the box themselves, either alone (individual action condition), or together with one of the adult models (joint action condition). Each trial thus included an exploration phase, a demonstration phase, and a test phase.

Exploration phase. Participants were brought to the testing room individually and were encouraged to explore the object on their own, with the models present throughout the phase but immersed in another activity or idle. The T-shaped stick was placed next to the box and could thus be explored by children. However, the reward box inside the apparatus was removed to prevent children from discovering the purpose of the demonstration before having a chance to see it modelled by the experimenter. While one of the models remained seated at a desk and pretended to write on a piece of paper, another stood next to her, looking in her direction and away from the child. However, the idle model was encouraging if they saw the child was too shy to explore the box, or otherwise insecure about what to do. If asked, they refrained from answering specific questions about how the box works but gave general directions and words of encouragement to the child to "go ahead and try it out" and to explore the box from all sides.

Demonstration phase. To begin the demonstration phase of the individual condition, Model 1 began by addressing the child, "Now ***I*** am going to show you how to open the box and find something that's hidden inside", and retrieved the hidden object from the puzzle box, saying, "Oh, look!", looking at the child. In the joint condition, Model 1 first invited Model 2 (who was engaged in a different task and sitting at a desk away from Model 1 and the child) to join the activity, and said, "Will you do this with me?". Model 2 agreed and sat on the opposite side of the box. Model 1 then addressed the child saying, "Now ***we*** are going to show you how to open the box and find something that's hidden inside", and retrieved the hidden object from the puzzle box, saying, "Oh, look!", taking turns looking at the child and at Model 2. The child was then escorted out of the room by one experimenter while the other reassembled the box.

Test phase. In the individual condition, the test-phase began when Model 1 turned to the child and said, "It's your turn now", moving away from their starting position, and away from the puzzle box.[1] Regardless of condition, the action sequence was always initiated by the Model sitting on the left hand-side (i.e., Model 2 in the joint condition), which was also the side the participant occupied when acting on the box. In the joint action condition, after exclaiming, "It's your turn now", Model 1 remained in their position, sitting idly next to the box and waited for the child to initiate the action sequence. Model 2 returned to their initial position at the desk, and immersed themselves in another activity (e.g., writing on a piece of paper). After the child initiated the action sequence, Model 1 followed closely with the same action (i.e., if the child started the sequence performing the first causally relevant action, Model 1 performed the same

[1] Model 2 was also present in the room to ensure equivalence across conditions.

causally relevant action on their side of the box). Importantly, Model 1 always waited to see if the child will reach for the stick (and grab it on one side only) in order to perform the causally irrelevant action, before mirroring the child's actions and performing the action with them (joint coordination). In the no-coordination condition, Model 1 would refrain from performing the causally irrelevant action unless invited by the child either verbally or non-verbally (e.g., staring, waiting for the Model to join in, and/or pointing). After retrieving the hidden object, the child could choose a sticker and was given a certificate of participation as a token of appreciation for taking part in the study.

Coding and Reliability

Replication of the causally irrelevant action. We considered any behaviors aimed at reproducing the irrelevant action as replications. These included reaching movements to grasp the T-shaped stick in the same or different manner as the one demonstrated by the model(s) (e.g., by using a different hand or one hand instead of two) and using it to touch the front top of the puzzle box. As this was a binary outcome measure indicating presence or absence of overimitation, we calculated the score in the following manner: 0=no replication, 1=replication of the causally irrelevant action.

The coding criteria were a result of expert consensus and based on prior research that employed a similar approach to assessing overimitation by evaluating the presence or absence of imitated steps and/or the presence or absence of related features of interest (for different examples, see Kenward et al., 2011; Keupp et al., 2013; Legare et al., 2015; Schleihauf et al., 2019).

Children's responses were coded from the videotapes by the first author. To assess inter-rater reliability, a second coder—who was one of the experimenters that was trained on the agreed-upon criteria, but blind to the study's hypotheses as well as the condition to which each child was assigned—re-coded 25 videos (approximately 25% of the dataset). The Kappa coefficient was calculated and indicated perfect agreement (κ=1) between the two coders regarding whether the causally irrelevant action was imitated.

3.4 Results

To examine whether children were more likely to imitate the causally irrelevant action after observing a joint demonstration, a logistic regression analysis was conducted for binary data. Social Condition (Individual vs. Joint) and Action Coordination (Yes vs. No) were included as between-subject factors, with overimitation as the dependent variable, with two possible response values: 0 (indicating absence of overimitation), and 1 (indicating presence of overimitation). The above described between-subject study design with binary outcome data justified the choice of logistic regression as the main method of analysis.

The results of the logistic regression analysis indicated that the odds of reproducing the causally irrelevant action were 1.44 times higher following individual demonstrations (58% imitated) compared to joint demonstrations (49% imitated). However, this difference was not statistically significant, 95% CI [-0.42, 1.15], p = .367. The corresponding effect size, Cohen's d = 0.20, suggests a small effect. Similarly, there was no statistically significant difference in the odds of reproducing the causally irrelevant action between coordinated demonstrations (53% imitated) and non-coordinated demonstrations (54% imitated). Participants in the non-coordination conditions were 1.04 times as likely to reproduce the causally irrelevant action as those in the coordination conditions, 95% CI [-0.75, 0.83], p = .922. The corresponding effect size, Cohen's d = 0.02, indicates a negligible effect. See Table 3.2 for a summary of the results.

The interaction between Social Condition and Action Coordination revealed that when the demonstration was not coordinated, the odds of reproducing the causally irrelevant action were 2.26 times higher following individual demonstrations (64% imitated) compared to joint demonstrations (44% imitated). However, this difference was not statistically significant, 95% CI [-0.32, 1.95], $p = .159$. The corresponding effect size, Cohen's $d = 0.45$, suggests a medium effect. Conversely, when coordination was present, there was no significant difference in the odds of reproducing the causally irrelevant action between individual demonstrations (52% imitated) and joint demonstrations (54% imitated). Participants in the joint coordinated condition were 1.08 times as likely to reproduce the causally irrelevant action as those in the individual coordinated condition, 95% CI [-1.03, 1.17], $p = .895$. The corresponding effect size, Cohen's $d = 0.04$, indicates a negligible effect.

Table 3.2 Model summary of the logistic regression

Model	**Deviance**	**AIC**	**BIC**	**df**	**X^2**	***p***	**McFadden R^2**	**Nagelkerke R^2**	**Tjur R^2**	**Cox and Snell R^2**
H_0	139.530	141.530	144.145	100						
H_1	138.701	144.701	152.546	98	0.829	0.661	0.006	0.011	0.008	0.008

Coefficients

					Wald Test			95% Confidence interval (odds ratio scale)	
	Estimate	Standard Error	Odds Ratio	z	Wald Statistic	df	*p*	Lower bound	Upper bound
(Intercept)	−0.059	0.342	0.943	−0.171	0.029	1	0.864	0.482	1.844
Coordination (low)	0.039	0.401	1.040	0.098	0.010	1	0.922	0.474	2.281
Condition (solo)	0.362	0.401	1.436	0.902	0.814	1	0.367	0.655	3.149

3.5 Discussion

In the present study, we sought to understand the impact of joint actions on imitative behavior of preschool children. To that end, we asked whether 3-6-year-olds are more likely to replicate causally irrelevant actions following joint compared to individual demonstrations of an instrumental (i.e., goal-directed) action sequence. We hypothesized that the tendency to overimitate extends to joint actions. Specifically, we predicted that compared to observing causally irrelevant actions in an individual context, observing such actions in a joint coordinated context would evoke a stronger socio-normative interpretation of the demonstrated behavior (e.g., Kenward et al., 2011; Kenward, 2012; Keupp et al., 2013), and lead children to suspend their expectations of individual efficiency (Begus et al., 2020; Vizmathy et al., 2024). This, in turn, would lead to higher rates of overimitation when reproducing the behavior with a partner.

Results from our study revealed that overimitation extends to joint actions, indicated by equal rates of copying of the causally irrelevant action following both individual and joint demonstrations. However, our analyses did not show any statistically significant differences in the expected direction—that is, children were not more likely to overimitate after joint demonstrations. In addition, action coordination did not seem to modulate children's imitative behavior. Instead, children were equally likely to copy the causally irrelevant action after individual and joint demonstrations, regardless of the presence or absence of action coordination involved in its performance. See also Appendix 1 for an exploratory analysis of the relationship between overimitation and age.

3.5.1 Study limitations

Several factors may explain the absence of a significant difference in imitation rates between individual and joint action conditions. First, we suspect that a lack of interactive cues between the two models performing jointly may have contributed to lower rates of overimitation in this condition. Indeed, the two models only briefly interacted before the demonstration began, with Model 1 inviting Model 2 to participate in the demonstration (see Procedure). However, during the demonstration phase, the models were instructed to avoid looking at each other. This was done to ensure that the joint action condition closely resembled the individual action condition, where a single agent operated the box without the possibility of interaction. Additionally, it aimed to rule out the influence of ostension during the joint performance of the causally irrelevant action which has been shown to elicit overimitation (Csibra & Gergely, 2011), thus ensuring that any increase in overimitation would be attributed to the social context in which the action occurred.

In hindsight, we suspect that such minimal interaction may have been insufficient in helping children disambiguate the event as joint. Indeed, based on the work of Fawcett and Gredebäck (2013), 18-month-old children were able to bind two agents' actions into a collaborative goal only when they observed them interacting socially before *and* during the demonstration of a novel action sequence. In addition, given that ostensive cues, such as eye gaze, are important for signaling commitment to a cooperative goal in young children during individual demonstrations (Siposova et al., 2018), the absence of such cues between models performing jointly may have further hindered children's ability to interpret the event as a cooperative, joint action.

Relatedly, it is important to note that our task was designed so that, in the joint conditions, only one of the models retrieved the object from the puzzlebox at the end of the demonstration. Such a setup may have indeed made it more difficult for children to infer a joint goal, potentially leading them to construe of the event as an act of helping in which one model assisted in achieving another's individual goal, rather than as a joint action in which both models worked towards a shared outcome. Consequently, this could have influenced children's behavior during joint action; for example, children may have imitated the goal of a single model rather than the shared goal, resulting in lower rates of overimitation. Therefore, future work investigating the influence of joint goals on imitative fidelity should make the joint goal more salient—for example, by having the models share rewards at the end, make eye-contact or interact socially in different ways with one another throughout the demonstration.

While previous observational studies with infants showed that a turn-taking sequence helps infants encode joint goals because it allows them to infer the causal relationship between co-actors' actions (Henderson & Woodward, 2011), the findings of this study suggest that synchronous coordination, as a cue to conventionality, may be necessary in joint imitation contexts to elicit faithful copying (e.g., Herrmann et al., 2013). Nevertheless, future studies could disambiguate the relative influence of action synchronicity and shared goals on imitative fidelity by having models share rewards at the end, while also acting synchronously *throughout* the joint demonstration—rather than doing so only while performing the causally irrelevant action.

Another possibility is that our method of assessing children's motivation to overimitate was too stringent. Specifically, the model acting with the child in joint conditions was instructed to wait for the child to initiate both the overall action sequence as well as the causally irrelevant action. This design aimed to mirror Fawcett and Liszkowski's (2012) approach, which tested whether children are more likely to initiate joint actions after observing a joint demonstration. However, while the relevant actions in the current study were performed in a turn-taking manner, the causally irrelevant action was carried out synchronously. As a result, the model could prompt the child to begin by performing the first relevant step if they were unsure about what to do (and actively mirrored them by performing the second relevant step) but could only passively wait for the child to initiate the performance of the causally irrelevant action or at least to confidently signal their intention to do so. This design aimed to ensure that the child's intention to perform the action was self-driven and not influenced by the model. However, the model's passive behavior may have been misinterpreted by children as hesitation, potentially discouraging them from attempting to replicate the causally irrelevant action even if they had intended to do so. Additional features absent in Fawcett & Liszkowski (2012), are the large size of the puzzle box and its central positioning obstructing a clear view of the partner may have caused additional difficulties in signaling an existing intention to overimitate. Thus, future research could heighten model responsiveness or encourage children to verbalize their thoughts while imitating. The latter, in particular, could offer deeper insights into children's underlying thought processes during replication.

