Preschoolers' recognition of and inferences from observed imitation

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Abstract

Six experiments explored the apparent discontinuity between infants' success at inferring affiliation from observed imitation (Powell & Spelke, 2018), and 4-year-olds' failure on the same inference (Over & Carpenter, 2015). We first tested whether children younger than age 4 (i.e., 3-year-olds) have an explicit, verbalizable, concept of imitation. Three-year-olds observed acts of imitation and could identify the copier (Exp. 1) and who the copier was "copying" (Exp. 2), thus demonstrating a lexicalized concept of imitation. Adults spontaneously inferred that the copier's affiliation lies with the model over the non-model and that she will continue to copy the same model in the future (Exp. 3), but even five-year-olds failed at these two inferences and preschoolers showed no improvement from ages three to five (Exp. 4). However, preschoolers succeeded at making correct inferences when we primed the concept of imitation either lexically by use of the word "copy" (Exps. 2 and 6), or non-lexically by drawing attention to the fact that the copier had done something "like" one of the models (Exps. 5 and 6). Taken together, the findings provide evidence of continuity between the representations of imitation from infancy through the preschool years to adulthood. In the context of the present experiments, however, young children do not always spontaneously encode the central character's preferential imitation of one model over another.

Keywords: imitation, social inferences, early childhood

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Imitative behavior emerges early in life (Meltzoff & Moore, 1977; Jones, 2007), and is an important tool through which infants and young children learn about the world around them and how to act on it. Young children are ignorant of the causal mechanisms through which almost all artifacts achieve their intended functions, leaving imitation of others' uses as a major way they themselves can come to use them. Moreover, imitation plays many social functions as well. For one, children are driven to imitate because they want to be like others and to demonstrate that they are willing to do things in a culturally-sanctioned way (Over & Carpenter, 2013). This motivation is one source of the phenomenon of over-imitation, excessive loyalty to copying a model's actions (Horner & Whiten, 2005; Lyons, Damrosch, Macris & Keil, 2011). Of course, another source of over-imitation is causal opacity; children assume adults know more than they do about what actions are necessary to achieve an effect. Evidence for the social function of over-imitation derives from many sources. For example, five-year-old children imitate with more fidelity when primed with social exclusion (Over & Carpenter, 2009a), suggesting that a motivation to affiliate with others can drive imitation. Going further, imitation has consequences for conformity, group cohesion, and prosocial behavior. For instance, adults who have been mimicked are subsequently more helpful and give more to charity than those who have not (van Baaren, Holland, Kawakami, & van Knippenberg, 2004). Similarly, 18-month-olds are more helpful after having been imitated, even towards someone who had not been their imitator (Carpenter, Uebel, & Tomasello, 2013).

All of the above phenomena reflect the role imitation plays in establishing and maintaining social relations. Because of these phenomena, another socially important function of imitation is that third-party observations of imitative behavior are informative about people's relationships with and attitudes towards each other. Evidence that adults make use of observed imitative behavior to this end derives from a study in which adults judged an individual who

mimicked a condescending interviewer as less competent than both a non-mimicker of the same interviewer and someone who mimicked a cordial interviewer (Kavanagh, Suhler, Churchland, & Winkielman, 2011). Although such sophisticated feats of inference are out of reach for younger viewers, even infants draw impressive inferences from observing one actor imitating another. Using a looking-time paradigm, Powell and Spelke (2018a) showed 4-month-old infants displays of cartoon characters involving imitators and non-imitators. Infants' looking times showed that they expected an imitator to approach and affiliate with the model of its imitation, but they were surprised to see a third character who had not copied the model approach it. In a separate experiment, they found that infants held no expectations about models of imitation approaching their imitators compared to approaching a third, non-imitator character. Further, infants in a separate study looked more at and reached more towards an imitator compared to a non-imitator when offered the chance to choose between physical replicas of the characters (Powell & Spelke, 2018b). These findings indicate that even very young infants see imitation as a positive act, with distinct roles of model and imitator, and associate imitation with affiliative goals from the imitator towards the model.

Studying an older age group, Over and Carpenter (2015) examined the link between imitation and affiliation in preschoolers. They showed children videos of three individuals, one of whom consistently copied four actions performed by one of the other individuals (two different sitting positions, object choice, action on an object). Children aged four and five years were asked whom the imitator liked more. Five-year-olds, but not 4-year-olds, responded by choosing the model of imitation significantly more than expected by chance, and the majority of those responding correctly provided explanations related to copying. Given that Powell and Spelke (2018a) showed that infants expect an imitator to affiliate with the model of imitation, it is puzzling that 4-year-olds failed to infer that an imitator likes the model she imitated more than the person she did not imitate. That is, the question arises why 4-year-olds did not infer affiliation from observed imitation, when infants did.

While puzzling, this seeming discontinuity between infants and preschoolers is not an isolated phenomenon. For instance, there is apparent discontinuity in understanding that objects cannot pass through solid barriers. While looking-time experiments show very young infants harboring the right expectations (Spelke, Breinlinger, Macomber, & Jacobson, 1992), children facing a similar conceptual task fail to reach in the correct location for a hidden object, when that location is constrained by a barrier through which the sought object could not pass, until well after three years of age (Hood, Prasada, and Carey, 2000; Berthier, DeBlois, Poirier, Novak, & Clifton, 2000). Another instance of discontinuity is that of false belief understanding, where there is evidence that infants demonstrate correct expectations in looking-time experiments (e.g. Onishi & Baillargeon, 2005; Southgate, Senju, & Csibra, 2007; but also see reports of lack of infancy replications, e.g. Powell et al., 2018; Kamps, Karman, Csibra, Southgate, & Hernik, 2021). In contrast, preschoolers do not pass the classic theory of mind task, which also requires false belief understanding, until age four (Wellman, Cross, & Watson, 2001).

Some interpretations of the disconnect between looking-time studies and later preschool studies draw a distinction between implicit and explicit representations, where explicit representations are encoded in linguistic symbols, and articulate explicitly held beliefs and intuitive theories. On this interpretation, the representations that underlie infant responses are implicit, and the tasks at which preschoolers fail require later-developing explicit representations.

It is possible that the process of building explicit concepts such as *imitation* and *like* (in the sense of affiliation) is a prerequisite to learning explicit generalizations such as “if agent A reliably imitates agent B, agent A probably likes agent B”. The hypothesis that children may need explicit concepts—in the sense of a symbol for a concept that can enter into propositional representations, like a word—in order to build theory-like generalizations such as the above raises several possibilities with respect to the 4-year-olds’ failure in Over and Carpenter (2015).

The present studies distinguish four possibilities about the source of this failure: 1) lack of an explicit concept of imitation, 2) lack of an explicit understanding that preferential imitation indicates that the copier likes the preferred model over the other individual, 3) lack of an explicit understanding that agents might have stable dispositions to imitate a preferred model, or 4) lack of spontaneously encoding imitation in these experimental situations, *even if* children have an explicit concept of imitation, an explicit knowledge of the likelihood of continued imitation of a preferred model, and an explicit knowledge that such imitative behavior signals affiliation.

We first tackle the possibility that children younger than five years might not have an explicit concept of imitation. Although having a verbalizable concept of imitation is not necessary for possessing the concept, having a word that means *imitate* certainly provides sufficient evidence for concept possession. One reason to think that children younger than five years, even 3-year-olds, do have the concept is the observation of the word “copy” in child speech at this age. A search of the CHILDES database (MacWhinney, 2000) using the R package *childesr* (Sanchez et al., 2019), which contains data from 847 children who are English-speakers and younger than four years of age, finds 52 instances of the word “copy” uttered by children. In 27 cases, “copy” is used to refer to imitating another person (e.g. “Are you copying me again?”). In the remaining 25 cases, “copy” is used to describe copying a drawing (3 cases), used in a compound format like “copycat” (5 cases), or is ambiguous as to whether it refers to copying people or not (17 cases, e.g. “I’m copying”). Thus, although the use of the word “copy” to mean imitate is rare in the transcripts of children under age 4, these observations suggest that at least some 3-year-olds have an explicit, verbalizable concept of imitation.

Experiment 1 explores whether 3-year-olds as a group understand the word “copy” to mean *imitate*. This requires testing whether 3-year-olds view imitative actions as true imitation, i.e. a directional act of observing then repeating the actions of another with distinct roles for the copier and the model, or if they see it as similarity of actions, i.e. two people doing the same actions as each other regardless of who went first. We probe whether 3-year-old children can

identify the complementary roles embedded in imitation. In Experiment 1, we ask 3-year-old children to identify the copier (“Who was copying the other one?”)

