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Infants' selective imitation of a transitive agent and an intransitive agent

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ABSTRACT

This study examined how the reliability (i.e., transitivity) of an agent's object choices affects 16-month-old infants' (N = 48) imitation of her unconventional way of turning on a touch light box with her head when her hands were available. When the agent made transitive choices (i.e., she chose Object A over Object B, Object B over Object C, and then A over C), infants imitated her head touch actions. When the agent made intransitive choices (i.e., after choosing A over B and B over C, she chose C over A), infants were more likely to use only their hands to touch the light box. In addition, when it was presumably difficult for infants to judge the transitivity of the agent's choices (i.e., she chose B over C, A over B, and then A over C), they used their hands more. These results demonstrate that infants' understanding informs their decisions to selectively imitate others' specific ways to act on novel artifacts, consistent with young children's selective trust in information provided by other people based on their epistemic reliability.

Introduction

Trust—the belief in a person to do a promised or expected action (Hardin, 2002)—is a cornerstone of social interactions and interpersonal relationships (e.g., Bowlby, 1969; Erikson, 1963; Fiske et al., 2007; Mayer et al., 1995; Simpson, 2007). There has been significant empirical research examining

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infants' and young children's selective trust in others' epistemic states (i.e., epistemic trust) for learning information from them (for reviews, see, e.g., Harris, 2012; Koenig & Sabbagh, 2013; Mills, 2013; Poulin-Dubois & Brosseau-Liard, 2016; Sobel & Kushnir, 2013). For example, in a pioneering study (Koenig et al., 2004), 3- and 4-year-olds first saw two human agents label familiar objects (e.g., a ball) correctly or incorrectly (e.g., calling the ball "shoe"). If children explicitly judged the agents to be correct or wrong, they also showed selective trust; they learned new labels for novel objects provided by the accurate agent but not the inaccurate agent. These findings not only replicated with infants and toddlers (e.g., Bazhydai et al., 2020; Koenig & Woodward, 2010; Luchkina et al., 2018), but also extended to situations in which the agents talked about functions of familiar objects, for example, a ball for playing with or for washing (Birch et al., 2008).

To examine epistemic trust in infants, researchers have also made use of infants' well-documented capacity to imitate others and thus learn from others. A groundbreaking study (Meltzoff, 1988) showed that 14-month-olds readily imitated an agent's action of using his forehead but not his hand to turn on a touch light box, even after a 1-week delay, demonstrating that imitation is a powerful learning mechanism during infancy. However, it remained puzzling why infants imitate this unusual way of activating the light box. To address this question, Gergely et al. (2002) introduced situational constraints into the light-box task. In their study, a female agent either had her hands occupied because she felt cold and needed to use her hands to hold a blanket (hands-occupied condition) or placed her hands on either side of the light box (hands-free condition) while demonstrating the head touch action. In the hands-free condition, 69% of the infants imitated the agent's head touch action on the light box, consistent with Meltzoff's (1988) study, yet significantly fewer infants (21%) did so in the hands-occupied condition. These results suggest that infants seemed to consider the constraints on the agent's choice of actions. When given a reason why the agent needed to use her head to illuminate the light box in the hands-occupied condition, infants did not copy her and opted to use their own hands. When it was unclear why the agent used the head touch action in the hands-free condition, however, infants might have resorted to their default trust in the agent to imitate her actions on the light-box because of their innate proclivity to learn from others (Csibra & Gergely, 2011; Hernik & Csibra, 2009). These findings from the imitation light-box task have been replicated and extended by various laboratories (for a partial summary, see Table 1).

Furthermore, 14-month-old infants were more likely to imitate the head touch action on the light box from a reliable agent on video who had previously expressed certainty while using familiar artifacts in conventional ways (e.g., put a shoe on his foot after saying "Ah!") than to imitate an uncertain agent who used the artifacts unconventionally (e.g., put a shoe on his hand after saying "Hm") (Zmyj et al., 2010). A follow-up study (Buttelmann & Zmyj, 2020) clarified that infants still imitated the reliable agent even when he appeared unsure about his actions more than the certain but incorrect agent. Similarly, infants used others' affective responses as a cue about their reliability (Chow et al., 2008; Repacholi, 1998). After seeing an agent look happily and excitedly into a container while saying "Wow!", 14-month-old infants discovered that either the container had a toy inside (reliable agent) or it was empty (unreliable agent). Subsequently, infants were more likely to faithfully imitate the head touch action of the reliable agent than the unreliable agent (Poulin-Dubois et al., 2011). These studies show that infants, like preschoolers, selectively trust agents' specific ways to act on artifacts based on their epistemic reliability (Baillargeon et al., 2016).

The cognitive mechanism for epistemic trust during early childhood

A theoretical framework for the extant research on epistemic trust was introduced by Sobel and Kushnir (2013), who proposed a rational approach (*rational account*). The account posits that young children might start out with a default tendency to trust other people, which is thought to be adaptive and serves important functions early in life such as laying the foundation for language acquisition (e.g., Baier, 1986; Coady, 1992; Jaswal et al., 2010). Importantly, with age, as children become able to judge information provided by others based on their own conceptual understanding (e.g., labels for or functions of familiar objects), they can make rational decisions about whether or not to trust what they are told or what they are shown. The rational account of epistemic trust thus hinges on children's cognitive capacities. It is not until children achieve the cognitive skills required to question

Table 1
Examples of studies using the imitation light-box task with infants aged 14–18 months in a between-participant design.

