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Do Babies Learn From the Impossible?

By

Yueyi Lei

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Faculty Advisor: Marc Colomer Canyelles
Preceptor: Danielle Bolling

Abstract

Based on core knowledge theory and several empirical findings, infants have basic expectations on objects and humans. These expectations are influential in infants' learning. Previous studies have found that infants' learning is promoted when objects previously violated physical principles, while learning is attenuated when people previously violated psychological principles. For instance, when infants see an object passes through a solid wall that violates principles of naïve physics, they want to explore and learn more about the object. Nevertheless, when infants see a person who grabs a ball inefficiently, which violates the principles of naïve psychology, infants do not choose to subsequently learn from that person. These findings raise the question of why expectancy violations in the object and social domains influence learning differently. In this thesis, we tested if seeing someone performing impossible actions by violating the physical principles would enhance or hinder 17 to 19-month-old infants' social learning from the person. We found no evidence that seeing human behaviors violate the naïve physics influence 17 to 19-month-old infants' social learning.

Keywords: core knowledge, naïve physics, naïve psychology, social learning, infancy, cognitive development

From the birth of infants, they start to explore the environment and learn new information about this world. With a plethora of information circulating around them, how infants understand and process information becomes an important question. A popular theory, the core knowledge, states that infants have the instinct cognitive ability to make sense of the world around them based on a set of basic expectations (Spelke & Kinzler, 2007). Core knowledge refers to commonsense conceptions or expectations, which is proposed to be the principal ground for infants' reasoning (Spelke et al., 1992).

Two core knowledge domains, naïve physics, and naïve psychology, have been demonstrated to play a critical role in how infants explore and learn from physical objects and social environment (Colomer & Woodward, under review; Stahl & Feigenson, 2015). Naïve physics principles allow infants to understand fundamental physical phenomena, presumably without previous experience. For example, as a physical principle, spatiotemporal continuity represents that when an object is hidden in one place, it cannot be in another different place when it is revealed. The object should still exist at the same spot and spacetime, even if it cannot be seen or heard. When a hidden object is revealed in another place, infants will look longer at it (Spelke et al., 1992). Object solidity is another principle of naïve physics. It refers to an object that will be stopped by another solid object (e.g., a wall) and not pass through it. If an object passes through another solid object, infants will also look longer at it (Spelke et al., 1992). These reactions indicate infants' core understanding of naïve physics (Stahl & Feigenson, 2015). Therefore, infants hold basic expectations about physical objects and are surprised when an object's behavior violates the principles. They do not expect the object to move non-continuously or pass through other solid objects.

A different core system, naïve psychology, represents people and their actions. Naïve psychology suggests that compared to objects, infants understand people under the assumption that they act toward goals (Woodward, 1998). There is a principle of action efficiency in naïve psychology proposing that people should achieve goals through efficient means (Gergely & Csibra, 2003; Sodian et al., 2004). For example, when a person tries to grab a cup from the table, they are supposed to raise the arm and use hand to grab it directly. Other unnecessary movements will be considered inefficient. In this way, when people conduct inefficient behavior when attaining goals, infants will look longer at events that violate the action efficiency, indicating infants have basic expectations of how people should act toward goals (Gergely et al., 1995).

From the evidence above, core knowledge gives infants the ability to expect certain physical phenomena and social situations. Infants' expectations of objects, people, and events could be the starting foundation for exploring and learning. However, suppose infants have basic core expectations about this world. In that case, it would be helpful to know the influences of the violations of these expectations. Specifically, the violations may suggest an opportunity for infants to learn. The purpose and the consequence of infants' longer looking time and surprising reactions are necessary for understanding infants' cognitive ability and development (Stahl & Feigenson, 2015).

A study by Stahl & Feigenson (2015) has shown how object motions that violate the naïve physics would influence infants' subsequent exploration and learning. They set two experiments on object solidity and spatiotemporal continuity. In the solidity experiment, they let the target object either pass through the solid wall or not, so it would be inconsistent or consistent with infants' expectations on the principle of solidity. The spatiotemporal continuity experiment had two screens on the stage. The target object was hidden behind the left screen. The final reveal showed whether the object was still on the left in accord with infants' expectations of spatiotemporal continuity, or on the right to violate the physical principle. Stahl & Feigenson (2015) used a sound to pair with the target object and let the infants learn this association to test if the violations of expectation influenced infants' subsequent learning. Then, a new distractor object was moved with the target object together while the taught sound was played. The proportion of the looking time at the target object would determine if infants have learned the object-sound association. The result showed that when the sound was played, infants tended to look longer at the target object versus the distractor (as compared to baseline) if the object previously violated the expectations. Nevertheless, infants did not look longer if the object was presented in an expected event. In addition, infants preferred to explore later more on the target object, which violated the expectations in naïve physics, than the object accorded the expectations. Therefore, the object with unexpected motions promoted infants' learning more than the object with expected motions (Stahl & Feigenson, 2015). This study took a step forward to studying the potential influences of the principles in naïve physics on infants' cognitive learning. But another critical question arises from their findings: how would expectancy violations of naïve psychology, such as seeing someone performing an inefficient action that violates the rationality principle, influence infants' learning from others?