We next test the second possibility raised above, namely that preschoolers (aged 3-5 years) may lack explicit knowledge that imitation signals affiliation from the copier towards the model. With respect to social affiliation generally, there is strong evidence to suggest that preschoolers have an explicit, verbalizable concept of “friend” in the sense of one individual harboring affiliative motivations towards another. Although the term “friend” has depth and meaning beyond affiliation to preschoolers (Afshordi & Liberman, 2020), tasks that ask children whether they would like to be friends with one of two individuals assume that their choice would be based on liking for that person. A host of studies have used this term to gauge young children’s affiliation towards others based on a variety of group markers including language, accent, gender, and race (Kinzler, Dupoux, & Spelke, 2007; Shutts, Roben, & Spelke, 2013). What these studies show is that children systematically extend their own affiliation towards fellow group members. When it comes to third-party judgments too, preschool-aged children infer liking or friendship between individuals. In some cases, these inferences rely on group membership markers, such as 4-year-olds inferring friendship between two children of the same gender or race (Shutts, Roben, & Spelke, 2013; Roberts, Williams, & Gelman, 2017). In other cases, children make inferences based on individual-level information, such as 4-year-olds’ inferences of friendship from similarities in skills or experiences (Afshordi, 2019). Thus, the above evidence shows that well before age five, children make explicit affiliation inferences for themselves and for others.

In Over and Carpenter’s (2015) study, the experimenter told children that the main character liked one of the other two individuals and subsequently asked them who she “liked most” (translated from German). Following this study, we use the wording “like best” rather than “friend” to ask about affiliation preferences in Experiments 2-6. Our goal is to test whether preschoolers infer affiliation from the copier towards the model. Furthermore, to infer affiliation

from imitation, the child must not only encode a single act of imitation as such, but must construe repeated imitation as a stable disposition to imitate. Thus, in addition to asking about affiliation, Experiments 2-6 also test whether children infer such a stable disposition to continue imitating a preferred target of imitation. This question tests the third possible interpretation of preschool failures to infer that the imitator likes the model of her imitation more than a person she has not imitated—that they do not see imitation as a stable disposition. Finally, we test the fourth hypothesis: that all of the above representations and inferences are in place early in the preschool years, but that children do not always spontaneously encode imitative acts as such. Experiments 4 - 6 examine whether and under what conditions children encode imitation and how this affects their inferences about affiliation and continued imitation of a preferred model.

Experiment 1

The goal of this experiment was to test whether 3-year-olds understand the word “copy” to mean imitate in the context of one agent’s imitation of another’s action. We tested this across four blocks with different pairs of characters and different kinds of actions. In Block 1, we gave children the opportunity to observe each character act and then recall individual characters’ actions prior to observing any imitation or being asked any questions about imitation. In Blocks 2-4, children observed imitation and were asked only about imitation with no previous experience naming characters or remembering who did what.

Method

Participants. Following the sample size used by Over and Carpenter (2015), this experiment and all subsequent ones included forty participants at each age tested. Forty 3-year-olds took part in this experiment ($M = 41.8$ months, 19 female). Due to the COVID-19 pandemic, children completed the study online. All children resided in the United States. The majority of the children ($n=36$) came from a database of interested families at the Harvard Lab for Developmental Studies. The families in the database are mostly White and middle-class (79% European American, 15% Asian American, 6% African American). A small number of children

were recruited by word of mouth ($n=4$). Parents or legal guardians provided informed consent for all experiments, and parents received a small gift card.

According to preset exclusion criteria, only children who responded to at least three out of four blocks were included in the final sample. (Blocks were dropped if a child failed to provide an answer, was distracted and inattentive during the stimuli, or experimenter error.) Nine additional children were excluded due to having fewer than three blocks (7), or technical issues that precluded them from hearing stimuli (2).

Materials. Stimuli were presented on slides.com, an online presentation platform. Following Sheskin and Keil (2018), we used colors in order to identify characters (e.g. by their t-shirt color and background) and facilitate children's responding in an online session (see Figure 1 for screen shots of the agents in each block).

Stimuli for Blocks 1, 3, and 4 (Body movements). A number of video stimuli involving pairs of characters were created using the software package, Poser. The characters shown in these videos were computer-generated, naturalistic-looking women (Block 1) and two separate pairs of men (Blocks 3 and 4). The characters performed different body movements, consisting of moving their head, arms, legs, or torso in different ways (e.g. bending sideways, knee lift). At the start of each action, a bell sound effect played and a black bar appeared beneath the character's feet, where it remained for the duration of the action. The individual performed his or her movement following this attention-getter sound and repeated it once more, e.g. lifting her knee twice. These measures were taken to ensure that children attended to the correct character at each point and did not miss any of the actions, especially subtler ones such as head movements. When the model was performing an action, the copier turned his or her head to face the model and kept watching until the action was complete before facing forward again and repeating the action.

Stimuli for Block 2 (Vocalizations). This block involved two cartoon characters (one red, one blue) created in Keynote whose actions consisted of jumping up and down and saying

short nonsensical words. The cartoon characters' appearance was adopted from Powell and Spelke (2018a). Utterances were recorded by female adults, who were chosen from an initial pool of six speakers because their voices were relatively distinct from each other. Each person recorded 16 disyllabic utterances (e.g. shay-shay). Consonants were used only once across the set, but there were two utterances using each of four vowels: /ä/ (la-la, ba-ba), /ü/ (soo-soo, roo-roo), /ā/ (tay-tay, shay-shay), or /ē/ (ghee-ghee, chee-chee), /aɪ/ (jai-jai, kai-kai), /ɔ/ (faw-faw, paw-paw), /oʊ/ (doh-doh, zoh-zoh), and /aʊ/ (vow-vow, mau-mau). When 'speaking', each character jumped up and down twice, and the vocalization played as she jumped. When the model was acting, the copier's eyes and mouth moved, giving the illusion that she had turned towards the model and was watching the actions. Following the end of the action, the copier once again looked ahead and repeated the action she had observed.

Figure 1. Characters from Blocks 1-4 in Experiment 1

Procedure. An experimenter video-conferenced with the child and parent using Zoom. After greeting them and answering questions, she instructed parents to not interfere or react in any way during the experiment. She also informed them that if their child preferred to point instead of giving their answers using color labels, the parent should indicate the child's choice

by relaying the alphabet letter associated with that choice. (Each option had an alphabet letter in a corner.) Before starting the experimental procedure, the experimenter turned her camera off, meaning that children could hear but no longer see her. The session was recorded.

Color warm-up. The experimenter showed a panel of four colors (red, blue, yellow, green), each containing a grayscale picture (e.g. ball, rabbit). She asked children to identify the color behind each picture as a way to test their knowledge of color labels. If children were unwilling or unable to answer, they were instructed to point to the item, and the parent was asked to say which option they had pointed to. Overall, 96% of responses for colors were correct showing that children knew and were able to use color words for generating answers.

The procedure for Block 1 was different from that of Blocks 2-4, so they are described separately below.

Block 1. This block consisted of Introduction, Memory checks, Imitation observation, and Test trial.

Introduction. The experimenter introduced the characters, “Here are two people. One is wearing a yellow shirt and standing in the yellow part, so we’ll call her “YellowGirl”. And one is wearing a green shirt and standing in the green part, so we’ll call her “GreenGirl”. Let’s watch and see what they do.” Then, children watched the characters perform two actions each (YellowGirl moved her legs, and moved her arms, GreenGirl turned to the side, and moved her head.) During each individual’s action, the other character was absent from the scene. The experimenter narrated the actions (e.g. “YellowGirl moved her leg.”) in order to familiarize children with the characters’ names and the actions that they performed.

Memory check. Children watched two trials in which each character performed one of her already-introduced actions while the other character was absent. At the end of each trial, children saw a picture of both characters and had to say who had performed which action. The experimenter praised correct answers, but corrected them and showed the video again if they answered incorrectly.

Imitation observation. Children watched five events in which one character performed an action while the other watched before repeating the action herself. Throughout all five events, one character was consistently the model and the other was the copier. (The identities of the copier and model were counterbalanced across participants.) The actions across each of these five events were unique.

Test Trial. The experimenter asked the Who was Copying test question, “One of these people was copying the other one. Can you tell me who was copying the other one? Was YellowGirl copying the other one or was GreenGirl copying the other one?” The experimenter provided neutral feedback to test question responses.

Blocks 2-4. As in Block 1, these blocks started with the experimenter introducing the characters by their names (Reddo and Bluey, RedGuy and YellowGuy, BlueGuy and GreenGuy). From then on, the structure of these blocks was different from Block 1. First, the experimenter immediately framed the goal of the block, “One of them is going to copy the other one. We’re going to watch what they do, and then I’m going to ask you who was copying who.” Second, children did not see the characters perform any actions on their own. Children also did not complete memory check trials that tested their attention to the specific movements each agent performed. Instead, right after learning the characters’ names, children moved on to Imitation observation (Block 2: Five events of vocalization actions performed by cartoon characters, Blocks 3 and 4: Two events of body movements). These observed events were then followed by the Who was Copying test question, which was worded in the same way as Block 1.