Moreover, it is possible that causally irrelevant actions are perceived differently in instrumental versus ritualistic contexts irrespective of the social context in which they occur. Specifically, the presence of an instrumental goal in our study (e.g., opening the box to retrieve a reward) may have led to lower rates of overimitation, as it provided information about the event's causal structure. This, in turn, may have been used to evaluate the function and relevance of individual action steps, including the causally irrelevant action (Bauer & Mandler, 1989; in Király, 2009). In contrast, ritualistic actions, which are typically oriented toward non-instrumental outcomes—such as following specific rules, like performing a particular action sequence during a task (e.g., Herrmann et al., 2013) or arranging tokens in a specific pattern before placing them in a tube to earn stickers (Zhao et al., 2024, with findings in 4- to 6-year-olds)—may emphasize the socionormative nature of the task, as no instrumental goal is available against which to evaluate the relevance of the individual action elements. Indeed, behaviors lacking an apparent instrumental purpose are more likely to be perceived as cultural conventions and imitated more faithfully by preschoolers (Herrmann et al., 2013). In such situations, the behavioral means of the models are often interpreted as the intended goal itself (e.g., Carpenter et al., 2005).

3.5.2 Conclusions and future directions

Overall, the results of this study suggest that the phenomenon of overimitation that has been documented for individual actions (Lyons et al., 2007) extends to joint actions, and as such showcases the importance of studying imitative learning in a wider range of social contexts. Although we found no evidence that the joint context enhances overimitation in 3-6-year-old children, we suppose that the lack of difference could be due in part to imitation already being highly social, even in individual settings (Over & Carpenter, 2012). In other words, learners may imitate causally irrelevant actions in individual contexts not only to learn important skills but also to express affiliation with the model and satisfy their need for social belonging (Over & Carpenter, 2012). Thus, the presence of a collaborative partner may not be essential to elicit high-fidelity copying.

Additionally, pedagogical features present in our design that are a general characteristic of imitative learning contexts (Hoehl et al., 2019) may have prompted children to imitate at high rates even in individual action conditions, thereby obscuring any differences that could arise from the different social contexts. In these scenarios, models typically make eye contact with child participants before the demonstration, address them by name, and direct attention to a new and exciting task the child is meant to learn (Hoehl et al., 2019). Such a setup is likely to create an expectation in the child that the information being presented is specifically intended for them and represents new, relevant, and widely shared knowledge worth imitating (Csibra & Gergely, 2009; Gergely & Jacob, 2012, Király et al., 2013). Similarly, children may have been driven to overimitate at high rates due to audience effects (e.g., Marsh et al., 2019; Nielsen

& Blank, 2011), regardless of the social context in which the action was observed. In other words, the mere presence of the model as an audience may have been sufficient to trigger the motivation to conform to the demonstrated behavior, without the need for an active joint action partner to enhance this effect.

This interpretation of our results carries practical implications for practitioners and caregivers. For example, recognizing that social motivations partly drive overimitation can inform early interventions that foster a sense of belonging and encourage prosocial or normative behaviors through group or collaborative activities. On the other hand, educators and caregivers can use this knowledge to create learning environments that balance prosocial imitation with critical thinking, for example, by encouraging children to question others' behavior and the necessity of their actions for learning.

Finally, given the highly social nature of imitative learning contexts, we suspect that a more effective approach to isolating the effect of joint actions on imitative learning would involve a scenario where the child, as a third-party observer, watches from a distance (e.g., out of the models' view) as two agents interact socially while jointly demonstrating an action sequence and sharing rewards at the end. The child would then be invited to manipulate the puzzle box either alone or with a partner. A benefit of such a design is that communicative cues directed at the child would be brought down to a minimum, thereby reducing the effects of an audience and the pedagogical context on learning, while still emphasizing the joint nature of the action through interactive cues and reward sharing between the models.

Results of such research could help clarify how shared goals and joint coordination inherent to joint actions guide imitation, and offer practical guidance for early educators, practitioners, and caregivers in designing and implementing targeted learning interventions that account for the collaborative nature of learning.

Chapter 4. Anticipating teaching influences the fidelity of children's imitation in complex ways

This chapter is based on Rizvanović, N., & Carpenter, M. (submitted). Anticipating Teaching Influences the Fidelity of Children's Imitation in Complex Ways. *Frontiers in Developmental Psychology.*

4.1 Introduction

The unparalleled complexity and success of human cultures hinges on the ability of group members to transmit information socially, from one generation to the next, thereby allowing for retention and accumulation of useful information over time (e.g., Burdett et al., 2018; Kline, 2015; Strauss & Ziv, 2012). One particularly effective means of transmitting information socially is active teaching: when experts transmit information and practical skills to less knowledgeable others (e.g., Ziv, 2005; Strauss et al., 2015). Compared with other, non-pedagogical forms of social learning such as incidental observation or learning by testimonial reports, teaching results in increased receptivity to and adoption of information by learners (Csibra & Gergely, 2009; Csibra & Gergely, 2011).

For example, infants and young children seem to intuitively recognize when others are teaching them and are particularly likely to learn information presented in this way (Csibra & Gergely, 2009; Gergel & Csibra, 2011; Futó et al., 2010; Topál et al., 2008; Yoon et al., 2008). Teaching contexts, which are often characterized by ostensive-referential cues such as eye contact, direct address, contingent reactivity, referential pointing, and exaggerated movements, have been found to improve learning by directing the learner's attention to relevant aspects of the task during a learning episode (Csibra & Gergely, 2009; Csibra & Gergely, 2011). Studies find that a pedagogical context leads children to expect information presented in this way to represent generic, culturally shared knowledge (Egyed et al., 2013), and this leads them to imitate it faithfully. For instance, when actions are demonstrated pedagogically, with ostensive cues like pointing, exaggerated movement, and/or saying “Look!”/“Now watch this!”/“Here!”, infants and young children copy the actions more often than when they are not demonstrated pedagogically, even when the actions are cognitively opaque and inefficient (Brugger et al., 2007; Király et al., 2013; Southgate et al., 2009).

Normative language has also been found to increase the frequency and fidelity with which young children learn from adults via imitation. Specifically, when normative language (e.g., “This is how we do this”) is used to convey that a demonstration has a social function and represents norms and conventions, children are more likely to imitate the demonstration faithfully compared to when it is framed in non-normative, instrumental terms (Legare et al., 2015). Further support for the idea that children encode demonstrations presented with normative language normatively comes from findings that children themselves use normative language to protest when a puppet subsequently performs the actions differently, saying, for example, “No, you must do it like this!” (e.g., Kenward, 2012; Keupp et al., 2013; Schmidt et al., 2012).

Taken together, these findings suggest that the use of pedagogy, in the form of ostensive cues and normative language, plays an important role in imitative learning at an early age by highlighting to learners which aspects of the task are culturally relevant and important to acquire. However, this line of research provides only a partial picture of the human propensity to teach, as it does not capture children’s active role in transmitting information themselves. Investigating children’s role as propagators of cultural information across various contexts can enhance our understanding of how this ability develops during childhood and, importantly, shed light on children’s active participation in shaping and curating cultural knowledge (Qiu & Moll, 2022).

4.2 Children as teachers

Research suggests that children are skilled pedagogues and begin sharing information with others already in infancy (Gweon, 2022; Ronfard & Harris, 2018). Whereas the first known instances of teaching involve its simplest forms, such as the use of corrective pointing by 18- to 24-month-olds (Brandl et al., 2023), during the preschool years, children often engage in a more explicit and direct form of teaching (Bazhydai & Harris, 2020; Brown & Pallinscar, 1989; Flynn, 2010; Rogoff, 1990). For example, 3-year-olds use elaborate demonstrations (Brandl et al., 2023; Strauss et al., 2002), and 5-year-olds accompany these with verbal explanations (Strauss et al., 2002) and provide individualized feedback when needed, tracking their pupils' progress (Ziv et al., 2016). Seven-year-olds show an increased sensitivity to learners' characteristics, by selectively teaching information that is useful (Bass et al., 2019), and hard to discover through individual exploration (Bridgers et al., 2020; Ronfard et al., 2016). Moreover, they modulate the content of what they teach based on the learner's background, such as their expertise and interest (Gweon et al., 2018; Gweon & Schulz, 2019), age (Qiu & Moll, 2024), occupation (Danovitch, 2020), and group membership (Karadağ & Soley, 2022).

Taken together, these studies show that children are adept teachers and can flexibly tailor what and how they teach depending on various cues available to them. In addition, they highlight children's active role in the transmission of cultural information.

4.3 The present study

Thus, young children can play the role of both learners and teachers. In the current study, we take both of these roles into account by asking whether children would imitate an adult's actions more closely when anticipating teaching others, compared to when learning the behavior for themselves. The reasoning was that if we told children that soon a video of them would be used to teach the behavior to someone else, this should lead them to interpret the demonstrated actions in conventional terms (i.e., as conveying culturally shared and therefore socially relevant knowledge), and they should then imitate the behavior with a greater degree of fidelity compared to when they observed the demonstration without any mention of teaching.

A study by Vredenburgh et al. (2015) explored a related question—namely, whether pedagogical cues influence the way in which children give information to others later. In that study, children first observed two adult models demonstrating distinct causal functions of a novel toy: one manipulating it to produce a sound and the other manipulating it to produce a light. One of the models (counterbalanced) did this pedagogically, with eye contact and "Look!", and the other did this non-pedagogically but intentionally. Afterward, children were invited to interact with the toy themselves. Initially, children imitated both causal functions equally, but when subsequently a new adult arrived, picked up the object, and asked children, "What is this? What does this do?", they selectively performed as their first action the function that had previously been modelled pedagogically.

These findings, and others like those of Schmidt et al. (2012), seem to suggest that although pedagogical cues may not be essential for *learning* novel actions, they may play an important role in the further *transmission* of information. Here, as the first aim of the current study, we focused on something related but different: not on manipulating whether pedagogical cues were present or not during a demonstration, but rather on manipulating, in an imitation context, whether children believed that their actions would serve to teach others or not. We thus minimized ostensive/pedagogical cues from the adult demonstrator in this study in all conditions. Investigating this provides insight into how children encode and transmit information when anticipating teaching rather than how they transmit information they learned through teaching.

Relatedly, the second aim of this study was to explore more generally whether what children learn, remember, and later reproduce from a demonstration depends on the information they receive about the goal or context of the demonstration, and when they receive this information. Previous research has shown that prior knowledge of the goal of a demonstration can facilitate children's organization of the actions demonstrated into meaningful units (e.g., Bauer, 1992; Bauer & Mandler, 1989; Bauer & Hertsgaard, 1993; Király, 2009; Travis, 1997) and enhance memory and recall of goal-relevant sub-actions (Carpenter et al., 2002; Loucks et al., 2017). Being in different contexts or having different goals can also affect how closely children copy a demonstration (Legare et al., 2015; Over & Carpenter, 2009; Yu & Kushnir, 2014). We thus manipulated whether children learned that they would be teaching other children or not before vs. after the demonstration. In doing so, we investigated whether children *encode all and select later* (cf. Whiten et al., 2009), i.e., learn and remember all the observed actions and retrieve actions selectively from them as needed later according to their goals at that moment, or whether they encode and remember only, or mainly, the actions that were relevant to the goal at the time of the demonstration.