Study	Age (mean and range [months; days], if available)	Demonstration mode	Length of response period	Coding	Results (% of infant imitation)	
Buttelmann et al. (2013	14-month-olds (*M* = 14;0, range = 13;15–14;15)	Video	60 s	Head touch	46% (language in-group)	21% (language out-group)
Chen & Waxman (2013, Experiment 1)	14-month-olds (*M* = 14;6, range = 13;0–15;6)	Face-to-face	120 s (with a 5-min delay)	Head touch or within 10 cm of light box	71% (hands-free)	23% (hands-occupied)
Gergely et al. (2002)	14-month-olds	Face-to-face	20 s (with a 1-week delay)	Head touch or within 10 cm of light box	69% (hands-free)	21% (hands-occupied)
Király et al. (2013, Experiment 1)	14-month-olds (*M* = 14;6)	Face-to-face	20 s (with a 10-min delay)	Head touch or within 10 cm of lightbox	64.7% (communicative, hands-free)	29% (non-communicative, hands-free)
Meltzoff (1988)	14-month-olds (*M* = 14;10, range = 14;0–14;16)	Face-to-face	20 s (with a 1-week delay)	Forehead touch or head within 10 cm of light box	67% (with demonstration)	0% (with no demonstration)
Paulus et al. (2011)	14-month-olds (*M* = 14;16, range = 13;15–14;31)	Face-to-face	60 s	Head touch or within 10 cm of light box	74% (hands-free)	32% (hands-occupied)
Pinkham & Jaswal (2011)	18-month-olds (*M* = 18;9)	Face-to-face	20 s	Head touch	72% (with demonstration)	14% (self-discovery)
Poulin-Dubois et al. (2011)	14-month-olds (*M* = 14;12, range = 13;10–16;14)	Face-to-face	~30 s	Forehead touch	61% (reliable agent)	34% (unreliable agent)
Zmyj et al. (2010, Experiment 1)	14-month-olds (*M* = 14;0, range = 13;15–14;15)	Video	60 s	Head touch	59% (reliable agent)	30% (unreliable agent)

others' reliability status that they become selective about who to trust. That is, children's epistemic trust is guided by their conceptual understanding (Sabbagh et al., 2017).

In previous studies using the imitation light-box task (Buttelmann & Zmyj, 2020; Poulin-Dubois et al., 2011; Zmyj et al., 2010), the manipulations on the agent's epistemic reliability rest on the agent's odd behaviors that violate social norms or conventions (Lucas & Lewis, 2010), or the agent's inconsistent affective responses. According to the *rational account,* at the root of these manipulations is the assumption that infants already have some conceptual understanding that serves as the basis to judge the agent. In the studies by Buttelmann, Zmyj, and colleagues (Buttelmann & Zmyj, 2020; Zmyj et al., 2010), the understanding is about conventionality; for example, people wear shoes on their feet but not on their hands. In Poulin-Dubois et al. (2011), this understanding is reflected in the knowledge that people should act consistently with their psychological states such as goals, perceptions, and emotions (e.g., Baillargeon et al., 2015, 2016). That is, people are usually happy at seeing something as opposed to nothing. As such, the manipulations lead infants to cast doubt on the agent's epistemic reliability, and consequently they are less likely to copy the agent's head touch action on the light box.

A recent account focusing on low-level associative learning processes (Heyes, 2016, 2017), however, questions whether children's conceptual understanding needs to be invoked to explain the selective trust results, as suggested by the rational account. Under this *associative account,* differences in how young children attended to the reliable and unreliable agents' behaviors during the experiments could suffice. For example, in the word-learning task described above (Koenig et al., 2004), children might have acquired differential associative processes *during* their exposure to agents' accuracy, causing them to attend more to the accurate agent when she subsequently provided novel labels (Schütte et al., 2020). Similarly, Heyes (2017) suggested that in Poulin-Dubois et al. (2011) infants in the unreliable condition might have learned that the agent's actions (i.e., being happy and excited at seeing nothing in a container) had low predictive value and hence attended differently to her head touch action on the light box than those in the reliable condition despite the fact that infants in both the reliable and unreliable conditions spent similar amounts of time looking at the agent's demonstrations.

Proponents of the rational account have pointed out that a variety of associative processes would need to be evoked as alternative explanations for only a subset of the epistemic trust results (Poulin-Dubois, 2017; Sabbagh et al., 2017). Critically, recent studies using the word-learning task (Koenig et al., 2004) lend more support for the rational account. For example, 18-month-old infants' performance in this task have been found to be linked to their emergent metacognitive abilities and their understanding of others' knowledge levels, demonstrating the impact of cognition on epistemic trust (Crivello et al., 2018; Kuzyk et al., 2020). Moreover, in a reversed version of the word-learning task, young children still endorsed novel labels provided by the accurate agent but not the inaccurate agent even if the labels were provided *before* they learned about the agents' accuracy (Dautriche et al., 2021; Luchkina et al., 2020; Schütte et al., 2020; Scofield & Behrend, 2008). Thus, these results are in direct conflict with predictions from the associative account.

The current research

The aim of the current study was to provide additional empirical support for the rational account of epistemic trust (Sobel & Kushnir, 2013) using the infant imitation light-box task. To this end, we also sought to use a more subtle cue of reliability than those used previously. Instead of directly observing an agent correctly versus incorrectly name familiar objects (e.g., Dautriche et al., 2021; Koenig & Woodward, 2010; Luchkina et al., 2018) or the agent behave normally versus oddly (Buttelmann & Zmyj, 2020; Poulin-Dubois et al., 2011; Zmyj et al., 2010), infants in the current study watched the agent make choices among objects. These pairwise choices among three objects (i.e., the agent chose Object A over Object B, Object B over Object C, and then A over C or C over A) were not outrightly incorrect in isolation. But these choices as a whole would inform infants on whether the agent made transitive choices (A > B, B > C, therefore A > C) or intransitive choices (A > B, B > C, then C > A).