Coding. For memory check trials in Block 1, responses were coded as correct if the child correctly answered both questions in a trial. For the test question, the choice of the copier in response to the question “Who was copying the other one?” was coded as correct.

Results

Analyses in all experiments were carried out using the lme4 package in the software, R (R Core Team, 2017). The proportion of children who provided the correct answer on the single test question of each block is depicted in Figure 2.

Figure 2. Three-year-olds' responses to the Who was Copying question ("Who was copying the other one?") across different blocks in Experiment 1. Significance level denote test against chance performance (* $p < .05$). Dotted line shows chance level. No error bars are shown because each participant gave only one response per block.

Block 1. Preset criteria for exclusion led the test trial of Block 1 to be dropped for seven participants due to being distracted (3), not answering (3), or experimenter error (1). Thus, responses for this block were available for 33 participants in the sample. Children answered the memory check questions with 86.4% accuracy. On the Who was Copying test question, 24 out of 33 children answered correctly (72.7%), which is significantly better than chance according to a binomial test ($p = .013$, Cohen's $h = 0.47$). There was no difference in performance depending on whether children heard the copier's name mentioned first (13/16 correct responses) or second (11/17 correct responses) on the test question (Fisher's exact test, $p = .44$).

Blocks 2-4. Data were available for all 40 participants (only one test question was dropped for one child due to experimenter error). Children provided correct responses on 55.5% of questions. To compare performance against chance, a mixed-effects binary logistic

regression analysis including the intercept as the only fixed effect and participant as a random effect was conducted (`glmer(Response ~ 1 + (1|Participant))`). (Henceforth, all comparisons against chance for measures where participants provide more than one response will be conducted using this same method of a mixed-effect binary logistic regression.) This revealed performance to be at chance ($p = .35$). Furthermore, performance was at chance for each block when considered separately.

Discussion

In the first block, 72.7% of 3-year-olds correctly identified the copier. They could identify that it was, for instance, YellowGirl who was imitating the other one, rather than GreenGirl who was imitating the other one. This is a complex question which requires seeing imitation as an asymmetric relation between two agents that are performing the same action. In contrast, 3-year-olds failed to identify the copier in each of the remaining three blocks. These findings suggest that a concept of imitation that encodes the asymmetric roles of model and copier is mapped onto the word “copy” by 3-year-olds as a group, otherwise children would have responded at chance levels in the first block too.

Why would children succeed in Block 1, and fail in Blocks 2 through 4? Clearly, practice encoding the actions of each character, one at a time, and practice naming the character who carried out an action, helped children encode the subsequent sequence of imitation events in terms of who was copying whom. Importantly, though, this practice provided no information about which character was the copier. Equally clearly, merely telling children they would be asked who was copying whom was not sufficient for them to encode the imitation in the events in Blocks 2-4. These results together suggest that 3-year-olds do have an explicit role-based concept “copy” that they can apply appropriately to acts of imitation, but that priming that concept (both from Block 1, and by telling them they will be asked about copying) is not sufficient to allow them to encode the imitation in events in which they have not had practice focusing on each participant, and remembering who did what. That is, the fourth hypothesis—

that acts of imitation are not always encoded as such—receives some support. All subsequent experiments include warm-up trials that focus children on individual actors, their actions involved in a series of events, and memory probes for which actors performed which actions prior to the child's being shown imitation events.

Experiment 2

Experiment 2 had two goals. First, we sought to confirm that three-year-old children can identify the model of imitation, in contrast to another actor whose actions were not imitated. After watching the imitation events, children were asked “Which one was Jenny copying?” Second, we began to probe what inferences 3-year-olds draw from observing that an agent selectively imitates one model over another. A minimal, non-social, concept of imitation might lead to no social inferences. That is, the content of “A copies B” may be exhausted by “agent A intentionally repeats an immediately preceding action of agent B”. If this is the concept that 3-year-olds hold, they may not expect an agent who preferentially imitated one model in preference to another several times to continue to do so in the future. Seeing a few acts of imitation does not warrant the prediction of another immediate act of imitation. However, the *social* concept of imitation warrants inferring a stable disposition of agent A to copy agent B, upon seeing a consistent choice of agent A to imitate agent B's actions but not agent C's. This aspect of the social concept may be necessary for, and thus precede, the explicit inference that the agent likes the imitated model more than the non-imitated model, the question answered correctly only at age 5 in Over and Carpenter (2015). Experiment 2 addressed this issue by asking children to predict who a copier will imitate in the future, as well as asking the main question of interest in the paper; whom the copier likes more between the model of her imitation and the individual whom she has not imitated. Experiment 2 included the characters and structure of Block 1 from Experiment 1.

Method

Participants. Forty 3-year-olds ($M = 42.7$ months, 21 female) participated in this experiment. An additional six participants were excluded due to not completing the task (4), or being extremely distracted (2). Children came from the Harvard Lab for Developmental Studies database. Parents received travel reimbursement and children chose a small toy as a prize after their participation. A small number of participants ($n=3$) took part in the study at the Boston Children's Museum. In accordance with museum guidelines, these children and parents did not receive a prize or travel reimbursement.

Materials. The experiment was conducted on a 13-inch Macbook laptop. The experimenter used a wireless mouse that she held out of the child's view, and the keyboard was covered to prevent distraction.

The video stimuli consisted of three computer-generated women, two of whom were also present in Block 1 of Experiment 1 (see Figure 3). The characters were introduced to children with proper names (Jenny, Alice, and Zoe). If the participant's name was the same as a character, that character was given an alternative name.

Figure 3. The central character is the copier, and the model and non-model are on the sides.

Introduction. The central character—who would later become the copier—appeared and was introduced, e.g. “This is Jenny. Let’s see what she does.” She then performed all the

actions she would have the chance to imitate later on. The purpose of this phase was to demonstrate to children that the copier was able to perform all featured actions, such that her future imitations were by choice rather than lack of ability. The experimenter narrated the actions as they were performed (e.g. “Jenny moved her arms.”), in order to familiarize children with the wording that would be used to refer to the actions in future questions.

Memory: Side-character actions. The two side characters—who would later become the model and non-model of imitation—appeared and were introduced. Children then watched two warm-up events in each of which the two characters performed different actions. After each event, the experimenter asked who had performed each action, e.g. “Who moved her leg? Was it Alice or was it Zoe?” Positive feedback was given for correct answers. If the child answered incorrectly for either action, both actions were shown again and the questions were repeated.

Memory: Central character actions. Children saw two events with all three characters. The central character, aka the copier, turned her head toward each of the side characters to watch their actions, and then repeated one of those actions. The copier imitated the same character on both trials. Children’s memory of the copier’s action was probed for each event, e.g. “Did Jenny move her head or did she move her leg?” Once again, correct responses received positive feedback, but actions and questions were repeated following incorrect ones.

Imitation observation. Participants viewed another three events in which the copier imitated the same model as before. These events were the same as Central character action ones, but no memory question was asked. The actions performed by the characters across the two Central character action events and the three Imitation observation events were unique.

Test questions. There were three test questions: the Who was Copied question first, followed by the Affiliation and Imitation Prediction questions in counterbalanced order.

Who was Copied. At the end of the last Imitation observation event, children were asked, “Who was Jenny copying?”

Affiliation. The experimenter asked the child whom the copier preferred, “Who do you think Jenny likes best?”

Prediction of future model of imitation (henceforth referred to as Imitation Prediction).

The experimenter played a new, incomplete event in which the side characters performed new actions while the copier watched, but the copier did not move when it was her turn to act. At this point, the experimenter asked the child to predict what the copier would do, for instance saying, “Oh, what happened? Can you help me figure out what Jenny is going to do? Do you think Jenny’s going to move her arms like Alice, or bend sideways like Zoe?”

Design. Each participant viewed one of eight orders, for which the identity of model of imitation, and the order of the specific actions performed during the Imitation observation events and Imitation Prediction event were counterbalanced across children. The order of action by the side-characters (e.g. model acting first or non-model acting first) was counterbalanced across events for each participant.

Coding. On all memory events (Side-character action, Central character actions), responses were coded as correct if the child gave the correct answers the first time. Choosing the model of imitation was counted as the correct response for all test questions.

Results

Memory questions. Three-year-olds remembered the actions of each character with high accuracy, responding correctly on 85% of trials for the side characters, and 87.5% trials for the central character. Both sets of responses were significantly higher than expected by chance performance based on mixed-effects binary logistic regressions (Side-character actions: $p < .0001$; Central character actions: $p = .004$).