Finally, we also explored the relation between gender and imitation of causally irrelevant actions in the context of teaching. Previous research on gender differences in overimitation in other contexts has yielded mixed results. For instance, Frick and colleagues (2017) found that in a cross-cultural sample of children aged 5-12 years, boys were more likely to overimitate than girls. This was attributed to boys being more inclined to view objects in their environment as potential problem-solving tools, making them more attuned to actions performed on objects. On the other hand, Barbarroja et al. (2024) found that between the ages of 3 and 6, boys showed an increase in imitative fidelity, whereas girls did not. They suggested that the lack of an increase in overimitation with age in girls may have resulted from girls' already high levels of fidelity at an earlier age. However, few, if any, studies have investigated gender differences in children's teaching abilities. Investigating the role of gender as a mediator in the relation between overimitation and teaching could help clarify the reasons behind the gender differences in overimitation observed in previous studies and provide insight into how boys and girls are socialized about teaching.

In the current study, 48 4- to 6-year-old children (12 per condition) were tested using a transparent puzzle box. In the first of two trials, the experimenter called children's attention to the fact that she was videotaping them, and then children observed her demonstrate how to retrieve a reward from the puzzle box using a fixed, five-step sequence consisting of two causally relevant and three causally irrelevant action steps. We used a 2x2 design with Teaching and Instruction Timing as between-subjects factors. In each of two Teaching conditions, children were instructed that the video of them would be used to teach other children how to work the puzzle box, whereas in each of two No Teaching conditions, they were instructed that the video could be used later if children wanted to remind themselves of how they worked the box. These instructions were given either before (Prior) or after (Post) the experimenter's demonstration of how to work the box. Thus, children were randomly assigned to one of four conditions: Teaching Prior, Teaching Post, No Teaching Prior, and No Teaching Post. They were then given a turn to operate the box and were scored on whether they reproduced the causally irrelevant steps, and how faithfully they reproduced them. Immediately afterward, a second trial was introduced in which children were invited to interact with the puzzle box in private (i.e., the experimenter was within view but not looking at children). However, in this trial, unlike in trial 1, children were given no further demonstration or instructions about the task. While we were mainly interested in children's behavior in trial 1, we recognized that the presence of the demonstrator could lead to copying of irrelevant actions due to "audience effects" (Marsh et al., 2019; Nielsen & Blank, 2011). To account for this, trial 2 allowed children to interact with the puzzle box privately.

Based on previous results and theory (see, e.g., Over & Carpenter, 2012, for a review), we predicted that the teaching instruction would lead the children who received it to consider the causally irrelevant actions as conventional and part of an overarching normative goal, resulting in greater fidelity of imitation in the Teaching conditions. In contrast, we predicted that the instruction involving individual learning would shift children's focus to the instrumental function of the behavior. As a result, children would be more likely to emulate the experimenter's behavior, omitting causally irrelevant steps and using more efficient means to obtain the reward in the No Teaching conditions. We predicted that children would be most likely to imitate the causally irrelevant actions in the Teaching Prior condition, when they knew as they were watching the demonstration that they would be serving as a teacher to other children. Beyond that, we did not have a strong prediction about the timing of the instructions in the other conditions. On the one hand, the previous research reviewed above shows that knowing the goal of the action before the demonstration can help children, so it was likely that children would do better in the Teaching Prior condition than in the Teaching Post condition. On the other hand, given the flexibility in children's imitation generally (see Over & Carpenter, 2012, for a review), it was possible that children do have an *encode all, select later* strategy, and thus would be able to easily retrieve the irrelevant actions even in the Teaching Post condition. Finally, given that the ages of 3 to 6 are a critical period for gender socialization (Grace et al., 2008; Hartup, 1983), we hypothesized that these processes might shape children's view of teaching and influence how they imitate others. However, due to the mixed findings in previous research, we did not have specific predictions about the direction of these differences.

4.4 Method

4.4.1 Participants

A total of 48 children aged 4-6 years (M_{age} = 5.04 years, SD_{age} = 0.77; 24 females) were included in the final analyses. For the choice of sample, we followed the lead of previous studies that tested a similar age range (e.g., Clay et al., 2018; Wood et al., 2016), and sample size (e.g., Fawcett & Liszkowski, 2012; Király et al., 2013; Over & Carpenter, 2009). There were thirteen 4-year-olds, twenty 5-year-olds, and fifteen 6-year-olds. Seventeen additional participants began the testing but were excluded from the final sample because they did not complete the testing due to shyness (n=1), experimenter error (n=2), or because they needed help from the experimenter to complete the task (n=14).[2] Participants were recruited on an opportunity basis and tested at Edinburgh Zoo's Budongo Research Unit. Upon completing the study, all children received stickers and a participation certificate as recompense, irrespective of their success on the task.

4.4.2 Materials and procedure

The transparent, plexiglass puzzle box from Wood et al. (2013) and Burdett et al. (2016) was used (see Figure 4.1a). The objective of the task was to retrieve a plastic egg containing a sticker, which was trapped (but visible) inside the box.

We used a 2x2 factorial design. Participants were randomly assigned to one of two teaching conditions (Teaching or No Teaching), and one of two instruction conditions (Prior or

[2] For the latter 14 participants, the distribution was as follows: Teaching Prior (n=2), Teaching Post (n=5), No Teaching Prior (n=1), and No Teaching Post (n=6). Including these participants, for as far as they got in the test, did not alter the pattern of significant results for the main measure of imitative fidelity reported below.

Post demonstration), for a total of four between-subjects conditions: Teaching Prior, Teaching Post, No Teaching Prior, and No Teaching Post.

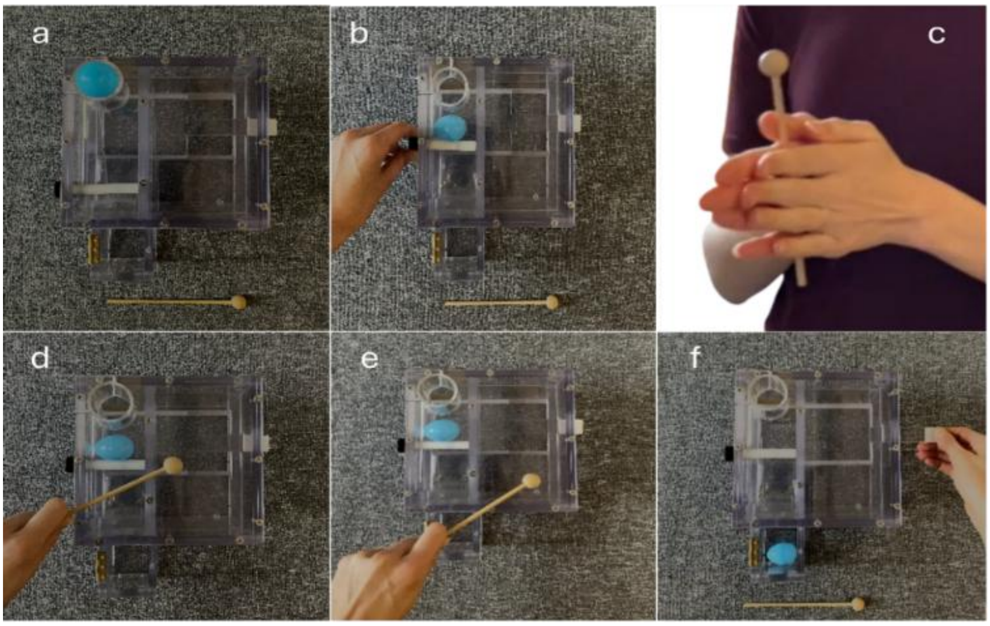

Figure 4.1 Illustration of the apparatus highlighting key features of the puzzle box (a) and the action sequence demonstrated by the experimenter (b-f).

Procedure

Each test session began with a brief warm-up period, during which participants colored while the experimenter chatted with them. When the experimenter felt that children were comfortable, she asked if they wanted to do something else. She then invited children to take a seat on the floor, facing a video camera on a tripod approximately 1m away. Prior to the demonstration of the task, the experimenter drew the attention of children in all conditions to the camera, saying, "I will be with you in a minute. I am just going to check that the camera is on and working properly", and turned on the camera. This was to ensure that children were aware of the camera and served as the basis for the experimental manipulation.

The experiment consisted of two trials. The first trial was divided into two phases: a demonstration and a test phase. Children who successfully completed the first test were given a second test trial without a further demonstration: the opportunity to manipulate the puzzle box privately, i.e., out of the experimenter's view, without any further instructions. The sequence of events was thus as follows: warm-up → demonstration (with the teaching or no teaching instructions given either prior to or post demonstration) → test trial 1 → test trial 2.

Trial 1

Demonstration. To begin the demonstration phase, the experimenter placed the puzzle box in front of children, saying, "Look! It is a box with an egg inside, and the egg has a sticker in it. In a moment, I will show you how to work the box, and then it will be your turn to try it out. Does that sound good?" Then participants in the **Prior** instructions conditions received their teaching or no teaching instructions, as follows. Participants in the **Teaching Prior** conditions were told: "Remember that camera over there? We are taking a video of you, and we will use that video to teach some other children how to open the box. Does that sound good?" Participants in the **No Teaching Prior** conditions were told: "Remember that camera over there? We are taking a video of you, and we can use that video if you want to remember how you did it. Does that sound good?" See Table 4.1 for an overview of the experimental design.

Participants then watched the experimenter as she demonstrated how to get the egg out, using a combination of two causally relevant and three causally irrelevant action steps in the following, fixed sequence (see Figure 4.1b-f): (1) moving a cylinder to push the egg forward onto a sliding platform (relevant), (2) rolling a xylophone mallet vertically between her palms three times back-and-forth for approximately 2 seconds (irrelevant), (3) tapping the top of the box three times with the mallet (irrelevant), (4) moving the tip of the mallet diagonally across the box in one and then the other direction in the shape of a letter X, one time (irrelevant), and, finally, (5) pulling the lever on the side of the box to release the egg, allowing it to drop into its final location (relevant).

Table 4.1 Overview of instructions provided to children across experimental conditions

<table>
<tr><th>Condition</th><th colspan="2">Before the demonstration</th><th>Demo</th><th colspan="2">After the demonstration</th><th>Test</th></tr>
<tr><td>Teaching Prior</td><td rowspan="4">Look, it's a box, with an egg inside, and the egg has a sticker in it. In a moment, I will show you how to work the box, and then it will be your turn to try it out. Does that sound good?</td><td>Remember that camera over there? We’re taking a video of you, and we will use that video later to teach some other children how to work the box.</td><td></td><td>--</td><td rowspan="2">Okay, now it’s your turn. Remember, later we will use the video of you using the box to teach some other children how to work the box.</td><td></td></tr>
<tr><td>Teaching Post</td><td>--</td><td></td><td>Remember that camera over there? We’re taking a video of you, and we will use that video later to teach some other children how to work the box.</td><td></td></tr>
<tr><td>No Teaching Prior</td><td>Remember that camera over there? We’re taking a video of you, and we can use that video later if you want to remind yourself how you did it.</td><td></td><td>--</td><td rowspan="2">Okay, now it’s your turn. Remember, later we can use the video of you using the box if you want to remind yourself how you did it.</td><td></td></tr>
<tr><td>No Teaching Post</td><td>--</td><td></td><td>Remember that camera over there? We’re taking a video of you, and we can use that video later if you want to remind yourself how you did it.</td><td></td></tr>
</table>

The experimenter then retrieved the egg for children and showed them the sticker that was inside. Then she put the sticker back into the egg, and addressed children again, saying, “Okay. I'm going to put the egg back inside the box for you, and then you may have a go. Does that sound good?” Participants in the ‘**Post**’ instructions conditions received their teaching or no teaching instructions at this point, using the same wording as for the Prior instructions above, respectively. Then all children were provided with a reminder of their instructions (see Table 4.1).