Prior research found that this cognitive ability of making transitive inferences is already present in 16-month-old infants (Mou et al., 2014). Mou et al. (2014) reported that having seen an agent choose A over B and B over C, infants then expected her to choose A over C based on transitivity. Further positive evidence indicates that younger infants (aged 10–15 months) also appear to expect transitivity in

social dominance relationships (Gazes et al., 2017; Mascaro & Csibra, 2014). These reports are consistent with preschoolers' success in transitive reasoning tasks (e.g., Braine, 1964; Bryant & Trabasso, 1971; Harris & Bassett, 1975; Riley & Trabasso, 1974; Trabasso et al., 1975) as well as more recent findings suggesting that transitivity of preference is an axiomatic assumption underlying adult decision-making processes (Regenwetter et al., 2011), contrary to earlier findings (Tversky, 1969).

Thus, if infants could judge the transitivity of the agent's choice, then they should consider the transitive agent's actions, but not the intransitive agent's actions, to be consistent and predictable. Therefore, they should view the transitive agent as more reliable than the intransitive agent. If so, they would be more likely to trust and imitate her unusual way of activating the light box with her head when her hands were available in the light-box task. This in turn would provide support to the rational account of epistemic trust by showing that transitivity as a cue of reliability would also serve as the cognitive basis for infants to selectively learn from others. (Issues of reliability will be further explored in the Discussion section.) In addition, in the current study, the intransitive agent's actions were designed such that they were *perceptually* more consistent or predictable than those of the transitive agent. Therefore, evidence that infants would nevertheless imitate the transitive agent more than the intransitive agent in the light-box task would argue against predictions based on lower-level perceptual processes, such as the associative account (Heyes, 2017), to the same effect as recent reports using the word-learning task (Dautriche et al., 2021; Luchkina et al., 2020; Schütte et al., 2020).

Experiment

We examined how a female agent's object choices (i.e., making transitive/intransitive choices) affected infants' trust in the agent in the imitation light-box task. Based on Mou et al. (2014), we tested 16-month-old infants. Infants participated in a three-phase experimental procedure that consisted of a familiarization phase, an orientation phase, and a test phase. In the first two phases, infants watched the agent make pairwise choices among three objects (i.e., colored toy footballs) on an apparatus resembling a small stage. In the test phase, the imitation light-box task was administered.

Infants were randomly assigned to one of three conditions: transitive, intransitive, or reversed (see Fig. 1). The three conditions differed only in the familiarization and orientation phases. In the *transitive* condition, as in Mou et al. (2014), in the first three familiarization trials infants watched the agent choose a red football (A) but not a yellow football (B) (A > B). In the next three familiarization trials, infants watched the agent choose the yellow football (B) but not a green football (C) (hence, B > C).[1] Then, in the orientation trial, the green football (C) and the red football (A) were on the apparatus, and the agent chose the red football (A) but not the green football (C) (A > C). Therefore, she made transitive choices. In the test phase (imitation light-box task), infants watched the agent demonstrate the head touch action to illuminate the light box three times (Chen & Waxman, 2013; Király et al., 2013; Meltzoff, 1988; Poulin-Dubois et al., 2011). They were then given the light box to manipulate in a 30-s response period, as in Poulin-Dubois et al. (2011). This was done due to similarities between Poulin-Dubois et al. (2011) and the current study in that the agent interacted with the infant face to face, different from Buttelmann & Zmyj (2020) and Zmyj et al. (2010), and there was no delay between the reliability manipulation phase and the imitation light-box task.

The *intransitive* condition was identical to the transitive condition with the exception that in the orientation trial the agent chose the green football (C) over the red football (A) (C > A). In accordance with the rational account, if infants used their understanding of whether the agent's choices were transitive or intransitive to inform their decision of whether to trust the agent, then infants in the

[1] A study with 8- and 9-month-olds, similar to Mou et al. (2014), obtained negative results (Robson et al., 2014). An important difference between this study and Mou et al. (2014) in addition to infant age, as suggested by Robson et al. (2014), lies in the presentation of the premise preferences. Robson et al. (2014) presented the two premises (A > B and B > C) in a block of two trials and habituated infants to the blocks. In Mou et al. (2014), only one premise preference was featured in each familiarization block of three trials, which might have contributed to infants' success in making transitive inferences. The current study followed Mou et al.'s (2014) design. Interestingly, in Gazes et al. (2017), which reported infants' success in a transitive task focusing on animal puppets' dominance relationships, although the two premises were presented in one setting (C < B and B < A), somewhat similar to Robson et al. (2014), all three puppets were also displayed simultaneously in a linear order (CBA). Thus, a linear display of all items might have enabled infants to succeed in these three-item transitivity tasks, a finding also reported in Mou et al. (2014).