Test questions. For the Who was Copied question, 77.5% of participants chose the model, which was significantly higher than chance (31/40 correct, binomial test, $p = .0007$, Cohen’s $h = .58$). There was no difference in likelihood of correct response to “Who was Jenny copying?” in Experiment 2 and to “Who was copying the other one?” in Experiment 1 (Fisher’s

exact test, $p = .79$). Experiment 2 contrasted two actors performing different actions such that the copier matched only one of them. If children took “copy” merely to apply whenever two agents do the same action, they should have performed better in Experiment 2 than in Experiment 1, and should have been at chance on Block 1 in Experiment 1. We take the similarity in level of success as evidence that the child was interpreting “copy” to mean imitation (with asymmetric roles for model and imitator) in both cases.

Responding to the other two test questions, children chose the model of imitation 67.5% of the time (60% for Affiliation, 75% for Imitation Prediction). This performance was significantly better than chance ($OR = 2.08$; 95% $CI = 1.31, 3.79$; $p = .002$). A binary logistic regression including question type (Affiliation, Imitation Prediction) and question order (Affiliation first or second) as fixed effects and participant as a random effect was conducted on the data. There was no effect of question type, meaning that responses were comparable across Affiliation and Imitation Prediction. There was a main effect of question order ($OR = 3.39$, 95% $CI = 1.27, 10.62$, $p = .018$), indicating that when the Affiliation question was asked first, performance on the inferences (Affiliation, Imitation Prediction) was higher than when it was asked second.

Finally, there was no significant difference between performance on the Who was Copied question (77.5% correct) on the one hand, and the Affiliation and Imitation Prediction questions (67.5% correct) on the other ($p = .24$). That is, the overall level of viewing these events as imitation was statistically the same as the likelihood of inferring that the copier liked the model and would continue to selectively imitate the model. This finding is consistent with the conclusion that when imitation was encoded, the other inferences came for free.

Discussion

The success at answering the Who was Copied question (77.5% correct) in Experiment 2 converges with the success at answering the Who was Copying question (73% correct) in Block 1 of Experiment 1, indicating that middle-class American 3-year-olds, as a group, have a verbalizable concept of imitation. They recognized and identified both the instigator and the

model of imitative behavior when viewing instances of imitation. This high level of performance appears to depend on practice at naming the character, encoding the actions of characters one by one, and recalling the actions of each character when multiple characters had acted before observing imitation.

The overall success on the Affiliation and Imitation Prediction questions suggests that in the context of an agent's repeated choices between two specific models to imitate, 3-year-olds consider Jenny to have a stable preference of whom to imitate, and to like the model over the non-model of imitation. That *3-year-olds* succeed at these inferences rules out that the failures of 4-year-olds to infer affiliation in Over and Carpenter's (2015) study is due to the lack of such a concept. However, the apparent need for guided attention to the movements of each actor (compare Block 1 to Blocks 2-4 in Experiment 1) suggests that young preschoolers do not always spontaneously deploy this explicit concept. Experiments 4 to 6 explore whether preschoolers can draw these inferences spontaneously or if priming the concept of imitation is required, as the "Who was Jenny copying?" question may have done in Experiment 2. First, however, Experiment 3 tests adults' inferences in these same situations.

Experiment 3

It is possible that in Experiment 2, responding to the Who was Copied question ("Who was Jenny copying?") may have influenced children's responses to the Affiliation and Imitation Prediction questions, which came after it. Thus, Experiment 2 leaves open whether children *spontaneously* encode the imitative behavior while watching the actions in this experiment, in the absence of this explicit question. In order to test this, it was necessary to avoid asking who Jenny was copying. Before testing this with preschoolers, the current experiment addressed this question with adults. The purpose of this experiment was to make sure that the imitative scenes presented in the stimuli were spontaneously seen as such by mature observers.

Method

Participants. A total of 80 adults were recruited through Amazon's mTurk and participated online ($M = 32$ years, 33 female). All participants gave informed consent.

Procedure. The procedure up to the test phase was the same as Experiment 2. We first introduced the central character, Jenny, and showed her performing a number of actions. Participants then viewed two memory trials in which the side characters performed actions, and they were asked questions about the actions (i.e. Memory: Side-character action trials). Next, they viewed two trials in which Jenny imitated one of the other characters and answered questions about what action Jenny had performed (i.e. Memory: Central character action trials). Finally, they saw three other instances of Jenny imitating the model (i.e. Imitation observation).

In the test phase, participants were asked the Imitation Prediction question ("Can you help me figure out what Jenny is going to do? Do you think Jenny's going to move her arms like Alice, or bend sideways like Zoe?"), and the Affiliation question ("Who do you think Jenny likes best?"). The order of the test questions was counterbalanced across participants. Importantly, unlike in Experiment 2, there was no "Who was Jenny copying?" question.

The online experiment was designed on the Qualtrics platform. We informed participants at the start that they would watch a number of animations designed for children and answer questions about them. They were also told that the task was straightforward and aimed at discovering their intuitions. Questions were asked using forced-choice options.

Results

Memory questions. Responses for Side-character actions were 92.5% accurate, while performance for Central character's actions was at 99%. Both sets of responses were significantly better than chance ($p < .0001$). Thus, adults remembered the actions each character performed with high accuracy, demonstrating that they were attentive to the task.

Test questions. Responses were 91% correct across Affiliation and Imitation Prediction questions, which was significantly better than chance ($p < .00001$). A binary logistic regression containing question type (Affiliation, Imitation Prediction), question order (Affiliation first or

second), and their interaction term found no significant main effects or interactions, indicating that adults succeeded at answering both questions equally well.

Discussion

Adults spontaneously made the correct inferences from our videos about who the copier likes and whose actions she will continue to imitate, even when the explicit concept of imitation was not primed in any way. Experiment 4 tests whether this is also true for young children.

Experiment 4

Experiment 4 expanded the ages tested to include 4- and 5-year-olds as well as 3-year-olds. Experiments 1 and 2 established that 3-year-olds have an explicit concept of imitation, and can identify both the copier and the model of imitation—at least in the context of the actions used in these studies. If preschool children, like infants, *spontaneously* encode imitative behavior and draw social inferences from it, they should succeed at the Imitation Prediction question and perhaps even the Affiliation question by ages 3 or 4, in the absence of being asked “Who is Jenny copying?” However, the failures in Blocks 2 to 4 in Experiment 1, suggested that spontaneous deployment of the concept of imitation is far from given.

Experiment 4 provided the introductory sequences of Block 1 in Experiment 1, but did not highlight the concept of imitation. In the absence of any mention of the word “copy”, children may merely view the scenes as a series of varied actions the characters carry out, such that 3- and 4-year-olds will fail both the Imitation Prediction and the Affiliation questions, as the 4-year-olds in Over and Carpenter (2015) did. Five-year-olds were included to test whether we replicate the developmental change between ages 4 and 5 observed by Over and Carpenter. Also of interest was whether the Imitation Prediction question is easier than the Affiliation question, as would be expected if considering continued imitation of one model over another as a stable social disposition is a prerequisite to inferring liking the model whose actions were imitated more. In Experiment 2, the Imitation Prediction question yielded a higher level of correct responding (75%) than did the Affiliation question (60%), although the rates of correct

responses did not differ significantly from each other. Finally, we tested whether the ordering of the test questions makes a difference to children's performance, as it did in Experiment 2.

Method

Participants. The sample was doubled to ensure we would have the power to detect an effect of question type, and/or an effect of order of question type, and possible effects of age. Eighty 3-year-olds ($M = 41.1$ months, 38 female), 80 4-year-olds ($M = 53.4$ months, 45 female), and 80 5-year-olds ($M = 66.1$ months, 34 female) from the same populations as before participated in this experiment. Nineteen participants took part in the study at Boston's Children's Museum, while the remainder came into the lab. An additional six children were excluded for extreme distraction (4), parental interference (1), and not completing the task (1).

Materials. The same set of animated stimuli from the previous experiment was used.

Procedure. The following phases were identical to those of Experiment 2 and 3: Introduction, Memory: Side-character actions (x2), Memory: Central character actions (x2); Imitation observation (x3), Test questions. At test, both the Affiliation ("Who does Jenny like best?") and Imitation Prediction ("Do you think Jenny's going to [action 1] like Alice, or [action 2] like Zoe?") questions were asked. The order of Affiliation and Imitation Prediction questions was counterbalanced across participants. Thus, the only difference between Experiments 2 and 4 was the absence of the Who was Copied question immediately preceding the Affiliation and Imitation Prediction questions, making Experiment 4 identical to Experiment 3 with adults.