Test. Children were considered to have completed the task once the egg was in its final location in the box, where it could be retrieved. If children showed signs of struggling to open the box, after approximately 20 seconds, they were encouraged in a neutral way by the experimenter to try again (e.g., “Give it another go.”). If, after a second round of encouragement, after approximately 15 seconds, children still failed to retrieve the egg, they were offered help until they could successfully complete the task; however, those children were excluded from the final analysis. The experimenter remained seated next to children, watching what they were doing, during this test phase. Upon completing the task, the experimenter neutrally stated, “You got it!”—deliberately avoiding positive feedback that might suggest a correct way of performing the task.

Trial 2

Children who successfully retrieved the egg in Trial 1 on their own were asked if they wanted to get another sticker out of the box. If they said yes, the experimenter quickly reset the box and placed another sticker inside the egg (in view of children), put the egg back inside the box through the top opening, and invited children to have another go (e.g., “Okay, you may have another go now.”). This time, however, the experimenter left children alone during the test, saying, “I have to go over there for a moment and talk to [the research assistant/your parent].

You just let me know when you're done. Okay?" Thus, here, unlike in Trial 1, children received no further instructions or demonstration of the task.

Coding and reliability

Children's responses were later coded from the videotapes by the first author. The main measures were two separate measures of imitative fidelity: a *coarse-grained measure* and a *fine-grained measure*. The coarse-grained measure was pre-planned, and we added the fine-grained measure later to explore whether a teaching context would encourage children not only to imitate more causally irrelevant steps but also to imitate them more faithfully. For the coarse-grained measure, we assessed *whether* children reproduced each of the causally irrelevant steps. Children received a score of 0 if they did not reproduce the step and 1 if they did. Thus, in each trial, children could score between 0 and 3 points, resulting in a total possible score of 0 to 6 across the two trials. For the fine-grained measure, we evaluated *how accurately* children imitated each causally irrelevant step. This measure combined two components: the imitation sub-score (0-6) and the sequence sub-score (0-2), yielding a total possible score of 8 points for each trial, and 16 points across the two trials. A summary of the coding criteria for correct responses for each type of measure is provided in Table 2 of Appendix 2. Processed data can be accessed here: https://osf.io/3n8wr/?view_only=b1a6031795fc406fa3b1ce9d577e6c41.

We also later decided to code the videos for any occurrence of pedagogical/communicative cues toward the camera that children produced during the test phase in both trials, such as looks, gestures (e.g., pointing at the puzzle box or manipulating the mallet in an exaggerated fashion to draw attention to it), or normative language (e.g., "This is how you should do it"). We hypothesized that children who engaged in teaching would exhibit more pedagogical/communicative cues toward the camera, as if instructing a novice on the correct way to complete the task. Moreover, we anticipated that children who displayed more of these cues would also imitate more faithfully. However, due to the very low rate of such cues produced by children (looks to the camera occurring in just 1 out of 48 children[3], and pointing and/or normative language in 0 out of 48 children), these were not analyzed further.

To assess inter-rater reliability, an independent observer coded the videotapes of twelve randomly selected children (representing 25% of the total sample). The second coder was unaware of the hypotheses of the study and the condition to which each child had been assigned. Reliability was excellent on all measures: for the number of causally irrelevant actions imitated, $\kappa = 1$; for the imitation sub-score, $\kappa = .83$, and for the sequence sub-score, $\kappa = .93$.

The data were analyzed using R (version 4.3.1) and JASP (version 0.17.3.0.).

4.5 Results

4.5.1 Coarse-grained measure: Reproduction of the causally irrelevant action steps

A GLMM was conducted to examine the effects of Teaching Condition (Teaching vs. No Teaching) and Instruction Timing (Prior vs. Post) on children's imitation, with random intercepts for participants. The dependent variable was a binary measure of reproduction of each of the irrelevant action steps (Yes vs. No), and a logit link function was used. We also attempted to fit a model with Trial Number as an interaction term, but this produced

[3] This child briefly looked at the camera, but the gaze was not prolonged or ostensive, suggesting that it was not an attempt to communicate with the intended audience of children for whom the video was said to be made.

convergence issues. Since no specific hypotheses had been made about differences in the likelihood of imitation as a function of trial number, we collapsed across trials and did not pursue this question further.

We found a significant main effect of Instruction Timing, indicating that the likelihood of imitation varied significantly depending on when participants received the instructions, $\chi^2(1) = 4.78$, $p = .029$. The main effect of Teaching Condition was not significant, $\chi^2(1) = 0.44$, $p = .507$, and there was no significant interaction between Teaching and Instruction Timing, $\chi^2(1) = 1.86$, $p = .173$. Analysis of the odds ratios (ORs) revealed that participants were 2.5 more likely to reproduce the causally irrelevant steps in the Prior compared to the Post conditions (OR = 2.58, 95% CI = [1.18, 5.99]; Figure 4.2).

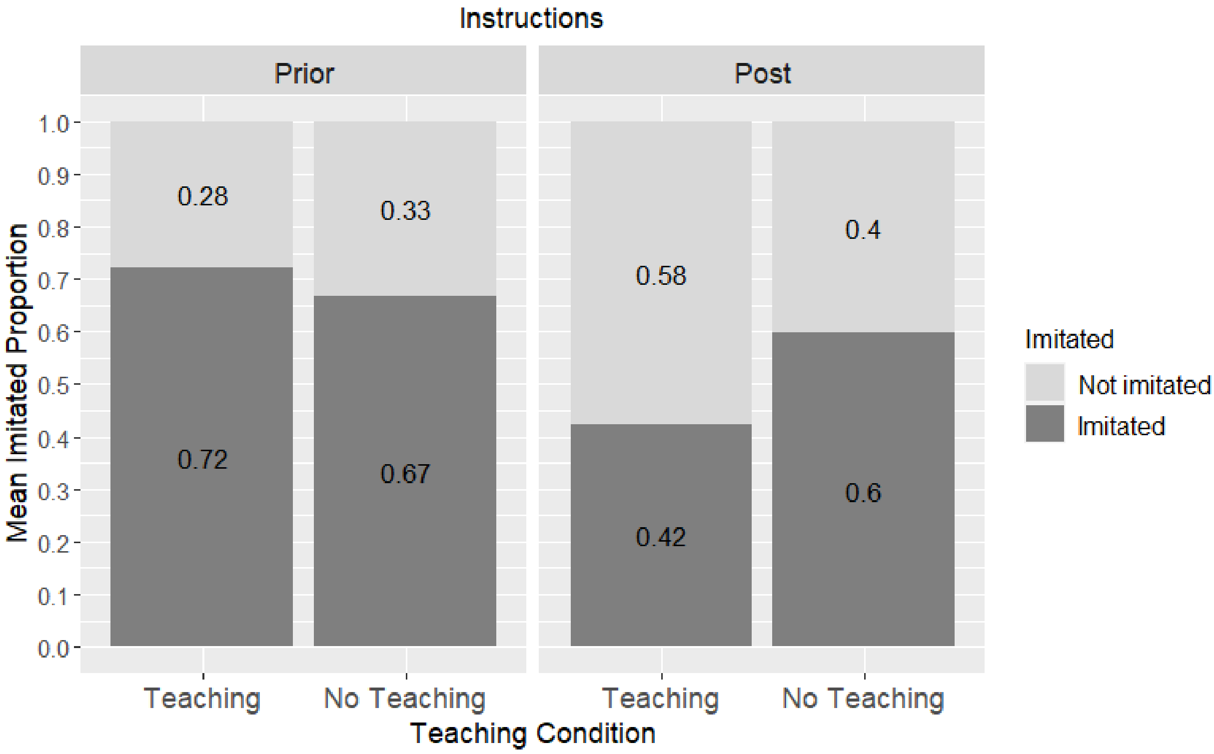

Figure 4.2 Proportion of irrelevant actions reproduced in each condition.

An additional exploratory GLMM was conducted to examine whether children's Gender (Male vs. Female) predicted the tendency to imitate. This decision was guided by previous research reporting gender differences in imitation (e.g., Barbarroja et al., 2024; Frick et al., 2017).

We found a significant three-way interaction between Teaching, Instruction Timing, and Gender, $\chi^2(1) = 5.25$, $p = .022$. To further investigate potential interactions between Teaching and Instruction Timing that might differ between genders, separate GLMMs were conducted for males and females. The GLMM for females yielded a main effect of Instruction Timing, $\chi^2(1) = 4.18$, $p = .041$. Analysis of the odds ratios revealed that females were 3.1 more likely to reproduce the irrelevant steps in the Prior compared to the Post conditions (OR = 3.08, 95% CI = [1.03, 9.164]; Figure 4.3). The GLMM for males yielded a significant two-way interaction between Teaching and Instruction Timing, $\chi^2(1) = 6.56$, $p = .010$. Pairwise comparisons between the conditions revealed that in the Teaching conditions, males imitated significantly more in the Prior compared to the Post conditions ($p = .008$; Figure 4.3). However, in the No Teaching conditions, they were significantly more likely to imitate in the Post compared to the Prior conditions, $p = .003$. (They were also significantly more likely to imitate in Prior No Teaching compared to Post Teaching ($p = .030$; Figure 4.3). We also found a significant main effect of Instruction Timing, with participants imitating significantly more in Prior compared to the Post conditions, $\chi^2(1) = 5.27$, $p = .022$.

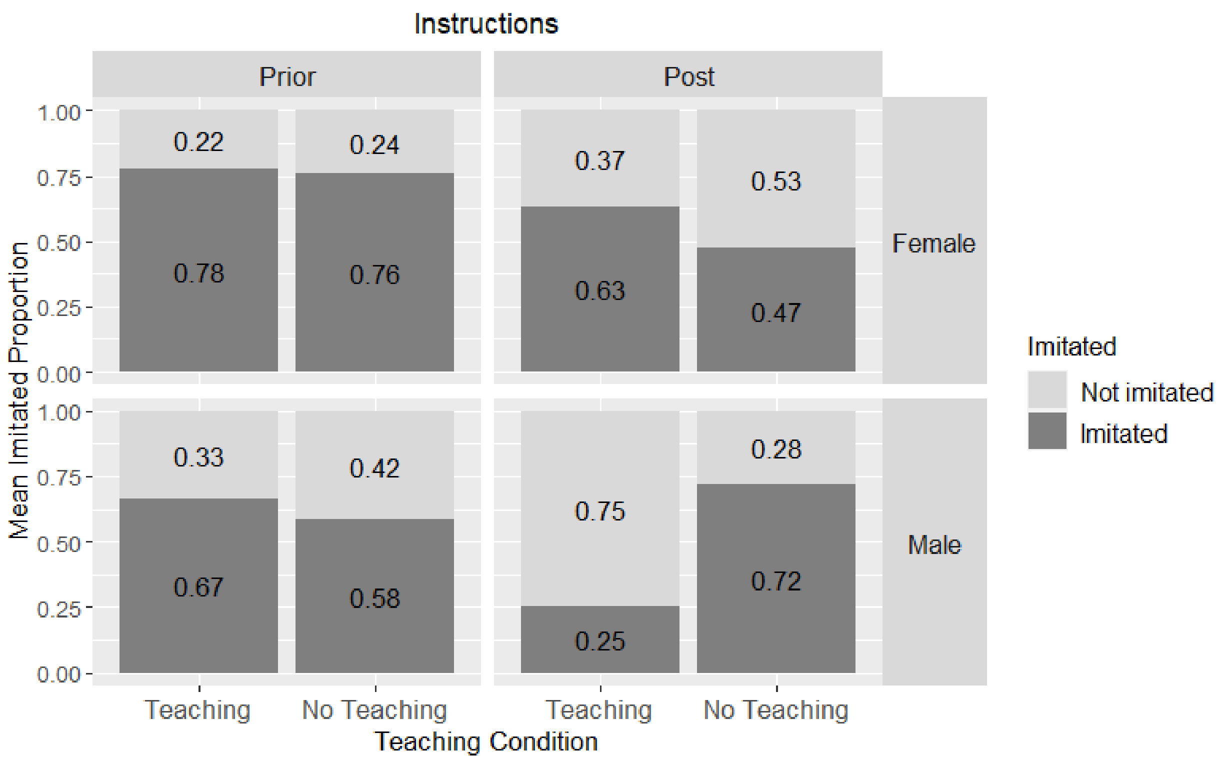

Figure 4.3 Proportion of irrelevant actions reproduced in each condition by gender.