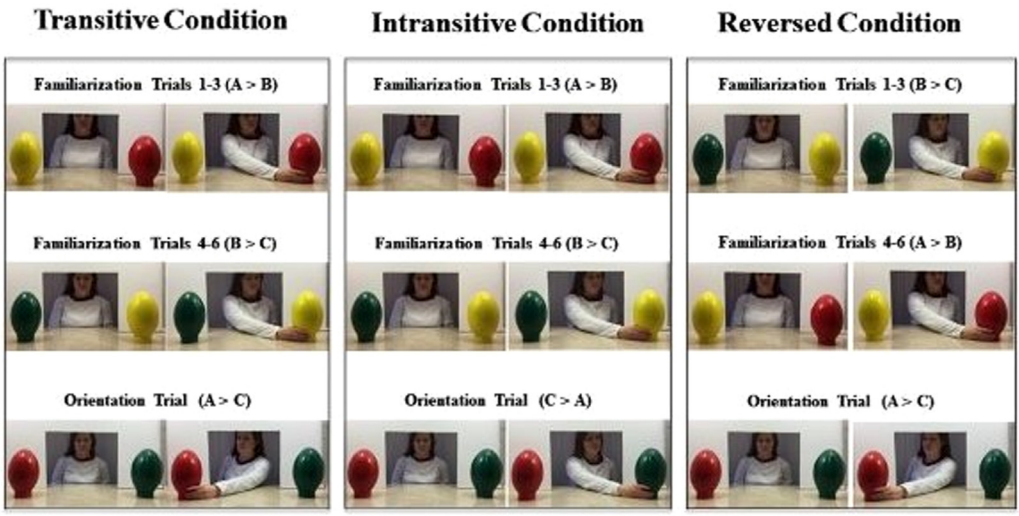

Fig. 1. Photographs of the familiarization and orientation trials presented to infants in the transitive, intransitive, and reversed conditions.

transitive condition should be more likely to imitate her head touch action on the light box than those in the intransitive condition.

In the transitive condition, however, the direction to which the agent reached for a football changed from the familiarization trials to the orientation trials (right to left). By contrast, in the intransitive condition, the direction of the agent's reach stayed the same throughout the familiarization and orientation phases; she consistently reached for the football on the right. According to the associative account, lower-level consistency, in this case unvarying or varying reach, could have led to infants' differential attention to the agent's head touch action in the light-box task without any considerations about the transitivity of the agent's choice. Because the intransitive agent's actions before the test phase could be deemed perceptually more consistent that those of the transitive agent, infants should imitate the agent more in the intransitive condition than in the transitive condition.

Based on this, the rational and associative accounts would make opposite predictions regarding the results of the transitive and intransitive conditions. The third condition, the *reversed* condition, aimed to eliminate both the cognitive basis for infants to judge the agent's transitive choice and the perceptual consistency in the unchanging direction of her reach and predict a low imitation rate. Given infants' default trust in others, as shown by their imitation of agents' head touch action in the original light-box task (Meltzoff, 1988), a low imitation rate would be of particular interest, similar to that of the hands-occupied condition in Gergely et al. (2002). Importantly, under the rational account, the imitation rate should be higher in the transitive condition, due to the presence of the cognitive basis (i.e., transitivity), than in the reversed condition. Conversely, under the associative account, the imitation rate should be higher in the intransitive condition than in the reversed condition.

The reversed condition was identical to the transitive condition with the exception that infants watched the agent choose the yellow football (B) over the green football (C) in the first three familiarization trials (B > C) and then watched her choose the red football (A) over the yellow football (B) (A > B) in the last three familiarization trials. In the orientation trial, the agent chose the red football over the green football (A > C). Therefore, the direction of the agent's reach changed from familiarization to orientation, as in the transitive condition. In addition, according to Mou et al. (2014), when the two premise choices were presented in such a reversed order (B over C and then A over B), it would have been too taxing for infants to judge whether or not the agent made the transitive choice by mentally forming a linear ordering of the agent's choices (A > B > C), which they might have done to succeed in the transitive condition, as did preschoolers in transitivity tasks (Trabasso et al., 1975).

Therefore, in the reversed condition, infants could not have relied on the agent's transitive choices to evaluate the agent's reliability status, unlike those in the transitive condition.

In summary, among the three conditions, only infants in the transitive condition would have the cognitive basis to judge the agent's reliability (i.e., transitive choices). Based on the rational account, infants in the transitive condition would be more likely to trust and hence imitate the agent in the light-box task than those in the intransitive and reversed conditions. By contrast, according to the associative account, infants in the intransitive condition might simply rely on the agent's unvarying reach to attend to her head touch action in the light-box task, differently than those in the transitive and reversed conditions, and hence imitate her more.

Method

Participants

Participants were 48 full-term healthy infants (27 male and 21 female; age range = 15 months 2 days to 19 months 0 days, *M* = 16 months 9 days). Of these, 16 infants were randomly assigned to one of the three conditions: the transitive condition (8 male; *M* = 16 months 13 days), the intransitive condition (10 male; *M* = 16 months 12 days), or the reversed condition (9 male; *M* = 16 months 1 day). This sample size was determined by a power analysis using a degree of freedom of 1 (2 × 2 contingency table: two conditions and two potential responses), an alpha level of .05, and a large effect size *w* of .50 for the χ^2 test to compare between two conditions, which can achieve power of .80 (Faul et al., 2007). Another 9 infants were tested but excluded because they did not act by the end of the 30-s response period of the imitation light-box task (*n* = 7, 1 in the transitive condition, 5 in the intransitive condition, and 1 in the reversed condition)[2] or because of parental interference (*n* = 2, 1 in the transitive condition and 1 in the reversed condition). Of the 57 infants, 49 (86%) were White based on parental report. Of the 57 infants in the original sample, 3 were exposed primarily to a language other than English at home and 3 other infants had some exposure (≤25%) to a non-English language; the rest were monolingual English-learning infants.

Apparatus

Familiarization and orientation trials (looking-time task)

The apparatus consisted of a wooden display box (106 cm high × 104 cm wide × 61 cm deep) mounted 76 cm above the room floor. The infant sat on the parent's lap and faced an opening (56 cm high × 102 cm wide) in the front of the apparatus. Between trials, a curtain consisting of a muslin-covered frame (61 cm high × 104 cm wide) was lowered in front of the opening. The white back wall was made of foam board and had a rectangular window (35 cm high × 45 cm wide) about 28 cm from each side of the back wall. The side walls of the apparatus were painted white, and the floor was made of foam board and covered with khaki-colored contact paper. The agent, wearing a white shirt, sat behind the window in the trials. A large white cloth curtain covered the area behind her.