Results

Memory questions. Children remembered the actions performed by each of the side characters with 90.1% accuracy and by the central character with 94.8% accuracy. Both sets of responses were significantly better than chance ($p < .00001$).

Test questions. Figure 4 shows performance on the test questions (Affiliation and Imitation Prediction questions). Eight participants did not have responses for their second test question (4 due to refusing to answer, and 4 due to experimenter error). In Experiment 4 (no

priming of the concept of imitation before the test questions), overall success on answering the Affiliation and Imitation Prediction questions was 56.8%. This performance was better than chance according to a mixed-effect binary logistic regression including only the intercept as a fixed effect and participant as a random effect ($OR = 1.41$; 95% $CI = 1.11, 1.83$; $p = .0063$). As can be seen from the odds ratio, the effect size is small. (For comparison, Cohen's d as calculated from a one-sample t -test against chance on responses is .16, which is a small effect size.) A binary logistic regression including question type (Affiliation, Imitation Prediction), question order (Affiliation first or second), age (in months), and their interaction terms as fixed effects and participant as a random effect failed to find any main effects or interactions. Unlike Experiment 2, there was no hint that children found the Imitation Prediction question easier (overall 56% correct) than the Affiliation question (overall 58% correct), nor any hint of an effect of order of question. Nor did performance improve with age between ages 3 and 5.

Figure 4. Combined responses for the test questions: Affiliation question (“Who does Jenny like best?”) and Imitation Prediction question (“Do you think Jenny’s going to [action 1], like Alice, or [action 2], like Zoe?”) from Experiment 4, which did not include priming of the concept of imitation, and the Body movement block from Experiment 5, which did. Dotted line shows chance level. Error bars reflect standard error of the mean. Significance levels denote test against chance performance for each experiment, and comparison between the two experiments (** $p < .01$, *** $p < .0001$).

Planned comparisons of Affiliation responses for 4- and 5-year-olds found no difference between the two age groups ($X^2(1) = .33, p = .56$). Unlike Over and Carpenter, we found that 5-year-olds did not differ from 4-year-olds. Moreover, at no age did children perform above chance at either the Imitation Prediction or Affiliation question when correcting for six multiple comparisons (Holm-Bonferroni, all p -values > 0.05). Even without the conservative cost of correcting for multiple comparisons, Affiliation responses from 5-year-olds were not above chance (45/80 correct, binomial test, $p = .31$, Cohen's $h = .12$).

We compared responses for Affiliation and Imitation Prediction from 3-year-olds in Experiment 4 (without Who was Copied question before test questions) with those from 3-year-olds in Experiment 2 (Who was Copied question before test questions). Performance was significantly lower in Experiment 4 compared to Experiment 2 (OR = 0.45; 95% CI = 0.21, 0.9; $p = .028$). Thus, children's above chance performance on the Affiliation and Imitation Prediction test questions in Experiment 2 required the Who was Copied question beforehand.

Discussion

The takeaway from Experiment 4 is that preschoolers very rarely spontaneously encode imitation from the events presented here in the absence of being asked "Who was Jenny copying?", even when they have been led to pay attention to the actions and to remember what the side-characters and the central character did. Obviously, if they do not encode the imitation they will not infer anything such as continued imitation or affiliation from imitation.

Asking children explicitly to look at upcoming interactions to identify who is copying the other one was not sufficient to lead 3-year-olds to encode acts of imitation in the absence of drawing their attention to the individual actors and the specific motions they are performing (Experiment 1, Blocks 2-4). Conversely, even when attention is drawn to the actors and their actions (Experiment 4), this is not sufficient for 3- to 5-year-olds to robustly encode imitation in the absence of being asked "Who Jenny was copying?" Asking children to both attend to the actors and their actions and answer a question about who the copier was copying, however,

improves performance on prediction of the model of future imitations (Experiment 2). This suggests that two things (attention to characters and their actions, emphasizing the concept “copy”) are needed in order for preschoolers to encode imitation and draw further inferences from it. The next two experiments put this possibility to the test.

Experiment 5

Experiment 5 explored whether the *concept* of imitation can be primed in the absence of a word for imitation. Here we drew attention to acts of imitation during the warm-up phase, by changing the wording of the memory questions about the central character’s actions. Instead of merely asking children to recall Jenny’s actions (“Did Jenny move her arms or her leg?”), we asked, “Did Jenny move her arms *like Alice* or her leg *like Zoe*?” This non-lexical priming of the concept imitation explicitly drew attention to the act of imitation children had just witnessed, by drawing attention to the identity of Jenny’s actions to one, and only one, of the characters’ actions, but did not use the word “copy”. It is a form of propositional scaffolding—“Jenny imitated Zoe” means “Jenny intentionally did something that Zoe previously did,” so answering the question whether Jenny moved her arms like Alice requires representing a proposition that is entailed by “Jenny imitated Zoe.” Further, in contrast to the Who was Copied question in Experiment 2, which came after all the imitation events, the non-lexical priming of Experiment 5 took place during the first two instances of imitation during the warm-up phase. This provided children with the opportunity to watch the three further imitative actions before the test questions (which children merely observe, but do not answer memory probes for) with the proposition in mind. Thus, Experiment 5 explored whether non-lexical priming of the concept of imitation leads to better performance on the Affiliation and Imitation Prediction questions in the test phase, relative to Experiment 4, where there was neither lexical reference to imitation (i.e. no mention of “copying”) nor non-lexical priming.

Experiment 5 also explored whether there are at least three classes of actions preschoolers can represent as acts of imitation. It included two additional blocks of novel agents

selectively imitating one other of two actors, in one block imitating vocalizations and in the other block imitating object choices. The structure of each block was identical to that of the body movement block. For reasons of manuscript length, the results from these blocks are not discussed here (see Supplementary materials for full analyses of these data).

Method

Participants. Forty 3-year-olds ($M = 43.0$ months, 20 female), 40 4-year-olds ($M = 53.3$ months, 20 female), and 40 5-year-olds ($M = 65.5$ months, 18 female) from the same laboratory population as before participated in this experiment. An additional five children were excluded due to not completing the task.

Materials. Three different action types were used in three separate blocks: Body movements, Vocalizations, and Object choices. The stimuli from Experiments 1-4 were used for the Body movement block, as well as the stimuli from the Vocalizations block in Experiment 1. Animations were prepared for Object choice actions. See Supplementary materials for details of Vocalization and Object choice blocks.

Procedure. The order of blocks was counterbalanced across participants. The general procedure for each block was highly similar to previous experiments. The Introduction and Memory: Side-character action phases were identical to those of Experiments 2-4. The difference in procedure was in the wording of memory questions for central character action memory trials, and the absence of a question concerning who the central character was copying.

Memory: Central character actions (*Non-lexical priming of imitation*). Children viewed two trials in which the central character imitated one of the side characters, and were asked about the copier's action. These trials were analogous to the central character action memory trials in previous experiments. Importantly, however, the wording of the memory probe scaffolded representing the central character's action as an imitative act. For instance, the experimenter said, "Did Jenny bend backwards like Alice, or move her arms like Zoe?" This was

in contrast to how the question was worded before (“Did Jenny bend backwards or move her arms?”) Correct answers were rewarded with positive feedback. Actions and questions were repeated for incorrect answers. These trials acted as a non-lexical prime of the concept of imitation. Thus, the *only difference* between the structure in Experiment 5 and Experiment 4 was the addition of the phrases “like Zoe” and “like Alice” to central character memory probe trials.

Imitation observation. Identical to Experiments 2-4, participants watched three further events involving all three characters in which the copier watched the side characters act, then imitated the model. No questions were asked on these events.

Test trials. Children viewed an incomplete event in which the copier watched as each of the side characters performed their actions, but did not perform any action when his or her turn came. Participants were then asked three test questions:

Imitation Prediction. The child had to predict whose action the copier would do next.

Affiliation. The experimenter asked the child to infer whom the central preferred, e.g. “Who do you think Jenny likes best?”

Affiliation Judgment Explanation. After the test questions for the last block, whichever it happened to be for a particular participant (i.e. Body movements, Vocalizations, or Object choice), the experimenter asked the child to provide their reasoning behind their choice on the Affiliation question, e.g. “How do you know she likes Alice best?”

The experimenter provided neutral feedback to all of the children's test responses. The order of questions was fixed, meaning that Imitation Prediction was asked before Affiliation, followed by the explanation of the Affiliation response (for the last block). As the task was quite long and repetitive, all children viewed an unrelated animation that depicted a dominance relationship between two cartoon characters and were asked some questions about it after completing either one or two blocks.

Design. The order of blocks, and the identity of the model for each block was counterbalanced across children. For each participant, the side of the model across the blocks

was counterbalanced. Within each block, the order of action by the side characters (e.g. model acting first or non-model acting first) was counterbalanced across trials.