4.5.2 Fine-grained measure: Fidelity of reproduction

To test the effects of teaching and instruction timing on imitative fidelity, a mixed model ANOVA with Teaching Condition (Teaching vs. No Teaching) and Instruction Timing (Prior vs. Post) as between-subjects factors, and Trial Number (Trial 1 vs. Trial 2) as a within-subjects factor was conducted on children's imitation fidelity scores (collapsed across accuracy and sequence sub-scores). For the results of each sub-scale separately, see Appendix 2. A total of 45 data points were included in the analysis, as 3 participants did not complete Trial 2. The results of the ANOVA revealed no significant main effects or interactions (See Table 4.2 for an overview). Numerically, children imitated most faithfully in the Teach Prior condition, in both trials (see Table 4.3).

Table 4.2 Summary of the ANOVA for the imitation fidelity score

Within Subjects Effects						
Source	Sum of Squares	df	Mean Square	*F*	*p*	η^2_p
Trial Number	3.84	1	3.84	2.49	.12	.06
Trial Number x Teaching	0.11	1	0.11	0.07	.79	.00
Trial Number x Instruction Timing	2.09	1	2.09	1.36	.25	.03
Trial Number x Teaching x Instruction Timing	3.19	1	3.19	2.07	.16	.05

Between-Subjects Effects						
Source	Sum of Squares	df	Mean Square	*F*	*p*	η^2_p
Teaching	1.24	1	1.24	0.14	.71	.00
Instruction Timing	3.40	1	3.40	0.38	.54	.01
Teaching x Instruction Timing	7.02	1	7.02	0.79	.38	.02

Table 4.3 Mean total imitation fidelity score by condition and trial

	Trial 1				Trial 2			
	Teaching Prior	Teaching Post	No Teaching Prior	No Teaching Post	Teaching Prior	Teaching Post	No Teaching Prior	No Teaching Post
Valid (N)	12	12	12	12	12	10	11	12
Missing (N)	0	0	0	0	0	2	1	0
Mean	4.33	2.83	3.25	3.33	3.17	2.90	2.82	2.92
Standard Deviation	1.50	2.48	1.77	2.67	2.48	3.14	1.54	2.19

Next, to assess gender differences in imitative fidelity, we ran a mixed-effects ANOVA with Gender (Male vs. Female), Teaching (Yes vs. No) and Instruction Timing (Prior vs. Post) as between-subjects factors, and Trial Number (Trial 1 vs. Trial 2) as a within-subjects factor. We found a significant interaction between Teaching and Gender ($F(1,37) = 8.28$, $p = .007$, $\eta^2_p = 0.183$, indicating a medium effect size). An analysis of simple main effects (Figure 4.4; see also Table 4.4) revealed a significant main effect of Teaching for females, $F(1) = 5.78$, $p = .028$, but not for males, $F(1) = 2.67$, $p = .118$, indicating that girls were significantly more likely to imitate faithfully when instructed that their video would be used to teach other children compared to when learning the behavior for themselves. No other significant interactions or main effects were found.

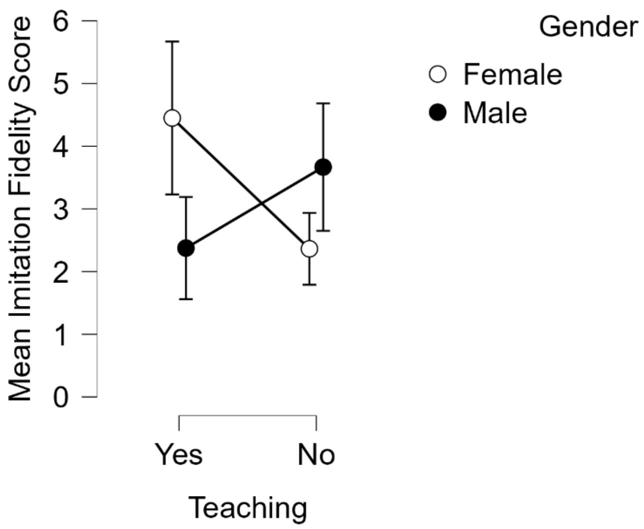

Figure 4.4 Mean imitation fidelity scores in the Teaching and No Teaching conditions by gender, across both trials combined. Error bars represent 95% CI.

Table 4.4 Mean total imitation fidelity score by condition, gender, and trial

	Trial 1				Trial 2			
	Teaching Prior	Teaching Post	No Teaching Prior	No Teaching Post	Teaching Prior	Teaching Post	No Teaching Prior	No Teaching Post
Valid (F)	6	6	6	6	6	4	5	6
Missing (F)	0	0	0	0	0	2	1	0
Mean (F)	3.833	3.333	2.833	1.667	3.167	3.750	2.600	2.000
Standard Deviation (F)	1.169	2.066	0.983	1.033	2.041	2.630	0.548	1.414
Valid (M)	6	6	6	6	6	6	6	6
Missing (M)	0	0	0	0	0	0	0	0
Mean (M)	3.167	1.333	2.667	3.667	2.000	1.167	2.333	3.000
Standard Deviation (M)	0.753	1.211	1.506	2.066	1.095	1.602	1.506	1.789

Note. For each trial, the maximum possible score was 8 points.

4.6 Discussion

Faithful imitation and teaching are two key mechanisms for the social transmission of information. Most previous studies have focused on children in their role as imitators, or in their role as teachers, but not both at the same time. Here, we had them play both roles at once. We investigated whether telling them that a video of them would be used to teach other children how to work a puzzle box would lead them to imitate an adult's initial demonstration more closely, as compared to when they were learning how to operate the box for their own sake. The reasoning was that giving them this teaching instruction should lead them to interpret the adult's actions as the conventional, normative way to operate the box. Moreover, we investigated children's ability to retrieve observed actions from memory flexibly even when surprised after the demonstration with a new task within which to imitate. We also explored gender differences in these abilities, and we considered two different ways of assessing how closely children imitated.

Overall, the results for both measures of imitative fidelity—a coarse and a more fine-grained one—suggested that, as a group, children were *not* more likely to imitate faithfully in the Teaching, compared to the No Teaching, conditions, counter to our predictions. They were more likely to imitate the causally irrelevant actions when they were provided with instructions about their video before (Prior), compared with after (Post), the demonstration in both the Teaching and the No Teaching conditions.

Different patterns of results were found for males and females. Females imitated the causally irrelevant actions significantly more often in the Prior than in the Post conditions overall, and, consistent with predictions, they reproduced the details of the demonstrated actions significantly more often in the Teaching than in the No Teaching conditions (though in general their imitation fidelity scores were relatively low). In contrast, males showed different patterns of results in the Teaching and No Teaching conditions. In the Teaching conditions, they, too, imitated the causally irrelevant actions more often in the Prior than in the Post condition. However, they showed the opposite pattern in the No Teaching conditions: there, they imitated the causally irrelevant actions more often in the Post than in the Prior condition.

Thus, at least with the more fine-grained measure of imitation fidelity, there was some evidence that females may have attributed normative significance to the demonstrator's actions in the teaching context. Males, on the other hand, imitated the highest number of causally irrelevant actions in the No Teaching Post condition. While the finding that they imitated more in the Prior condition when anticipating teaching may point to an encoding effect of teaching, such that a prior teaching goal facilitated retention of normative components of the demonstration, we can only speculate about why males imitated more of the causally irrelevant actions in the Post condition when learning the behavior for themselves. One possibility is that mentioning the video camera just before participants engaged with the box heightened their attention to their own performance. However, since males did not imitate more in the Post condition when anticipating teaching, it is likely that the impact of mentioning the camera was not due solely to its timing after the demonstration. Instead, it may also reflect a greater sensitivity among males to maintaining their self-image when learning for themselves compared to when preparing to teach.

Another possibility is that females imitated more to conform to the female demonstrator who modelled the actions. However, this is unlikely, as increased imitation was observed only in the Teaching conditions. If same-gender conformity were the driving factor, we would expect to see greater imitation from females across all conditions. In previous studies, there are mixed results with regard to gender differences in children's overimitation, and there are few studies on gender differences in children's teaching; thus we can only speculate about reasons for the observed differences. One possibility is that the difference stems from variations in how males and females are socialized about teaching or in how frequently they engage, or are encouraged to engage, in teaching-related activities during early childhood.

In hindsight, one reason for the finding of few differences between the Teaching and No Teaching conditions might be that, for practical reasons, children were only informed that their video would be used to teach other children how to open the box; they did not actually engage in direct teaching. This setup may have diminished the impact of the teaching context, making it less likely that the manipulation was effective. Given the finding that none of the children produced communicative cues to the camera that would signal an intention to teach someone (e.g., looking at and speaking ostensively to the camera, pointing, ostensively performing the actions), we were led to conclude that our teaching manipulation might not have been very effective. Therefore, future studies could further explore the link between teaching and imitative fidelity by having participants engage in actual, live teaching with the learner present.

We found little evidence for the idea that young children *encode all and select later*, i.e., learn and remember all the observed actions and retrieve actions selectively from them as needed later according to their goals at that moment. Instead, in most cases, they imitated more faithfully in the Prior than in the Post conditions. The finding that, overall, they did this across both Teaching and No Teaching conditions suggests that the prior mention of the video, rather than the prior mention of teaching, might have prompted them to pay closer attention to the demonstration and/or remember the actions better. This extends results showing that knowing about the purpose of the demonstration facilitates the retention of actions in memory (e.g., Carpenter et al., 2002; Király, 2009; Liechtenstein & Brewer, 1980; Loucks et al., 2017; Schank & Abelson, 2013). Still, it is noteworthy that even though the response period took place just seconds after the demonstration in Trial 1, children in the Post conditions could not (or did not) retrieve all the details of what they had just seen, even in the Teaching condition.

Perhaps older children would be able to do this, or perhaps if there had been fewer irrelevant actions, these younger children could have done it.