The three toy footballs were covered with red, yellow, and green tape, respectively. Each football was attached on a small circular base (2.6 cm high × 7.5 cm in diameter) to stay upright. The combined height of the football and the base was 24 cm, and the diameter of the football at the widest point was 14 cm.

The apparatus was also equipped with two video cameras. One recorded the events being shown on the apparatus, whereas the other recorded the infant. The input from the two cameras could be

[2] The ratio of infants excluded for not responding to those included (7:48) was comparable to that (13:60) of Poulin-Dubois et al. (2011), which had a response period of similar length. It is interesting to note that in the current study there were more infants in the intransitive condition than in the other two conditions who did not respond in the imitation light-box task. It is possible that infants' failure to respond also reflected their distrust in the agent and/or the unease they felt around her, which could be linked to aspects of infants' temperament such as shyness (Dweck, 2017).

monitored online and checked offline to ensure proper testing. A metronome that beat softly once per second was used to help agents adhere to the scripts.

Test trial (imitation light-box task)

The test apparatus was located in a different part of the experiment room than that used for the familiarization and orientation phases. This apparatus consisted of a small wooden table (51 cm high × 56 cm wide × 76.5 cm deep). The round touch light box was white with a gray rim and 14 cm in diameter. It was mounted on a rectangular piece of foam board (26 cm wide × 16 cm deep and covered with khaki-colored contact paper) so that the agent could easily move the light box on the table. One video camera was used to record the agent and the infant during the light-box task.

Procedure

Familiarization and orientation trials (looking-time task)

The infant sat on the parent's lap in front of the apparatus. Parents were instructed not to interact with the infant during the trials. Before the experiment, the agent and the infant played with toys in the waiting room for a few minutes as a warm-up period. After the infant and the parent sat in front of the apparatus, the agent again greeted the infant. The agent was always a White, female, college-aged research assistant who spoke English at the native proficiency level. She was blind to the hypotheses of the study. Two naïve observers (blind to the hypotheses and condition) monitored the infant's looking behavior by viewing the infant through peepholes in large cloth-covered frames on either side of the apparatus. Each observer held a controller linked to computer software (Baillargeon & Barrett, 2005) and pressed the button when the infant looked at the event. Looking times recorded by the primary observer were used. To assess inter-observer agreement, each trial was divided into 100-ms intervals and the computer software determined within each interval whether the two observers agreed on whether the infant was looking at the event or not looking. Percentage agreement was calculated for each trial by dividing the number of intervals in which the observers agreed by the total number of intervals in the trial. For 14 of the 48 infants, only the primary observer was present. Inter-observer agreement for the remaining 34 infants averaged 93% per trial per infant.

In all three conditions, there were six familiarization trials and one orientation trial (see Fig. 1). In each trial, after the infant watched the static scene for a cumulative 2 s with the agent and the two footballs on the apparatus, 43.5 cm apart and 11 cm from the back wall, the agent reached for and grasped one of the footballs in a 2-s action sequence. The agent paused with her eyes fixated on the football she grasped until the trial ended, when the infant looked away for a consecutive 2 s after having looked at the paused scene for at least a cumulative 2 s or looked for a cumulative 30 s.

In the *transitive* condition, infants saw the red football (A) and yellow football (B) pair in the first three familiarization trials, and the agent chose the red football on the right (A > B); infants saw the yellow football (B) and green football (C) pair in the last three familiarization trials, and the agent chose the yellow football on the right (B > C). In the orientation trial, the agent chose the red football but not the green football on the right (A > C). The *intransitive* condition was similar except that the agent chose the green football but not the red football in the orientation trial. The *reversed* condition was similar to the transitive condition except that infants saw the pair of yellow and green footballs in the first three familiarization trials and then the red and yellow pair of footballs in the last three familiarization trials. In all three conditions, infants were attentive during the 2-s action sequence of the familiarization and orientation trials (M = 1.94 s, SD = 0.24).

Test trial (imitation light-box task)

Infants in all three conditions participated in the light-box task. After the orientation trial, the parent and the infant were led to the table. The infant stood, with the parent's support if necessary, across the table from the agent; the parent sat behind the infant and was instructed to remain neutral. The agent had the light box in front of her and rested her hands flat on either side of the light box. She looked at the infant and said "Look at this—what I can do!" in infant-directed speech (Fernald & McRoberts, 1996). She then bent down and pressed the light box with her forehead to turn on the light. As discussed by Király et al. (2013), eye contact, infant-directed speech, and the outcome of

the light being turned on by the agent in the light-box task all are important cues for infants to learn the agent's unconventional head touch action on the light box. Once the agent's forehead released the light box, the light was off. The agent demonstrated the action two more times except that she only said to the infant "Look at this!" before illuminating the light box with her forehead. The three demonstrations lasted about 15 s. Then, the agent pushed the light box across the table to the infant's side (3 s), retreated her arms and hands, and said in infant-directed speech "Now it's your turn!" (3 s). After the agent stopped talking, the 30-s response period started.[3] After the test session, one coder recorded whether any part of the infant's head, including the chin or a cheek, touched on the light box or came within 10 cm of it, at least once, or only the infant's hand(s) touched the light box before the end of the response period. In previous studies using the imitation light-box task, at least two factors varied—the length of the response period and the coding scheme of imitation (see Table 1) (Gellén & Buttelmann, 2017, 2019). The results are nevertheless comparable, for example, an imitation rate ranging from 61% to 74% in face-to-face studies. In the current study, we adopted the coding scheme that included the infant's head coming near the light box. A second coder watched 47 of the 48 video-recordings of the test trials to check accuracy (1 infant's test trial was inadvertently not recorded).