Results: Body Movements Block

We consider responses to the Body Movements block separately, in order to directly compare this experiment with previous ones, which only involved body movements. The results from all blocks are reported in Supplementary materials. There was no main effect or interactions involving block order. Furthermore, the results from the memory questions as well as the Imitation Prediction and Affiliation test questions in the Vocalization and Object choice blocks converged with those of the Body Movements Block in every respect.

Memory questions. Participants answered the memory questions on Side-character action trials 90% accurately, and, importantly, on the Central character actions trials (non-lexical priming of the concept of imitation) 89.5% correctly. Both were significantly better than expected by chance ($p < .00001$ for both).

A mixed-effects binary logistic regression model including experiment as a fixed effect and participant as a random effect was run on pooled responses for Central character action memory trials in Experiments 4 and the analogous trials in the movements block from Experiment 5. This found no difference between the experiments; the wording of the question (i.e. “Did Jenny move her arms...” in Exp. 4 vs. “Did Jenny move her arms *like Alice*...” in Exp. 5) did not affect memory for the central character’s action. That the question referenced the side characters in the current experiment neither helped nor hindered children’s rate of remembering the copier’s action correctly.

Test questions. Responses were 74% successful overall (across Affiliation and Imitation Prediction questions), and better than chance (OR = 5.79; 95% CI = 2.98, 23.41; $p < .0001$). A logistic binary regression model including question type (Affiliation, Imitation Prediction), age (in months), and their interaction term as fixed effects and participant as a

random effect found no main effects or interactions. Thus, responses were comparable across Imitation Prediction and Affiliation questions, as well as age, which varied from 3 to 5 years.

Next, a binary logistic regression model compared responses from Experiment 4 and the Body Movements block data in Experiment 5. Responses from both are shown in Figure 4. This model included question type (Affiliation, Imitation Prediction), experiment (Exp. 4, Exp. 5), and their interaction term as fixed effects and participant as a random effect. There was a significant main effect of experiment (OR = 2.8; 95% CI = 1.50, 5.54; $p = .002$), and no other main effect or interaction. That is, performance on Affiliation and Imitation Prediction questions was better following non-lexical priming of the concept of imitation in Experiment 5 than without it in Experiment 4.

Affiliation Judgment Explanations. Explanations came from all three block types (i.e. Body movements, Vocalizations, Object choice). Since each child provided only one explanation (on the last block of trials), we report data from all three imitative action types for this analysis only. Asking for explanations was added to the procedure roughly midway through data collection. As a result, explanations were asked of only 20 3-year-olds, 31 4-year-olds, and 35 5-year-olds. Of the 86 children asked for justification, 10% said nothing (no codable response). The likelihood of providing a response at all increased with age (80% of 3-year-olds, 90% of 4-year-olds, 94% of 5-year-olds), although these rates of responding do not differ statistically.

The following analyses include only the trials in which children provided a response. Each explanation was categorized into one of three categories: 1) Asymmetric imitation (36% of all responses): the child mentioned copying as an asymmetrical imitation of an action, e.g. “Because she says everything Katie says”, “Because he did all his stuff”, 2) Similarity (12% of all responses): the child mentioned similarity of actions without referencing asymmetric roles, e.g. “Keeps doing the same thing”, “Sometimes they do the same”. 3) Irrelevant (52% of all responses): the child’s justification did not fit in the other categories, e.g. “I don’t know”, “Because I like him.”

The rate of asymmetric imitation explanations increased significantly with age (6% of 3-year-olds, 29% of 4-year-olds, and 58% of 5-year-olds, $p = .0001$, Fisher's exact test; see Figure 5). In contrast, the rate of similarity explanations did not change with age (6% of 3-year-olds, 21% of 4-year-olds, and 6% of 5-year-olds, $p = .16$, Fisher's exact test). Finally, the rate of irrelevant responses decreased with age (88% of 3-year-olds, 50% of 4-year-olds, and 36% of 5-year-olds, $p = .002$, Fisher's exact test). Furthermore, children who appealed to asymmetric imitation or similarity were significantly more likely than chance to answer the affiliation test question correctly, while those who gave irrelevant justifications performed at chance (Asymmetric imitation: 93% correct, $p < .0001$; Similarity: 89% correct, $p = .0391$; Irrelevant: 60% correct, $p = .27$; all p -values from binomial tests)³.

That children who appealed to similarity of motions (either by appealing to asymmetric imitation or by simply mentioning that the two characters did the same thing) were almost perfect in the affiliation inferences they were justifying, whereas those who did not were at chance, suggests that many children have explicit knowledge of the relation between similarity of motion between two characters what agents like other agents. This relation leaves open exactly what explicit beliefs children have: people imitate people they like, that people are doing the same thing means they like each other, or both. Moreover, children who answered the Affiliation question correctly gave 3.25 times more asymmetric imitation explanations ($n = 26$) than mere similarity explanations ($n = 8$). We take this pattern of results as suggesting that children have explicit access to the belief that imitation, per se, signals liking, and at least some of the children mentioning similarity may have meant to, but did not succeed, to refer to asymmetric imitation. To conclude, while children's ability to articulate asymmetric imitation as the basis of an Affiliation choice changed with age, those who mentioned it were almost certain to have succeeded on Affiliation, regardless of their age. This result converges with the effect of

³ Like children who gave irrelevant justifications, children who did not give any answer to the justification question also responded at chance level to the affiliation question (67% correct, $p = .51$, binomial test).

priming the concept of imitation on success in the test questions (Exp. 4 vs. Exp. 5). Together, they locate one source of variance in children's likelihood of inferring affiliation from imitation, namely the likelihood of explicitly noticing the imitation.

Figure 5. Children's explanations for Affiliation responses in Exp. 5, separated by age, explanation category, and whether they answered the Affiliation question correctly.

Discussion

Success on the test questions (Imitation Prediction, Affiliation) was observed when the imitation involved body movements, vocalizations, and choices between objects, establishing that preschoolers' concept of imitation is expansive enough to cover at least three diverse types of actions (see Supplementary materials).

The important finding from Experiment 5 was that including non-lexical priming of the concept of imitation in the memory probes (e.g. "Did Jenny move her arms *like Alice* or her leg *like Zoe*?") occasioned far better performance on the subsequent test questions than when the memory probes merely asked what Jenny had done (e.g. "move her arms or her leg?"). These data leave two important questions open. First, what exactly was primed by the Who was

Copied question in Experiment 2, and the non-lexical propositional scaffolding probes of Experiment 5? One possibility is that the abstract concept of imitation was primed, making it more likely that the child noticed the central character's consistent imitation of one of the side characters in subsequent events, and thus more likely to infer continued imitation and differential liking of that side character, relative to the other one. Another possibility is that what was primed was the specific proposition "Central character (e.g. Jenny) is imitating side character A (e.g., Zoe)." If the latter is necessary for the better performance on the test questions of Experiments 2 and 5, relative to Experiment 4, then priming the concept of imitation on different actions, with different characters, will not lead to the same level of robust success on the test questions as we observed in Experiment 5. We test this hypothesis in Experiment 6.

Finally, there is one low level interpretation of the successes on the Affiliation and Imitation Test questions in Experiment 2 and 5 in which they do not reflect inferences from observed imitation at all. In both studies, prior to the test questions, attention has been differentially drawn to a side character as the correct answer to a question. In Experiment 2, that question was "Who was Jenny copying?" and in Experiment 5, it was the memory probe "Did Jenny move her arms like Zoe or her leg like Alice?" Of course, that children could answer these questions reflects some appreciation of imitation, but that they then performed better than chance on the test questions does not entail that these were inferences that followed from the representation of imitation. Instead, perhaps observation of imitation had no inferential consequences concerning affiliation and continued imitation, and children may have simply picked the same character that had been the previously correct choice, a choice that had been praised. That is, they may have had a bias to pick the previously targeted character for *any* subsequent question that required a forced choice between the two side characters. Indirect evidence against this hypothesis comes from explanations for Affiliation judgments, because almost all children who referred to asymmetric imitation answered the Affiliation question

correctly. This suggests that at least some children were explicitly inferring affiliation from observed imitation. Experiment 6 puts this alternative hypothesis to a direct test.

Experiment 6

In Experiment 6, children were lexically and non-lexically primed with the general concept of imitation at the start, with a different set of characters and a different action type (Vocalizations) from those used at test (Body Movements). If the mechanism that led to success in Experiment 5 was increasing the salience of imitation, the general priming of imitation in the context of Vocalizations should achieve the same goal and result in children's success on the test questions. However, if what was primed in Experiment 5 was the particular character's imitation of a particular model, a general priming of imitation should not help them. Further, if the mechanism that led to improved performance in Experiment 5 was simply to induce a bias to pick the same side character no matter what question was asked, this initial experience should not help them either, for *nothing* drew attention to one of the side characters in the Body movement test block, which was identical to that of Experiment 4, where children failed.