The current results highlight a key methodological consideration in social learning research. Specifically, they present empirical evidence in support of Charbonneau and Bourrat's (2021) proposal that varying the level of granularity when evaluating imitative fidelity within a single episode of cultural transmission can produce very different outcomes. Coarse-grained analyses, which emphasize mere presence or absence of traits, often overlook subtle differences between the demonstrator's and the learner's behaviours. In contrast, fine-grained analyses capture greater behavioural variation, enabling a broader range of potential deviations to be observed (Charbonneau & Bourrat, 2021). In the present study, the coarse-grained measure, which treated fidelity as a binary outcome indicating the presence or absence of imitation, revealed a significant difference in the likelihood of imitation of causally irrelevant actions between the Prior and Post conditions, overall. However, this result was not replicated when a finer-grained measure of imitative fidelity was applied. Similarly, for females, a significant difference between the Prior and Post conditions was again observed with the coarse-grained measure, whereas a significant difference between the Teaching and No Teaching conditions was observed with the finer-grained measure of imitative fidelity. Additionally, the interaction between Teaching and Instruction Timing observed for males using the coarse-grained measure was absent with the finer-grained measure.

These differences in findings were likely because even if a child performed perfectly on the coarse-grained measure (imitating all three causally irrelevant steps), they could receive a score of 0 on the fine-grained measure if the 'style' (Hobson & Lee, 1999) with which they imitated the steps deviated from the original demonstration (e.g., tapping the mallet 5 times instead of 3). Since our scoring system permitted only one "mistake", multiple deviations automatically resulted in a score of 0. Therefore, because the level of analysis chosen in a research study reflects the researchers' specific interests in highlighting different aspects of the same behavior, what researchers interpret as an episode of high- or low-fidelity transmission is a subjective matter (Charbonneau & Bourrat, 2021).

Overall, the results of this study add to the growing body of literature on children's active role in propagating cultural knowledge. They suggest a complex interplay between the context in which children find themselves and the timing of their instructions when imitating novel actions. Furthermore, our findings are the first to reveal gender differences in how males and females imitate while anticipating teaching, paving the way for exciting new research avenues.

Chapter 5. General Discussion

Research on social learning, and overimitation more specifically, has made important contributions to the field by elucidating the strategies involved in learning from others and teasing apart possible motivations behind them. Similarly, over the past two decades, research on joint action has significantly deepened our understanding of the mechanisms involved in collaboration and successful interaction with others. This dissertation aimed to contribute to these research fields by synthesizing insights and bridging the gap between them, by exploring how observing and participating in joint actions influences imitative learning. Throughout this thesis, I have argued that a comprehensive account of imitative learning should not only focus on the question of how novices learn by observing individuals acting alone but could benefit from a widening of focus to include a systematic investigation into how observing and participating in social interactions guides early learning.

Following this assumption, the thesis investigated (a) how adults judge others' imitation of a joint action that is inefficient and whether they expect such an action to be reproduced faithfully (Study 1) and (b) how preschool children (aged 3-6) that have observed an inefficient joint action imitate it when doing so entails coordinating with a partner (Study 2). In a related study, I have investigated more broadly the scope of children's imitative flexibility and understanding of teaching by exploring their motivations to overimitate when anticipating having to teach others (Study 3).

In the remainder of this chapter, I will briefly summarize the empirical findings of this thesis and discuss how they relate to the existing frameworks of imitative learning, and overimitation more specifically. Finally, I will outline key limitations of the studies presented and suggest possible directions for future research.

5.1 Summary of results

Study 1 investigated whether adults are more likely to expect irrelevant actions to be reproduced in a joint context where two individuals are coordinating to reach a shared instrumental goal, compared to a solo context in which the irrelevant action is produced individually and without coordination. First, participants correctly identified that the irrelevant step was not causally necessary for achieving the goal, as they consistently rated the relevant actions as more necessary than the irrelevant ones. However, they judged the solo irrelevant action as significantly more necessary than the joint irrelevant action. The results also revealed that adults expect others to imitate joint actions more faithfully compared to individual actions. Interestingly, this expectation did not extend to their own imitation behavior.

Overall, these findings suggest that although adults understand the causal link between actions and their outcomes, they still expect others—though not themselves—to reproduce joint actions more faithfully. This pattern likely reflects a normative interpretation of joint activities, where actions are seen as socially, rather than instrumentally or causally, significant. More broadly, the results support the view that imitation is a rational and interpretive process (Gergely et al., 2002), rather than a reflexive response driven by causal misunderstanding (Lyons et al., 2007; Lyons et al., 2011).

Study 2 investigated whether 3-6-year-olds are more likely to replicate causally irrelevant actions following joint compared to individual demonstrations of an instrumental (i.e., goal-directed) action sequence. Furthermore, I investigated whether the type of action coordination involved in performing the causally irrelevant step (e.g., bimanual or joint) modulated the tendency to overimitate.

The results of Study 2 suggest that the tendency to overimitate extends to joint contexts, indicated by similar rates of copying following individual and joint demonstrations. Furthermore, the results suggest that action coordination did not play a significant role in modulating children's tendency to overimitate. Overall, the findings indicate that while overimitation occurs in joint contexts, observing coordinated actions and coordinating with a partner during an imitative learning episode does not increase imitative fidelity.

Study 3 investigated the link between teaching and imitative fidelity where children take the role of teachers. Specifically, we sought to understand whether compared to learning a novel (inefficient) behavior for one's own sake, learning the same behavior with the goal of teaching another (e.g., a peer) would lead children to copy adult's actions more closely. We also investigated whether knowing the goal of the demonstration while observing the model—rather than learning about it only after—would help children recall and retrieve the relevant steps when imitating.

We used two methods of assessing imitative fidelity—one which aimed to capture children's tendency to reproduce causally irrelevant steps (coarse-grained measure), and one which aimed to capture the accuracy/fidelity with which children imitated these steps (fine-grained measure). Overall, the results suggest that when coarse-grained (binary) categories were used to assess imitative fidelity, children were sensitive to the timing of the goal such that they were more likely to imitate in the Prior compared to the Post conditions. However, when examining imitative fidelity using a finer variant, no specific patterns emerged. A binary analysis also revealed gender differences in the likelihood of overimitation. Females demonstrated sensitivity to the timing of the goal, imitating more in the Prior compared to the Post conditions. Males, on the other hand, were influenced by both the timing and type of goal. They exhibited an encoding effect when teaching, replicating more steps when anticipating teaching. However, this pattern was reversed when learning for themselves, with males more likely to overimitate in the Post compared to the Prior conditions. Using a finer-grained measure of imitative fidelity, we also identified gender differences. Females were highly sensitive to teaching goals, replicating the original demonstration more faithfully when preparing to teach compared to when learning for themselves. This pattern was not observed in the male group.

Overall, the results of Study 3 add to the growing body of literature on children's active role in propagating cultural knowledge and suggest that children are sensitive to goal type and its timing when imitating novel actions. The findings highlights the central role of goals in the interpretation and encoding of events and suggests that learning with a goal in mind may help learners bind the ensuing actions into a meaningful unit, thereby facilitating their retention in memory when reproducing the event later (Király, 2009; Liechtenstein & Brewer, 1980; Loucks et al., 2017; Schank & Abelson, 2013).

Furthermore, findings of this study are the first to reveal gender differences in how males and females imitate while preparing to teach, paving the way for exciting new research avenues.

5.2 Research contributions

Altogether, the empirical work in this thesis adds substantial contributions to our understanding of imitative learning in children as well as reasoning about imitation in adults. First, they show that the tendency to overimitate—previously documented for individual actions—extends to joint actions. However, participating in a joint activity does not necessarily enhance imitative fidelity, suggesting that coordinated actions within a joint context may differ from coordinated activities in other contexts, like parallel synchronous activity (e.g., Herrmann et al., 2013).

Second, our results suggest that in online settings, people's expectations about imitation differ depending on whether they are considering themselves or others. Specifically, adults expect others to imitate joint activities more faithfully than individual actions, a pattern not seen in their expectations regarding their own behavior. Third, we found that access to goal information enhances the retention and recall of actions.

Finally, our findings also shed new light on gender differences in teaching behaviors during childhood.

5.3 Interpretation of the results in view of the existing theories of children's imitative learning

Early theories of imitative learning proposed that imitation is an automatic process, in which observers encode all intentionally performed actions they perceive as causally relevant (e.g., Lyons et al., 2007; Lyons et al., 2011). Within this framework, overimitation is viewed as a mistaken inference—whereby learners assume that even causally irrelevant elements must contribute to achieving the goal and therefore reproduce them.

However, more recent theoretical and empirical work has challenged this view, emphasizing that children do not imitate blindly or indiscriminately. Instead, they exhibit considerable flexibility when learning imitatively, suggesting that imitation is a rational and context-sensitive process. Naïve learners actively interpret contextual cues—such as the goal of the model, situational constraints and other features pertaining to the learning environment—to decide which elements of an action sequence to reproduce (Gergely et al., 2002; Legare et al., 2015; Over & Carpenter, 2012).

Prominent accounts that speak to the flexible nature of imitation include the rational accounts (Gergely et al., 2002), as well as the affiliative (Over & Carpenter, 2012) and normative frameworks (e.g., Kenward et al., 2011; Keupp et al., 2013). Other approaches emphasize more generally imitation's dual function in supporting both cultural and instrumental skill acquisition (Legare & Nielsen, 2015; Legare et al., 2015).

The overarching aim of this thesis was to contribute to the growing body of research on imitative flexibility in childhood by expanding the focus from individual learning contexts to include joint actions. Specifically, the goal was to explore how the context of joint action influences imitation, and whether learners apply the same principles as they do when observing individual actions—or whether joint actions are interpreted and imitated differently.

Given the inherently social, shared and potentially normative/conventional nature of joint activities (e.g., Rakoczy et al., 2008; Rakoczy & Schmidt, 2013), we hypothesized that observing joint actions would lead to stronger expectations for faithful imitation, and that participating in coordinated joint actions with a partner will increase fidelity with which the behavior is imitated. This hypothesis was informed by prior research showing that children are more likely to imitate actions faithfully and jointly after observing coordinated activities (Fawcett & Liszkowski, 2012). It also draws on findings from infant research, which suggest that while learners generally expect individual goals to be pursued efficiently (Gergely & Csibra, 2003), inefficiencies are more acceptable when individuals are seen as collaborating toward a common goal (Begus et al., 2020; Vizmathy et al., 2024).

Overall, the findings from this thesis offer support for the view that imitation is a rational, interpretive, and flexible process, rather than a blind or automatic learning response. Study 1 showed that individuals take social context into account when passing judgments regarding others' imitative behavior. Specifically, participants expected more faithful imitation when the actions were performed jointly. This expectation extended beyond their own imitative behavior to include judgments about how others should imitate, demonstrating that the flexibility of imitation also applies to how people evaluate others' actions.

Contrary to our predictions, action coordination involved in the performance of the causally irrelevant action did not affect participants' expectations of imitation fidelity. Participants did not expect more faithful imitation of the coordinated irrelevant joint action compared to the non-coordinated version. This may be because coordination varied only in a single, causally irrelevant action, while the rest of the demonstration consistently featured turn-taking between partners. In other words, even though some steps were less coordinated, the overarching goal of jointly opening the box was still achieved through coordination. As a result, participants likely perceived the demonstration as highly coordinated overall, reducing the impact of coordination in the irrelevant action on their imitation judgments. Moreover, this finding suggests that participants may have interpreted coordination at the level of the overall joint goal, rather than focusing on the specific action kinematics.

Observing coordinated joint actions may have led observers to interpret the behavior as normative—i.e., as an activity that, being shared, represents culturally accepted and stable ways of doing things. This interpretation is supported by research from Rakoczy and colleagues (Rakoczy et al., 2008; Rakoczy & Schmidt, 2013) who suggest that during childhood, children view social activities (such as joint games) through a normative lens, closely adhering to the associated rules and protesting when a third party deviates from the norm by attempting to play the game differently. Additionally, joint actions may signal shared commitment, indicating that those involved are mutually invested in the activity. Studies with both adults and children show that joint participation can enhance perceptions of commitment, which in turn may increase expectations for faithful imitation (Gräfenhain et al., 2009; Michael et al., 2016). In sum, joint actions likely serve as indicators of both normativity and shared commitment, prompting observers to anticipate higher fidelity in imitation as a result.