Infants' looking times in the familiarization and orientation trials were log-transformed to reduce positive skewness (Csibra et al., 2016). Analyses were performed on log looking times; raw looking times are provided to facilitate communication. Preliminary analyses on the log looking times in these trials revealed no effect of sex, $Fs(2, 42) < 0.87$, $ps > .250$; therefore, the data were collapsed across this factor.

Results

Familiarization and orientation trials (looking-time task)

Infants' log looking times in the six *familiarization* trials were averaged and analyzed by a 3×2 analysis of variance (ANOVA) with condition (transitive, intransitive, or reversed) as a between-participant factor and event (the event shown in the first three trials or the last three trials) as a within-participant factor. This analysis yielded a significant effect of event, $F(1, 45) = 15.74$, $p = .0003$, $\eta_p^2 = .259$, suggesting that infants across the three conditions looked reliably longer at the event presented in the first three familiarization trials than at the event presented in the last three familiarization trials (transitive condition: Familiarization Event 1, $M = 14.28$, $SD = 3.83$; Familiarization Event 2, $M = 9.19$, $SD = 3.78$; intransitive condition: Familiarization Event 1, $M = 15.42$, $SD = 6.77$; Familiarization Event 2, $M = 11.90$, $SD = 7.79$; reversed condition: Familiarization Event 1, $M = 14.99$, $SD = 7.54$; Familiarization Event 2, $M = 11.14$, $SD = 4.40$).

Infants' log looking times in the *orientation* trial were analyzed using a single-factor ANOVA with condition as the between-participant factor. The effect of condition was not significant, $F(2, 45) = 1.10$, $p > .250$, $\eta_p^2 = .047$, suggesting that infants in the three conditions looked similar amounts of time in the orientation trial (transitive condition: $M = 9.71$, $SD = 4.84$; intransitive condition: $M = 11.58$, $SD = 5.15$; reversed condition: $M = 13.23$, $SD = 7.53$). Interestingly, infants in the intransitive condition tended to look longer in the orientation trial than those in the transitive condition. These trends were similar to those in Mou et al. (2014) but did not reach significance to suggest that infants responded with heightened interest when the agent acted against transitivity. This was possibly due to procedural differences between the two studies. Mou et al. (2014) used a within-participant design and the maximum looking time in the trials was 60 s, whereas the current study used a between-participant design and the maximum looking time was 30 s.

Critically, the lack of a difference in looking times among the three conditions suggests that infants were similarly attentive in the familiarization and orientation phases prior to participating in the imitation light-box task.

[3] Therefore, the infant had about 33 s with the light box close to him or her. Only 1 of the 48 infants acted on the light box immediately after it came close, before the agent finished talking. This infant's data were kept in the sample. In addition, 1 infant was inadvertently given a 20-s response period. Because the infant imitated the agent's head touch action within the 20 s, this infant's data were also kept in the sample.

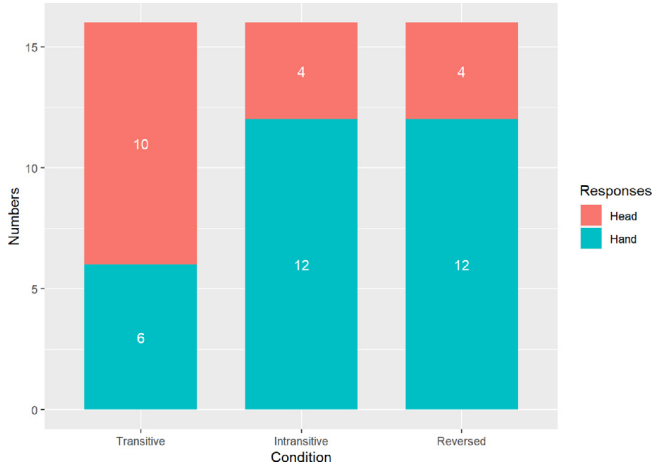

Fig. 2. Numbers of infants who imitated the agent's head touch action or used only their hand(s) to touch the light box during the test trial in the three conditions.

Test trial (imitation light-box task)

In the transitive condition, 10 of the 16 infants (62.5%; 5 male and 5 female) imitated the head touch action at least once (see Fig. 2). In the intransitive and reversed conditions, only 4 of the 16 infants (25%; 1 male and 3 female in both conditions) did so. Chi-square tests (Preacher, 2001) showed that the response patterns differed significantly among the three conditions, $\chi^2(2, 48) = 6.40$, $p = .041$, Cramer's $V = .365$, as well as between the transitive condition and either one of the intransitive and reversed conditions, $\chi^2(1, 32) = 4.57$, $p = .037$ (Fisher's exact one-tailed) (Preacher & Briggs, 2001), odds ratio = 5.00.

All infants attended to at least two of the agent's three head touches on the light box. The majority of infants in each condition attended to all three head touch demonstrations. There was no difference among the three conditions (transitive condition: 10/16; intransitive condition: 13/16; reversed condition: 12/15 [1 infant's test trial was inadvertently not recorded]), $\chi^2(2, 47) = 1.83$, $p = .400$. The light box was illuminated by the agent in the three demonstrations. However, because it took some force to press on the light box to activate it, only 4 of the 48 infants were able to illuminate the light box (1 each in the transitive and intransitive conditions and 2 in the reversed condition).[4] Most of the infants (41/48) used hand(s) as their first attempt, similar to the patterns from previous studies (Gergely et al., 2002; Király et al., 2013; Paulus et al., 2011). However, of the 16 infants in the transitive condition, 5 (2 male) imitated the agent's head touch action in their first attempt, whereas only 1 (female) of the 16 infants in either one of the intransitive and reversed conditions did so.