Method

Participants. Forty 4- and 5-year-old children were tested ($M = 60.0$ months, 20 female). As none of the previous experiments found a difference in performance between 4- and 5-year-old children, half of the children in this sample were four years old (48-59 months), and half were five years old (60-72 months). Three other children participated but were excluded due to not completing the task (2), or for answering the Who was Copied question in the priming phase incorrectly (1). The criterion for inclusion in the final sample was preset as answering the Who was Copied question correctly because if the child had not encoded the imitation on the Vocalization block, then that block could not have primed the concept of imitation. Note that only 1 of 43 participants was excluded for this reason, consistent with the conclusion that by age 4, almost all children have an explicit concept of imitation lexicalized as "copy."

Materials. The stimuli in the Body movements test block were the body movement stimuli from Experiments 1-5. Stimuli drawn from the Vocalization block in Experiments 1 and 5 were used to prime the general concept of imitation.

Procedure. The procedure consisted of two blocks: 1) Imitation concept priming with vocalizations, and 2) Test with body movements.

1) Imitation concept priming block (Vocalizations).

1. *Introduction.* The central character was introduced and performed a number of vocalizations to demonstrate that she was able to utter them all.
2. *Memory: Side-character actions (2 trials).* These trials involved the side characters, and children's memory for their utterances was probed.
3. *Memory: Central-character actions (Non-lexical priming of the concept of imitation; 2 trials).* All three characters were shown, and the central character imitated the model. Children were asked about the copier's action, e.g. "Did Emily say vow-vow like Hannah or zoh-zoh like Katie?"
4. *Imitation question (Lexical priming of the concept of imitation).* We asked children who the central character had imitated, "Who was Emily copying?"

2) Test block (Body movements). The procedure for this block was identical to that used in Experiment 4.

Design. The side of the models of imitation was counterbalanced across children. Importantly, the model of the priming block was always on the opposite side from the model of the test block.

Results

Memory questions. Participants remembered the side-character actions extremely well, responding correctly on 99% of the memory probes in the Vocalization block and with 96% in the Body Movements block. Both sets of responses were significantly above chance ($p < .0001$). They also remembered the Central character's actions ($p < .0001$ for both blocks),

whether probed in a way that primed the concept of imitation in the Vocalization block (81% accuracy) or simply asked about her action in the Body Movements block (96% accuracy).

Test questions: Body Movements block. At 74% accuracy, responses were significantly higher than chance ($OR = 4.19$; 95% $CI = 1.94, 24.7$; $p = .0058$), with no effect of question type or age. See Figure 6 for responses from the 4- and 5-year-olds combined (because in no experiment did the performance of children of these two ages differ) from Experiments 4-6 on the Body Movements block.

Using data from 4- and 5-year-olds, we ran a regression model including experiment (Exp. 4, Exp. 5, Exp. 6), question type (Affiliation, Imitation Prediction), their interaction, and question order (Affiliation first or second) as fixed effects, and participant as a random effect. This model found no effect of question type or order and a significant effect of experiment, such that performance in Experiment 5 and in Experiment 6 was significantly higher than in Experiment 4 (Exp. 5 vs. Exp. 4: $OR = 3.8$, 95% $CI = 1.67, 9.69$; $p = .002$; Exp. 6 vs. Exp. 4: $OR = 3.09$, 95% $CI = 1.16, 9.26$; $p = .03$), while responses in Experiments 5 and 6 were comparable ($p = .48$). Thus, Experiment 6 establishes that general priming of the concept of imitation leads to markedly increased performance on the Affiliation and Imitation Prediction test questions (74% across both) relative to Experiment 4 (57%), even though the Body Movements block in Experiment 6 was *identical* to the Body Movements block in Experiment 4. Furthermore, the level of success here in Experiment 6 was exactly the same as in Experiment 5 (74%), where non-lexical priming happened within the same block of action trials. This finding suggests that the improvement of Experiment 5 over Experiment 4 reflects the priming of the abstract concept of imitation, rather than inducing a low level bias to always choose a particular side character, or priming a specific proposition “Jenny is imitating Zoe.”

Figure 6. Overall correct responses for Affiliation and Imitation Prediction from 4- and 5-year-olds in Experiments 4 (no priming), Body movements block in Experiment 5 (non-lexical, within-block, priming of the concept of imitation), and Experiment 6 (lexical and non-lexical, separate block, priming of the concept of imitation). Performance was significantly better in Exp. 5 and Exp. 6 compared to Exp. 4, and comparable between Exp. 5 and 6. Dotted line shows chance level. Error bars reflect standard error of the mean. Significance levels denote comparison between experiments (* $p < .05$, ** $p < .01$).

Discussion

The present experiments, all taken together, establish that preschool children (even 3- and 4-year-olds) can indeed infer affiliation from observed imitation, and that unlike in Over and Carpenter's study (2015), 5-year-olds are no better at this than 4-year-olds. However, the concept of imitation is not always spontaneously encoded when watching events such as these. One will not see evidence for inferences from observed imitation if the child has not encoded it. Throughout the preschool years (ages 3 to 5), the concept of imitation must be primed in some way to ensure spontaneous encoding—either by asking about who is copying whom (lexical priming), or drawing attention to the fact that the central character's actions were the same as one of the side characters' (non-lexical priming). The present study included both types of priming on the vocalization trials. A follow-up study could consider using only a lexical prime or only a non-lexical prime in these trials to test their separate efficacy.

General Discussion

The current experiments yielded several findings. First, 3-year-olds identified the copier after observing imitation in a dyad (Exp. 1, Block 1, “Who was copying the other one?”) and recognized the model after observing imitation in a triad of a copier, model, and non-model (Exp. 2, “Who was Jenny copying?”). Together, these results provide evidence for an explicit concept of imitation, lexicalized in the word “copy” in 3-year-olds as a group. Second, Experiment 1 also found that 3-year-olds could not answer “Who was copying the other one?” if not guided to attend to the characters, their actions, and to practice remembering who did what (Exp. 1, Blocks 2-4). This shows that the “Who was copying the other one?” question was not sufficient to guide 3-year-olds to attend to what is relevant in an event when deciding who is copying whom. Third, Experiment 4 showed that preschoolers (ages 3 to 5 years) fail to make two inferences that might follow from having encoded imitation: predicting continued imitation and affiliation. While preschoolers performed barely above chance overall, no age group succeeded at either inference when considered separately, in spite of having been guided to attend to the characters, their actions, and given practice at remembering who did what. These results suggest that preschoolers do not always spontaneously encode imitation. Fourth, preschoolers succeeded at both inferences when the concept of imitation was primed either by propositional scaffolding (Exp. 5), i.e. drawing attention to the proposition that the copier is doing a series of actions like one of the other characters, by lexical priming (Experiment 2), i.e. by drawing attention to whom the central character was “copying,” or by propositional scaffolding in addition to lexical priming, even when the scaffolding and priming involved totally unrelated events to those involved in the Imitation Prediction and Affiliation questions (Exp. 6). These studies all together provide evidence for an explicit concept of copying available at least by age 3 that is not always spontaneously encoded when observed. Finally, we found no age differences across ages 3 to 5, in spite of having considerable power in these studies (e.g. 80 participants in each age group in Exp. 4).

Our findings provide evidence that preschoolers' inferences were based on their perception of the events as imitation rather than similarity of actions. In addition to identifying the model of an imitative act in Experiment 2, 3-year-olds identified the copier in a dyad in Experiment 1. Had 3-year-olds' concept of copying been reducible to similarity, they might have succeeded in identifying the model in Experiment 2, but they would not have been able to recognize which of the two agents was the copier. Thus, 3-year-olds have a concept of copying that goes beyond similarity of actions and includes asymmetry of roles. Other evidence in support of representing imitation as asymmetrical comes from the similar rates of success at inferring affiliation and continued imitation. If preschoolers saw the actions as merely similar, the inference about affiliation could well have been generated. Inferences of affiliation from similarity have in fact been reported elsewhere (e.g. Shutts et al., 2013; Afshordi, 2019; Liberman & Shaw, 2019; Fawcett & Tunçgenç, 2017). However, there would have been less reason for children to infer continued similarity of actions. That is, to infer that the copier will intentionally repeat the actions of one agent over the other is, by definition, an inference about imitation. This is especially meaningful in light of evidence that young children tend to expect individuals to change their behavior and not be consistent with what they have done in the past (Kalish, 2002). Further evidence that representations of imitation were driving the inference of liking comes from children's explanations: Those who talked about asymmetric imitation almost universally inferred affiliation correctly, showing that framing the events as imitation gets children purchase on affiliation. Finally, we built into our stimuli that the copier looked at the model before copying an action to make clear that imitation was taking place, as did Over and Carpenter (2013). It is worth noting that neither study tested whether this was necessary to encode the actions as imitation, and future work should explore this issue. Overall, however, there is reason to conclude that preschoolers were treating the events as imitation of actions rather than mere similarity of actions.