Participants were also able to distinguish between causally relevant and irrelevant actions, consistently rating irrelevant steps as less necessary. Yet, even with this understanding, they still expected more faithful imitation—of both relevant and irrelevant steps—when the action was performed jointly. This suggests that the mere presence of a shared goal in the joint context served as a potent cue, prompting expectations for higher imitation fidelity.

Taken together, these findings support the idea that overimitation is not simply the result of causal confusion, where irrelevant actions are misunderstood as necessary (Lyons et al., 2007), but rather a context-sensitive, interpretive behavior. They align with theoretical accounts (e.g., Gergely et al., 2002) that view overimitation as a rational response to social and communicative cues. Overall, the results offer valuable insight into how joint actions contribute to the cultural transmission of shared practices and provide evidence that a joint context increases expectations of imitative fidelity.

However, the results of Study 2 did not provide evidence that participating in a joint activity increases imitative fidelity in childhood. One possible explanation for this null finding lies in the inherently social nature of imitation—children may feel a strong social drive to overimitate simply due to being observed by another (Lyons et al., 2007; Marsh et al., 2019; Nielsen & Blank, 2011) or out of a desire to affiliate with the model and be like them (Over & Carpenter, 2012) even when acting alone. This suggests that the characteristics of live imitative learning contexts may naturally promote faithful imitation (Hoehl et al., 2019), regardless of whether the action is performed solo or jointly. Importantly, the findings from Studies 1 and 2 suggest that third-party observation and active participation offer distinct avenues for understanding how joint actions shape learning. While observation may shed light on how normative expectations shape learning, active participation may be better suited to exploring the social pressures that live learning contexts have on imitative learning.

In Study 3, we found that—across both measures of imitation fidelity—children were *not* more likely to imitate faithfully in the Teaching, compared to the No Teaching, conditions, counter to our predictions. However, they were more likely to imitate the causally irrelevant actions when they were provided with instructions about their video before (Prior), compared with after (Post), the demonstration in both the Teaching and the No Teaching conditions. These findings speak in support of previous research showing that prior knowledge of the goal of a demonstration can facilitate children's organization of the actions demonstrated into meaningful units (e.g., Bauer, 1992; Bauer & Mandler, 1989; Bauer & Hertsgaard, 1993;

Király, 2009; Travis, 1997) and enhance memory and recall of goal-relevant sub-actions (Carpenter et al., 2002; Loucks et al., 2017).

However, using a fine-grained measure of imitation fidelity, there was some evidence that females viewed the demonstrator's actions as normatively significant in the teaching context. Females not only imitated irrelevant actions more in the Prior than Post conditions overall but also copied the specific details of the actions more in the Teaching than No Teaching conditions—consistent with our predictions. Males, however, showed a different pattern. Like females, they imitated more irrelevant actions in the Prior than Post condition when teaching was involved. However, in the No Teaching conditions, they did the opposite—imitating more irrelevant actions in the Post than the Prior condition.

The increased imitation in the Prior condition when participants expected to teach suggests that having a teaching goal beforehand may help encode and retain normative aspects of the demonstration. However, the reason males imitated more irrelevant actions in the Post condition when learning for themselves is less clear. One possible explanation is that being reminded of the video camera just before performing increased their self-awareness. However, since this effect was not observed when males anticipated teaching, it is likely that the timing of the camera mention alone does not explain the pattern of results. Instead, the results may also reflect a greater sensitivity among males to maintaining their self-image when learning for themselves compared to when preparing to teach.

One possible explanation for the gender differences observed in Study 3 is that males and females may be socialized differently about teaching or have varying early exposure to teaching-related activities. However, this remains an open empirical question. Given the mixed findings on gender differences in overimitation and the limited research on gender-patterns in teaching behavior, further investigation is needed to clarify these potential differences and their developmental origins.

Overall, Study 3 contributes to research on how children actively transmit cultural knowledge (e.g., Qiu & Moll, 2022), highlighting the influence of context and timing on their imitation of novel actions. Notably, the study is the first to identify gender differences in imitation when anticipating teaching, opening up new directions for future research.

5.4 Limitations and future directions

We acknowledge several key limitations that may have influenced our findings. In Study 1, for example, we did not find evidence that action coordination modulates expectations of imitative fidelity. As we have argued on page 32, one possible explanation is that the coordination associated with the irrelevant action was not made sufficiently salient in the current design to meaningfully assess its impact on transmission fidelity. Specifically, the level of coordination differed only slightly between the joint coordinated and joint non-coordinated conditions, while models coordinated throughout the rest of the demonstration to open the box.

Therefore, future research exploring the relationship between joint action coordination and imitative fidelity should aim to more clearly differentiate between coordination that is intrinsic to the joint activity and coordination that is specific to targeted components within that activity. One approach to achieving this distinction in the current paradigm would be to include a control condition in which both partners perform the irrelevant action independently but simultaneously, while still coordinating turn-taking for the relevant steps—i.e., a parallel action setup (e.g., Fawcett & Liszkowski, 2012). This would help determine whether jointly performing the irrelevant action leads to stronger expectations of faithful imitation than simply acting in parallel.

Moreover, a study design in which all actions are performed in parallel and on two identical objects could offer deeper insight into how different forms of coordination influence expectations of imitation, depending on whether they emerge from joint intentionality (e.g., coordination aimed at achieving a shared goal) or from parallel but independent activity (as in Herrmann et al., 2013). Addressing this open question remains a task for future research.

It is possible that distinct cognitive processes underlie learning from these different forms of coordinated activity. For example, observing individuals performing actions in parallel may evoke a ritualistic interpretation, leading to (expectations of) high-fidelity imitation regardless of the absence of shared goals (Herrmann et al., 2013). Similarly, when people observe the same action being performed by many individuals, they may expect that behavior to be imitated more faithfully simply because it appears to be the most common within the group (e.g., a majority bias; Haun et al., 2012; Haun et al., 2013). In contrast, when observers see two individuals coordinating toward a shared goal, they may be more likely to interpret the behavior normatively—i.e., as a socially endorsed way of doing things. This can lead to expectations of faithful imitation, based on the assumption that such joint actions reflect culturally shared practices.

One way to test whether observers interpret joint—but not parallel—actions normatively, is to present them with a scenario where one participant disengages from the activity and assess whether observers respond with protest, following the approach of Rakoczy and Schmidt (2013).

In Study 2, the relatively low rates of overimitation in the joint action condition may be explained by the absence of interactive cues between the two models, which may have made it difficult for children to recognize the event as truly joint. This was an intentional design choice to keep the joint and individual conditions closely matched and avoid the influence of ostensive cues, such as direct gaze, which are known to enhance overimitation (Csibra & Gergely, 2011). However, prior research suggests that social interaction—both before and during action demonstrations—is critical for young children to interpret actions as collaborative (Fawcett & Gredebäck, 2013; Siposova et al., 2018). The lack of social engagement and the fact that only one model completed the task may have led children to interpret the event as helping rather than as a joint goal, reducing their likelihood of faithfully imitating irrelevant actions.

To better isolate the effects of joint action on imitation, future studies should enhance the salience of shared goals—possibly through mutual reward sharing and visible social interaction. A promising approach could involve having children observe joint demonstrations from a distance, reducing direct communicative cues towards them while providing strong cues of joint coordination between the models. Such designs could help determine how joint intentionality and social context shape imitative learning, providing valuable insights for educators and caregivers seeking to foster collaborative learning environments.

In Study 3, one reason for the lack of observed differences between the Teaching and No Teaching conditions might be that, for practical reasons, children were only informed that their video would be used to teach other children how to open the box; they did not actually engage in direct teaching. This setup may have diminished the impact of the teaching context, making it less likely that the manipulation was effective. Given the finding that none of the children produced communicative cues to the camera that would signal an intention to teach someone (e.g., looking at and speaking ostensively to the camera, pointing, ostensively performing the actions), we were led to conclude that our teaching manipulation might not have been very effective. Therefore, future studies could further explore the link between teaching and imitative fidelity by having participants engage in actual, live teaching with the learner present.

In summary, the findings presented in this thesis show that adult observers develop context-sensitive expectations about others' imitative behavior. Moreover, young children do not show increased imitative fidelity when participating in minimally interactive joint actions—likely because these interactions lacked sufficient social or ostensive cues to be recognized as genuinely collaborative. Additionally, when imitation is framed as a preparation for teaching, females tend to imitate with greater fidelity than when learning for themselves, whereas males exhibit more variable patterns across these contexts. Finally, children recall and reproduce actions more accurately when they understand their goal in the situation, underscoring the importance of goal attribution in imitation. This finding supports theoretical accounts of teleological reasoning and highlights the rational and flexible nature of early imitative learning (Gergely & Csibra, 2003; Legare et al., 2015).

5.5 Practical implications

The findings of this thesis offer practical insights for practitioners and early caregivers, with implications for educational practice. For example, since young children may not recognize minimally interactive joint actions as genuinely collaborative, educators should include clear social and ostensive cues—such as eye contact, turn-taking, and shared goals—when designing group learning activities. This approach can facilitate children's understanding and engagement in collaborative activities. Given the early-emerging preference for attending to social stimuli (Abassi & Papeo, 2020; Papeo & Abassi, 2019) and the importance of coordinated behavior in social practices like rituals and conventions, further investigating how these contexts shape learning is a crucial next step.

Additionally, observing individuals performing together may foster a normative interpretation, leading the observing learners to view the behavior as socially and culturally relevant. As a result, actions modeled by two individuals acting jointly may be a more effective way of transmitting practices to novices than having them modeled by a single person.

Furthermore, since girls often show higher imitative fidelity when anticipating a teaching role, classroom strategies that frame learning as preparation for peer teaching (e.g., "You'll show this to your friend later") could enhance learning and retention (for similar findings on the effects of peer teaching and preparing to teach on memory for actions, see Bargh

& Schul, 1980). This approach may also reduce reliance on adult-child instruction and foster peer collaboration. This is particularly significant considering previous research showing that participation in joint activities can improve rapport (Bernieri, 1988), increase cooperation (Wiltermuth & Heath, 2009), build trust (Mitkidis et al., 2015), and promote prosocial behaviors such as helping, among participants (Kokal et al., 2011).

Lastly, ensuring that children understand the purpose behind an action—rather than simply demonstrating it—can improve both recall and fidelity. Teachers and caregivers should thus clearly articulate the "why" behind tasks and actions, in line with theories of teleological action understanding (Csibra & Gergely, 2003) and rational imitation (Gergely et al., 2002).

Appendices

Appendix 1

The following section outlines the results of exploratory analyses examining the relationship between overimitation and age.

To determine whether age was a significant predictor of overimitation in children, a logistic regression analysis was conducted with Social Condition (Individual vs. Joint) and Action Coordination (Yes vs. No) as fixed factors, and Age as a covariate. The analysis revealed no significant effect of Age on overimitation rates, $p = .221$. The corresponding effect size, Cohen's $d = 0.17$, indicates a small effect.

A closer analysis of the numerical differences indicates a gradual increase in overimitation rates with age, aligning with previous research and underscoring the rising importance of high-fidelity copying as a key learning strategy in childhood (Brugger et al., 2007; Lyons et al., 2007).