Following Király et al. (2013), we also examined the variability of infants' imitation. Of the 18 infants who imitated the agent's head touch action on the light box, only 3 infants' head came very close but did not touch the light box (1 in the transitive condition and 2 in the reversed condition). Of the 15 infants who touched the light box, 5 used only the forehead (3 in the transitive condition and 2 in the intransitive condition); 2 used the forehead and then other parts of the head such as face and nose (both in the transitive condition); and the remaining 8 infants used only different parts of

[4] In previous studies, infants usually activated the light box. For example, in Experiment 1 of Király et al. (2013), 67.8% of infants who imitated the head touch action illuminated the light box, whereas all infants illuminated the light box by their hands. However, it appeared that infants' failure to activate the light box in the current study did not affect the results given that 62.5% infants in the transitive condition imitated the agent's head touch action during the test trial, a proportion similar to those in previous studies in which infants did activate the light box (69% in Gergely et al., 2002, and 64.7% in Experiment 1 of Király et al., 2013). The proportion of 25% in the intransitive and reversed conditions was also similar to low imitation rates obtained in previous studies (e.g., 21% in Gergely et al., 2002).

their head other than the forehead such as chin, mouth, nose, and cheek (4 in the transitive condition and 2 each in the intransitive and reversed conditions). Therefore, whereas only 38.9% (7/18) of the imitators did the high-fidelity forehead touch, 50% (5/10) of the imitators in the transitive condition did so.

Discussion

The current findings suggest that the transitivity of an agent's choices influenced infants' trust in her specific ways of acting on a novel artifact. When the agent made transitive choices among objects (i.e., if she chose Object A over Object B, Object B over Object C, and then A over C), infants seemed to trust her and hence imitated her head touch action in the light-box task. When the agent made intransitive choices (i.e., if she chose A over B, B over C, but then C over A), infants were less likely to trust her actions and more likely to use only their hands to touch the light box. In the reversed condition, although the agent made transitive choices, infants could not evaluate the transitivity of her choices, presumably because of the reversal of the two premise choices (B > C, A > B, then A > C) (Mou et al., 2014). Infants again did not copy her head touch action in the light-box task. Together, the results of the three conditions suggest that infants relied on their interpretation of the agent's choices to inform their selective imitation of her unusual head touch actions to illuminate the light box. Only when infants judged the agent's choices to be transitive, as in the transitive condition, did they trust and imitate her. These results provide further empirical support for the rational account of epistemic trust (Sobel & Kushnir, 2013) that infants' cognitive capacities form the basis for their selective trust in others.

Explanatory accounts based on low-level processes (e.g., Heyes, 2017) cannot fully explain the current results. Specifically, these low-level processes might have predicted a high imitation rate from the intransitive condition because the direction of the agent's reach remained constant in the familiarization and orientation phases, leading to infants attending to her head touch during the test trial differently from those of the transitive and reversed conditions. Infants, however, seemed unaffected by this factor and did not adopt the intransitive agent's head touch action on the light box. In fact, the imitation rate was significantly lower in both the intransitive and reversed conditions than that in the transitive condition. These results were not due to varying attentional levels. This is because, as in previous studies (Buttelmann & Zmyj, 2020; Zmyj et al., 2010), infants in all three conditions looked similar amounts of time at events before the imitation light-box task. They were also similarly attentive during the agent's demonstrations in the light-box task. Admittedly, infants across the three conditions might have encoded different aspects of the agent's choices and head touch actions, as argued by Heyes (2017), which remains a possibility in the absence of detailed eye-tracking data. However, based on the current results, any such differential fine-grained encoding would likely have resulted from infants' conceptual understanding of the transitivity of the agent's choice as opposed to perceptions of the direction of the agent's reach. Thus, together with results obtained from the word-learning task (Dautriche et al., 2021; Koenig et al., 2004; Kuzyk et al., 2020; Luchkina et al., 2020; Schütte et al., 2020; Scofield & Behrend, 2008), these data support the view that selective epistemic trust during early childhood is best explained by the rational account (Sobel & Kushnir, 2013).

In the original light-box task (Gergely et al., 2002; Meltzoff, 1988), the agent's head touch was unusual or inefficient compared with a usual hand touch. Infants' neural responses, from event-related potential (ERP) measures, suggest that they indeed find the head touch unexpected (Langeloh et al., 2018, 2020). This does not, however, prevent infants from imitating her head touch, presumably because infants trust that there are underlying reasons for the agent to do so (Buttelmann et al., 2008; Gergely et al., 2002). In the transitive condition of the current study, the transitivity of the agent's choice thus effectively maintained infants' trust in the agent, as did the previous experimental manipulations that demonstrated an agent's reliability in various ways (Buttelmann & Zmyj, 2020; Poulin-Dubois et al., 2011; Zmyj et al., 2010). That is, once infants find an agent to be reliable, they also trust her subsequent inefficient or unusual actions. In the intransitive condition, the familiarization and orientation trials before the imitation task led infants to judge that the agent made intransitive choices and hence cast doubt on her reliability status. These findings thus establish transitivity as

another cue of reliability. Previous reliability manipulations that clearly show agents' lacking correct or appropriate information (e.g., Buttelmann & Zmyj, 2020; Koenig et al., 2004; Zmyj et al., 2010) point to agents' incompetence. Infants and toddlers also use other markers of agents' competence such as certainty and confidence as cues of reliability (Birch et al., 2010; Buttelmann & Zmyj, 2020). By contrast, an agent's intransitive choices perhaps speak more about her irrational or inconsistent behavior than about her competence. Therefore, the current study is similar to Poulin-Dubois et al. (2011) in showing that infants consider inconsistent agents to be less reliable sources of information (Baillargeon et al., 2016). A closer look reveals that infants' imitation in Poulin-Dubois et al. (2011) was of higher fidelity than that in the current transitive condition. In a response period similar in length to that in the current study, Poulin-Dubois et al. (2011) obtained a rate of 61% infant forehead touch with the reliable agent. In the current transitive condition, the forehead touch imitation rate was only 31.3% (5/16). The two studies differed in several aspects such as infant age and positioning (i.e., infants were seated in a chair attached to the apparatus in Poulin-Dubois et al., 2011). Nevertheless, it remains an intriguing question whether infants might treat affective responses as a better indicator of an agent's reliability than the transitivity of her object choices.