A question that arises from Experiment 1 is why guiding attention to the agents and actions was necessary in order for 3-year-olds to identify the copier in a dyad (Block 1 vs. Blocks 2-4). The answer may lie in the fact that imitative actions are complicated events. There are many relevant pieces of information in the input that need to be sorted in the right way in order for the child to recognize it as imitation. In our stimuli, an observer had to keep track of three characters and their actions, compare them to each other, note the order in which actions were performed, and perhaps also which character looked at the other, in order to identify the copier and the model. Guiding attention to the characters (as potential model and copier), their actions, and the correspondence between characters and actions likely helped 3-year-olds organize the information in such a way as to recognize the different roles (Exp. 1, Block 1). In contrast, knowing the question ahead of time ("Who was copying the other one?") did not help 3-year-olds (Exp. 1, Blocks 2-4). Thus, it is not that 3-year-olds struggled to discover the goal of the task, but rather that they had trouble proactively preparing to process the event correctly, an aspect of executive function skills (Munakata, Snyder, & Chatham, 2012). Given the considerable improvement in executive function from 3 years to 5, we predict that recognizing the copier and model would be easier for 5-year-olds, and they might well succeed in Blocks 2-4 of Experiment 1, where practice in naming of the characters and attention to their movements were not provided. A future study should test this prediction.

Taken together, the findings suggest continuity of inferring affiliation from observed imitation from infancy through the preschool years. Preschoolers did not fail to infer affiliation in Experiment 4 or in Over and Carpenter (2015; 4-year-olds) for lack of the concept imitation; even 3-year-olds had a verbalizable concept of imitation in the form of the word 'copy' (Exp. 1, 2). Further, we found no evidence of age-related improvement in performance. That is, children did not show evidence of getting better over time due to social experience or conceptual change. Rather, when the concept of imitation was primed, even 3-to 5-year-olds succeeded at the affiliation inference that infants make in Powell and Spelke's (2018a) looking-time

experiments (Exps. 2, 5, 6), even though they largely failed when imitation was not primed (Exp. 4). We take the correct inferences drawn from encoded imitation as evidence that it is not the concept of imitation that changes over age but the circumstances of its deployment. Thus, we see these studies as providing evidence for deep continuity across infancy and the preschool years.

But why do infants encode imitation from events without priming, whereas preschoolers, even 5-year-olds largely fail? One possibility is that preschool children are impeded by virtue of having a much richer conceptual repertoire for understanding these events. They can encode them as dancing, exercising, performing, imitating, etc. The role of priming the concept imitation, by asking who is copying whom or whether the central character performed an action “like” a side character, was to draw attention to one of a large possible pool of bases of encoding. When imitation is primed (Exp. 5, 6), the inferences of affiliation and continued imitation come along for free, suggesting that continued imitation and affiliation are part and parcel of the concept *imitation*. On this hypothesis, infants do not need priming because there are limited construals that they can glean from a scene, and the scenes Powell and Spelke (2018a) presented to them made imitation the main candidate, given their conceptual repertoire.

Our findings with regard to age do not align with those of Over and Carpenter (2015). They found failure at four years, success at five, and a difference between them. In contrast, we found success as young as three years on some versions of the task and failure on others as old as five, no age differences, with success contingent on whether imitation was primed or not. What explains the difference? One possibility is that if children know they will be asked about affiliation ahead of time as was the case in Over and Carpenter’s study, finding a basis for it in imitation is easier at five years than at four. This may be due to the development of proactive executive function skills, which begins to emerge at age 5 (Doebel et al., 2017). In addition, our explanation data show that explicitly connecting affiliation to imitation does indeed increase with age. This in turn suggests that older children (e.g. 5-year-olds) may be better positioned than

younger ones (e.g. 4-year-olds) to take advantage of an explicit mention of affiliation and home in on imitation as a relevant basis for deciding who the central character likes.

Inferring the general attitude of individuals towards each other is a key problem that children need to solve when making sense of the social world around them. Knowing that one person likes another as opposed to disliking them or being indifferent to them gives the child considerable purchase on higher-order inferences such as a person's likely behaviors towards another, the likely relationships with each other (friends, members of the same social group), and even possible ramifications of that attitude towards the child herself. Many social behaviors, including imitation, are laden with such information and correctly interpreting observations of such behaviors can help children uncover attitudes like affiliation. Here, we have shown that children possess the representational machinery to support inferences about affiliation and continued imitation based on observed imitation from early on, but that they do not always deploy it readily. This case study of explicit inferences of affiliation from evidence of imitation demonstrates how challenging social inferences can be for children, even when they are equipped with the requisite conceptual tools.

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Supplementary materials

Experiment 5 - Method and Results for all blocks

Method

Vocalizations. The cartoon characters were the same as Experiment 1, with the difference that this experiment involved three characters (red, yellow, and green) instead of two. Each character was voiced by a different person. Given that their voices were female, the characters were assigned female names (Hannah, Emily, and Katie). They were presented in a horizontal line equidistant from each other (see Figure S-1).

Object choices. Three new cartoon characters were involved in this block. The characters had heads and arms. Their facial features were identical to each other, but their faces varied in color (pink, orange, and teal) and shape (oval, square, and diamond). Their formation on the screen was as a triangle with the central character above the other two (see Figure S-1). Each action in this block involved making a choice between two objects. The objects were of the same category, but distinct (e.g. top hat and cowboy hat). For each character's action, the objects moved into the screen from the side and landed below his arms. Then, the objects jiggled one by one accompanied by a ringing bell sound effect. The character looked at each object as it moved, then picked up one and acted on it (e.g. wore the glasses, held the umbrella above their head). Following this, the character looked straight ahead briefly, before both the chosen and unchosen objects disappeared in anticipation of the next character's action. In scenes with all three characters present, the central character's eyes looked toward the other character who was acting at the relevant point. These characters were assigned male names (Tommy, Ben, and Jason). The animations were created in Keynote.

Figure S-1. Characters from the Vocalization block (left) and the Object choice block (right) in Experiment 5.

Procedure

The procedure was identical in structure to the Body movements block, with the exception of the Introduction part, which is described below. All test questions were worded in a similar way to the Body movements block.

Introduction. Like the Body movement block, the experimenter narrated the actions as they were performed in the Object choice block (e.g. “Ben wore that hat.”) In the Vocalizations block, repeating each vocalization was deemed unnecessary, so the experimenter simply said “Emily says different kinds of things.” after the character had completed several utterances.

Results: All action blocks.

Memory questions. Across all three action blocks, children performed well on the memory probes. Accuracy in remembering side-character actions and central character actions were 90.2% and 90.3% respectively, both significantly better than chance ($p < .00001$ for both).

Test questions. Children responded to the test questions (Affiliation and Imitation Prediction) correctly 69.9% of the time, which was significantly better than chance (OR = 2.94; 95% CI = 2.18 3.97; $p < .00001$, mixed-model binary logistic regression). Block order—i.e. order of presentation of different action types (Body Movements, Vocalizations, Object Choices)—had no effect on performance, so it was removed from further analyses. See Figure S-2 for a graph

of the responses according to action type and age. An additive regression model explored the effects of question type (Affiliation, Imitation Prediction), age (in months), and action type (Body Movements, Vocalizations, Object Choices) on percent correct responses. The variables named above were fixed effects and participant was a random effect. We again found no main effect or interactions involving question type. The analysis found a significant, but small, main effect of age (OR = 1.04; 95% CI = 1.01, 1.08; $p = .003$), and a significant effect of action type. Adjusted pairwise comparisons found that performance on Object choices was significantly lower than Body Movements (OR = 1.83; 95% CI = 1.16, 2.89; $p = .029$), but other pairings were comparable. Despite this difference, responses on the Object Choices were still significantly better than chance (OR = 3.19; 95% CI = 1.55, 6.57; $p = .0016$).

Figure S-2. Combined responses to Affiliation (“Who does Jenny like best?”) and Imitation prediction (“Do you think Jenny’s going to [action 1] like Alice, or [action 2] like Zoe?”) questions in Exp. 5 (non-lexical priming) separated by action type. Dotted line shows chance level. Error bars reflect standard error of the mean. Significance levels denote test against chance performance for each action type, and comparison between action types (** $p < .01$, *** $p < .0001$)