While the numerical increase in overimitation rates holds true for 3-year-olds (25% imitated), 4-year-olds (48% imitated) and 5-year-olds (68% imitated), there is a slight decrease observed in 6-year-olds, with 47% imitating the causally irrelevant action. However, when looking at the percentage of overimitation for the different conditions separately, the data indicate that the observed numerical decrease in overimitation in 6-year-olds might be due to the overall lower rates of overimitation for the No coordination compared to Coordination conditions in this age group. For details on the four age groups, see Table 1.

Table 1. Overimitation rates by age group, social condition, and action coordination

Age group	Individual NC	Individual C	Joint NC	Joint C
3-year-olds	25% (n=4)	0% (n=2)	0% (n=2)	100% (n=1)
4-year-olds	83.33% (n=6)	40% (n=10)	33.33% (n=9)	42.86% (n=7)
5-year-olds	75% (n=12)	62.5% (n=8)	63.63% (n=11)	57.14% (n=14)
6-year-olds	33.33% (n=3)	80% (n=5)	20% (n=5)	50% (n=4)*

* N represents the total sample size in the corresponding age group.

Appendix 2

Table 2. Coding scheme for the two main measures of imitative fidelity

Steps	**Coarse measure: 0-3**	**Imitation sub-score** (for irrelevant actions only): **0-6**	**Sequence sub-score: 0-2**
Step 1: Push egg onto platform	--	--	Child receives **2 points** if they performed all the steps in the correct order Child receives **1 point** if they made one mistake (omission/incorrect order/non-consecutive repetition of steps) Child receives **0 points** if they made more than 1 mistake (omission/incorrect order/non-consecutive repetition of steps)
Step 2: Roll mallet between hands		Child receives a **score of 2** if they rolled the mallet more or less vertically back and forth between their two palms more than once (back and forth at least twice = 4 rolls)	
	Child receives a **score of 1** if they rolled the mallet in any direction (vertically/horizontally/diagonally) between their two palms any number of times	Child receives a **score of 1** if they rolled the mallet in any direction (vertically/horizontally/diagonally) between their two palms only once back and forth for more than one second, or more than 3 times	
	Child receives a **score of 0** if they did not perform the step	Child receives a **score of 0** if they did not perform the step	
Step 3: Tap top of box with mallet		Child receives a **score of 2** if they tapped on top of the box 3 times with the round part of the mallet	
	Child receives a **score of 1** if they tapped on any part of the box with any part of the mallet (or a finger) any number of times	Child receives a **score of 1** if they tapped on any part of the box with any part of the mallet (or a finger) any other number of times (i.e., fewer or more than 3).	
	Child receives a **score of 0** if they did not perform the step	Child receives a **score of 0** if they did not perform the step	
Step 4: Move mallet diagonally across top of box twice to make an X		Child receives a **score of 2** if they dragged the round part of the mallet across the top of the box (i.e., moved it along the box at least 5cm approximately) diagonally twice to make an X	
	Child receives a **score of 1** if they dragged (i.e., moved along the box at least 5cm	Child receives a **score of 1** if they dragged any part of the mallet (or a finger) across any	

	approximately) any part of the mallet (or a finger) across any part of the box any number of times	part of the box (i.e., moved it along the box at least 5cm approximately) at least once in any direction/shape	
	Child receives a **score of 0** if they did not perform the step	Child receives a **score of 0** if they did not perform the step	
Step 5: Pull lever to release egg	--	--	

We conducted an additional, separate set of analyses on the two components of the imitative fidelity measure: the imitation sub-score and the sequence sub-score. This approach, consistent with prior studies on imitation (e.g., Király, 2009; Legare et al., 2015), aimed to explore whether teaching and instruction timing had distinct effects on two aspects of children's imitation: the accuracy of reproducing the modeled irrelevant steps (imitation sub-score) and the preservation of the step order in the action sequence (sequence sub-score).

Imitation sub-scores

A mixed model ANOVA with Teaching (Teaching vs. No Teaching) and Instruction Timing (Prior vs. Post) as between-subjects factors, and Trial number (Trial 1 vs. Trial 2) as a within-subjects factor was conducted on the imitation sub-scores. The ANOVA yielded no significant results (see Table 3 for a summary).

Including Gender as a between-subjects factor yielded a significant two-way interaction between Teaching and Gender ($F(1,37) = 8.12$ $p = .007$, $\eta^2_p = 0.180$). An analysis of simple main effects (Figure 1) revealed a significant main effect of Teaching for females, $F(1) = 4.80$, $p = .043$, but not for males, $F(1) = 3.29$, $p = .085$, indicating that females were significantly more likely to faithfully imitate the irrelevant steps when instructed that their video would be used to teach other children compared to when learning the behavior for themselves.

Table 3. ANOVA summary for the imitation sub-score

Within Subjects Effects						
Source	Sum of Squares	df	Mean Square	*F*	*p*	η^2_p
Trial Number	2.24	1	2.24	2.29	.14	.05
Trial Number x Teaching	0.45	1	0.45	0.46	.50	.01
Trial Number x Instruction Timing	1.21	1	1.21	1.24	.27	.03
Trial Number x Teaching x Instruction Timing	1.14	1	1.14	1.16	.29	.03

Between Subjects Effects						
Source	Sum of Squares	df	Mean Square	*F*	*p*	η^2_p
Teaching	0.07	1	0.07	0.02	.90	3.873×10^{-4}
Instruction Timing	3.61	1	3.61	0.80	.38	.02
Teaching x Instruction Timing	4.33	1	4.33	0.96	.33	.02

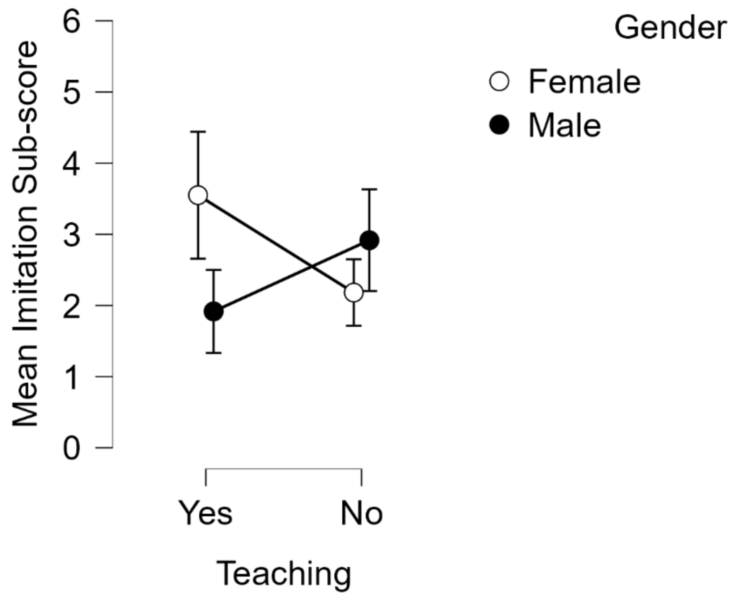

Figure 1. Mean imitation sub-scores comparing the Teaching and No Teaching condition by gender**.** Error bars represent 95% CI.

Sequence sub-scores

A mixed model ANOVA with Teaching (Teaching vs. No Teaching) and Instruction Timing (Prior vs. Post) as between-subjects factors, and Trial number (Trial 1 vs. Trial 2) as a within-subjects factor was conducted on the sequence sub-scores. The ANOVA yielded no significant results (see Table 4 for a summary).

Table 4. ANOVA summary for the sequence sub-scores

Within Subjects Effects						
Source	Sum of Squares	df	Mean Square	F	p	η^2_p
Trial Number	0.21	1	0.21	1.35	.25	.03
Trial Number x Teaching	0.12	1	0.12	0.75	.39	.02
Trial Number x Instruction Timing	0.12	1	0.12	0.75	.39	.02
Trial Number x Teaching x Instruction Timing	0.52	1	0.52	3.27	.08	.07

Between Subjects Effects						
Source	Sum of Squares	df	Mean Square	F	p	η^2_p
Teaching	0.72	1	0.72	0.67	.42	.02
Instruction Timing	0.00	1	0.00	0.00	.96	7.550×10^{-5}
Teaching x Instruction Timing	0.33	1	0.33	0.31	.58	.01

Including Gender as a between-subjects factor yielded a significant interaction between Teaching, Instruction Timing, and Trial Number ($F(1,37) = 4.41$ $p = .043$, $\eta^2_p = 0.107$), a significant interaction between Teaching and Gender ($F(1,37) = 5.89$ $p = .020$, $\eta^2_p = 0.138$), and a significant interaction between Trial Number and Gender ($F(1,37) = 6.82$ $p = .013$, $\eta^2_p = 0.156$).

Further analysis of the interaction between Teaching, Instruction Timing, and Trial Number conducted through separate univariate ANOVAs for each trial revealed no significant effects and is therefore not reported here. Further analysis of simple main effects for the interaction between Teaching and Gender (Figure 2) revealed a significant main effect of Teaching for females $F(1) = 5.47$, $p = .032$, but not for males, $F(1) = 1.07$, $p = .313$, indicating that females were significantly more likely to faithfully imitate the order of the action steps in the Teach compared to the No Teach condition. Finally, further analysis of simple main effects for the interaction between Trial Number and Gender (Figure 3) revealed a significant main effect of Trial Number for males $F(1) = 5.00$, $p = .037$, but not for females, $F(1) = 2.34$, $p = .144$, indicating that males were significantly more likely to faithfully imitate the order of the action steps in Trial 1 compared to Trial 2. No other significant interactions or main effects were observed.

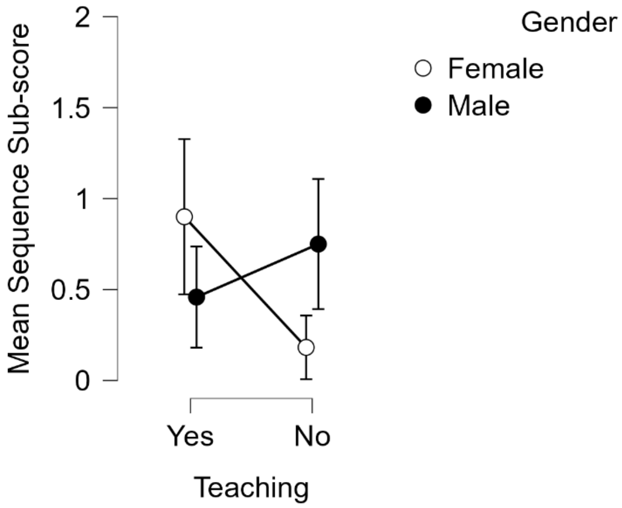

Figure 2. Mean sequence sub-scores comparing the Teaching and No Teaching conditions by gender**.** Error bars represent 95% CI.

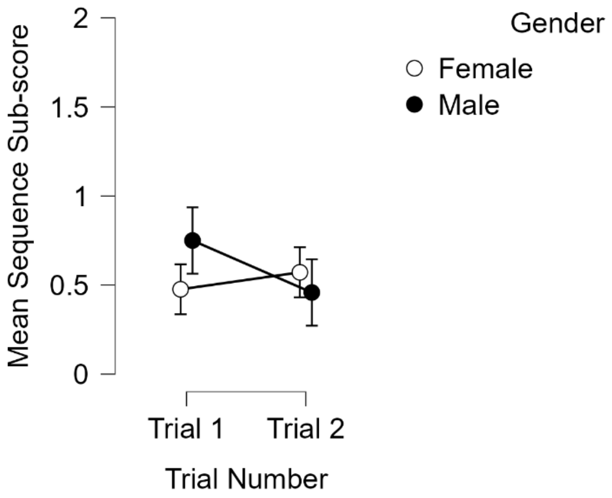

Figure 3. Mean sequence sub-scores by gender and trial number**.** Error bars represent 95% CI.

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