In the reversed condition of the current study, the familiarization and orientation trials before the light-box task might have left infants unable to evaluate the transitivity of the agent's choices. Although each one of the agent's pairwise choices (i.e., Object B over Object C, Object A over Object B, and A over C) was reasonable in isolation, the three choices as a whole might have posed a difficulty to infants. That is, the sequence of choices did not violate infant transitivity expectation, as did that in the intransitive condition, nor was it consistent with transitivity (based on infants' cognitive processing), as in the transitive condition, and hence it might have been considered inexplicable by infants. Therefore, we speculate that the agent's inexplicable behavior was in effect similar to agents' odd behavior such as putting a shoe on their hand and showing excitement about an empty container, which did violate infants' understanding (Buttelmann & Zmyj, 2020; Poulin-Dubois et al., 2011; Zmyj et al., 2010). Such inexplicable behavior might be another cue of the agent's epistemic unreliability given that the trials before the light-box task in the reversed condition essentially eroded infants' default trust in the agent. Future research can further examine how infants conceptualize agents' inexplicable behavior. Nevertheless, in the current study, the results of the intransitive and reversed conditions suggest that once infants find an agent to be unreliable for being irrational, inconsistent, or inexplicable, they also cease to trust her unusual actions. Whereas a "baseline" measure similar to that of the original hands-free condition (Gergely et al., 2002), without reliability manipulations, was obtained with 14- and 18-month-olds (e.g., Chen & Waxman, 2013; Pinkham & Jaswal, 2011), this has not been shown with 16-month-olds, the target age of the current study. Future research will address this issue. It will also be interesting to examine older infants' imitation in the reversed condition when they *can* infer the transitivity of the agent's choice even when the two premise choices are presented in a reversed order.

Under the rational account, the cognitive basis for children's selective epistemic trust is their conceptual understanding, including their knowledge of physical and social aspects of the world (Poulin-Dubois & Brosseau-Liard, 2016; Sobel & Kushnir, 2013). Research on early psychological understanding suggests that infants expect agents to be rational and to act within three constraints: consistency (e.g., agents should behave consistently with their psychological states; Baillargeon et al., 2015), efficiency (e.g., agents should act with the least effort possible; Gergely et al., 1995), and normalcy (e.g., agents are expected to act in accordance with social norms and conventions; Schmidt & Rakoczy, 2018). Considerations of these constraints allow infants to interpret and predict agents' behavior (Baillargeon et al., 2015, 2016). To date, the studies on selective imitation using the light-box task employed the links between infants' psychological understanding and their judgment of reliability (or trust). Buttelmann & Zmyj (2020) and Zmyj et al. (2010) made use of infants' understanding of normalcy/conventionality, in line with preschooler research focusing on their knowledge of linguistic labels, as in the word-learning task (Koenig et al., 2004), which are essentially conventional referents used by specific groups. Poulin-Dubois et al. (2011) and the current study used infants' understanding of consistency. Because the current study used infants' expectation that people's choice of objects should conform to logic (or transitivity), it also demonstrates how infants bring their emergent logical abilities into their understanding of the social world (see also Cesana-Arlotti et al., 2020;

Gazes et al., 2017). Interestingly, infants' understanding of efficiency, by contrast, does not appear to directly link to their decision to trust given that infants readily imitate agents' inefficient actions (Gergely et al., 2002; Meltzoff, 1988).

Finally, it is worth noting that although infants' selective imitation has been used as a measure of epistemic trust, imitation also serves a social purpose during early childhood, such as for young children to establish affiliation with others, at both the individual and group levels (Nielsen, 2006; Nielsen & Blank, 2011; Nielsen & Tomaselli, 2010; Nielsen et al., 2014, 2018; Over & Carpenter, 2009, 2013; Zmyj & Buttelmann, 2014; Zmyj & Seehagen, 2013). Previous studies have examined the impact of intergroup factors, such as age and accent, on selective trust (Aldan & Soley, 2019; Corriveau, Kinzler, & Harris, 2013; Jaswal & Neely, 2006; Kinzler et al., 2011; Seehagen & Herbert, 2011; Zmyj & Seehagen, 2013). For instance, in the imitation light-box task, Buttelmann et al. (2013) found that the language spoken by an agent on video influenced 14-month-old infants' trust in the agent. However, in a context where infants interact with an agent face to face, as in the current study, social considerations should also play a role in selective trust (Altınok et al., 2022; Howard et al., 2015; Markson & Luo, 2020).[5] Examining the various social factors and cues of reliability infants can use to inform their selective imitation therefore will shed new light on the development of trust during early childhood.

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[5] Therefore, we included in our sample 3 infants who were mostly exposed to a non-English language. Of these 3 infants, 1 infant's parent interfered during the test trial and thus this infant's data were excluded from the final sample. The other 2 infants were in the transitive and reversed conditions, respectively, and both used only their hands to touch the light box. These 2 infants were also non-White, different from the White agent with whom they interacted.

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