A study by Colomer & Woodward (under review) found that when manipulating actions based on principles of naïve psychology, expectancy violations disrupted rather than induced infants' learning. The experiment started with a familiarization phase.

Infants would first see an agent who grasped an object from the other side of the table by following a curvilinear movement around a solid wall. These actions would let infants understand that the agent's actions had an instrumental goal. Next, in the main manipulation phase, the wall was removed, and the agent tried to obtain the target object through either efficient behavior (e.g., obtaining an object with a direct movement) or inefficient behavior (e.g., obtaining an object following the same curvilinear movement as in the familiarization, which in this case involved an unnecessary cost). Then, the agent would teach infants to associate the target object with an audio label (e.g., the target object called a "gombie"). For testing, the target object was shown with a new distractor object side by side on the screen. The taught label was played repeatedly in one trial, and a novel label was played in another trial.

The results found that under the efficient condition, infants looked longer at the target object when hearing the taught label as compared to the novel label, suggesting they had learned the object-label association. This indicated that infants preferred to look at the target object (as compared to the distractor) with the taught label under the efficient condition. However, the study found no evidence of learning the label-object association in the inefficient condition (Colomer & Woodward, under review). This suggested that violations of action efficiency do not facilitate infants' learning but instead attenuate infants' subsequent social learning. Under social contexts, infants do not seem to consider the situation when a person violates the principle of action efficiency as an optimal opportunity for learning (Colomer & Woodward, under review).

Stahl & Feigenson's (2015) study has shed light on the relationship between infants' learning choices and violations of expectations in naïve physics. Colomer &

Woodward (under review) have found a new direction of infants' learning preferences when violations of expectations in the social world happen. These studies show that infants' learning is promoted when objects previously violated physical principles, while learning is attenuated when people previously violated psychological principles. These findings raise the question of why expectancy violations in the object and social domains influence learning differently.

The present project focused on investigating two of the factors that could explain the different findings between Stahl & Feigenson (2015) and Colomer & Woodward (under review). First, one study manipulated expectancy violations about objects' behavior, whereas the other study manipulated expectancy violations about people's behavior. Thus, it could be that the entity related to the expectancy violation matters. Second, one study manipulated expectancy violations about naïve physics (e.g., principle of solidity), whereas the other study manipulated expectancy violations about naïve psychology (e.g., principle of rationality). Thus, it may be that the key distinction is not about objects versus people, but what domain of knowledge is being manipulated. A study from Saxe et al. (2005) has shown that 5-month-old infants can also apply some physical principles to humans. Infants expect people to be solid like material objects. Thus, one can ask the question of how infants will learn from people when people violate expectations on principles of naïve physics, instead of naïve psychology. Would any violation of expectation on people's actions attenuate infants' subsequent learning under social context, or is this effect only specific to violations of naïve psychology?

Specifically, suppose a person violates the principle of naïve physics by acting impossibly (e.g., unexpectedly passing the arm through a solid wall to grab an object).

What learning preference would infants display for people between impossible actions and possible (e.g., passing the arm around the wall to grab an object) actions? Does seeing someone performing impossible actions enhance or hinder infants' subsequent social learning from the person? Here, this thesis will test two hypotheses. One hypothesis is that infants will not learn from people who violate the expectations of naïve physics. An alternative hypothesis is that infants will learn from people who violate the expectations of naïve physics.

This thesis will help determine how people's actions influence infants' learning in social contexts. It will facilitate discovering what information shapes infants' interests in learning from other people. The learning preferences obtained from infants could be helpful for caregivers, educators, and researchers to understand and help infants' social learning during early cognitive development.

Method

Participants

Participants were recruited through advertisements on social media (e.g., Facebook) and the existing database from the Infant Learning and Development Laboratory at the University of Chicago. Infants were 17 to 19-month-old and were exposed to English at home. This age range was the same as Colomer & Woodward's (under review) study. Fifty-three infants participated in the study. Twenty-two participants were rejected from the analysis due to fussiness (13), parental interferences (6), not being able to code the videos (2). An additional participant was excluded due to having a looking preference that was 2.5 standard deviations (SD) above or below the mean. The expected final sample was 80; for the purpose of this thesis, we analyzed the data with 31 participants (Impossible condition; M = 18.11 mo, SD = 1.13; 11 girls, 5 boys; 10 White, 5 Bi-Racial, 1 Asian; Possible condition; M = 17.82 mo, SD = 1.02; 7 girls, 8 boys; 10 White, 3 Bi-Racial, 2 Asian)

Procedure

The experiment was released on Lookit (https://lookit.mit.edu/exp/studies/1347/), a website dedicated to posting online research about infants and children. The experimental data was also collected through it.

The whole experiment was around 10 minutes. Parents or legal guardians would first read and agree with the instruction and consent form. Before beginning the study, adults would be asked to sit the infants in their laps or a highchair and use the webcam to capture the infants' eyes to record their eye movements. Parents or legal guardians were told to close their eyes during the study until a voice in the middle of the study told them they could open them. They were also asked not to interact with the infants during the study. This would avoid influencing infants' performances and study results.

Event Phase

Infants would watch video clips for three experimental phases: familiarization, pretest, and posttest. The total experimental video clips for infants were about 3 minutes. Before starting each experimental phase, an attention-getter image with a sound (1s) was embedded to draw infants' attention. For each video clip, a black curtain would open with a ring tone to catch infants' attention as well (1.5s). After the clip was played, the curtain would close. After the pretest and before the posttest, which was the middle of the study, a calibration video with a tinkling sound (18s) was presented to spot infants' gaze at different sides of the screen.

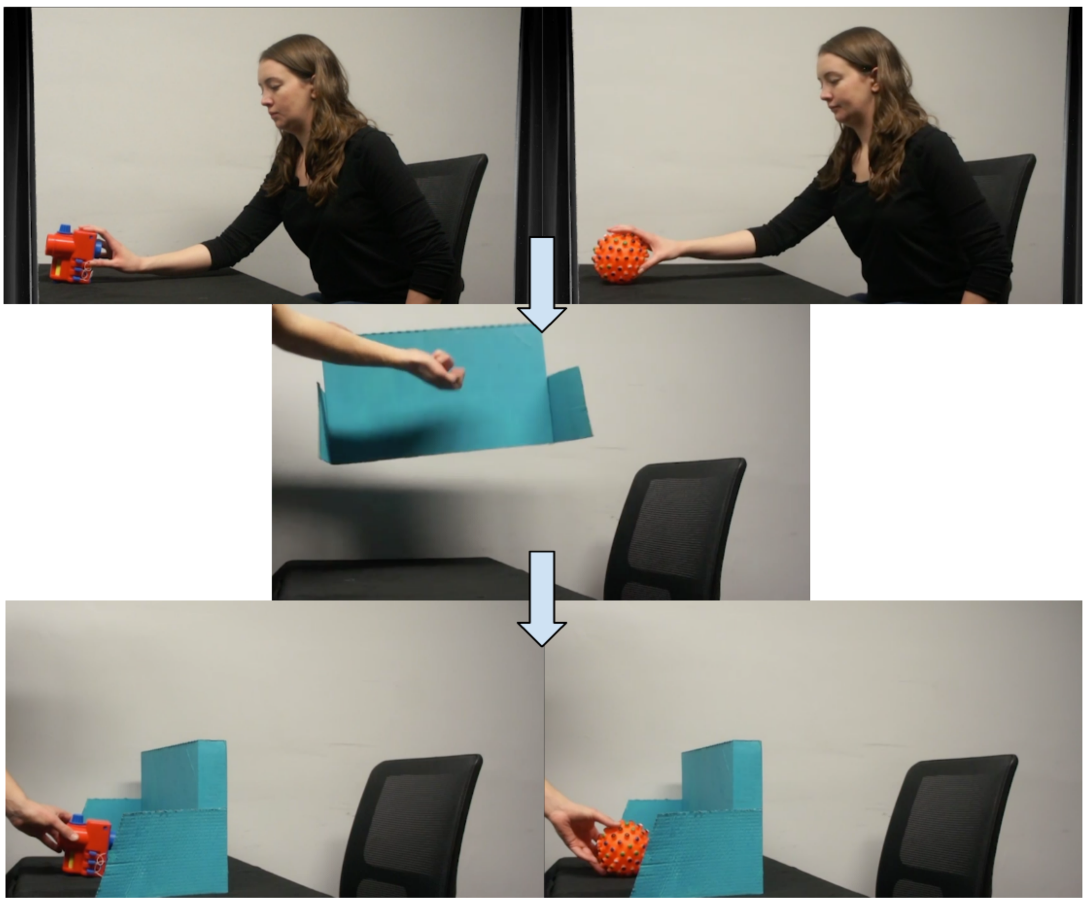
In familiarization, each infant would watch a video with an agent reaching for and grasping a target object (e.g., an orange ball or a red cube) on a table and bringing it closer to her for two trials (10s each). Infants would see the same object across the two trials. These actions let infants understand the agent's instrumental goal of obtaining an object. Next, infants would be introduced to a thick blue wall on the table. A hand was knocking on the wall. By knocking, infants would know that objects cannot pass through this solid wall. The wall was then placed on the table, with the target object on the side, ready for the pretest (see Figure 1).

Then, each infant was randomly assigned to the pretest condition. Fifteen infants were in the Possible condition. Sixteen infants were in the Impossible condition. There was only one trial per infant during the pretest (35-36s). In the Possible condition, infants saw the agent trying to grab the same target object (e.g., an orange ball or a red cube). The agent would pass the arm around the wall to grab it, which did not violate the physical principle. Then, the agent would repeatedly label the object (18s). For example, she would start by saying, "Hi baby, look! A gombie!" to teach the infants a label to associate with the target object.

Infants would learn that the target object was either called a "gombie" or a "blicket". Similarly, the agent tried to grab the target object in the Impossible condition. The video was edited in advance so that infants would see her arm passed through the solid wall, violating the physical principle. Then, the agent would teach infants to learn a label associated with that object, same as in the Possible condition (see Figure 2).

Figure 1

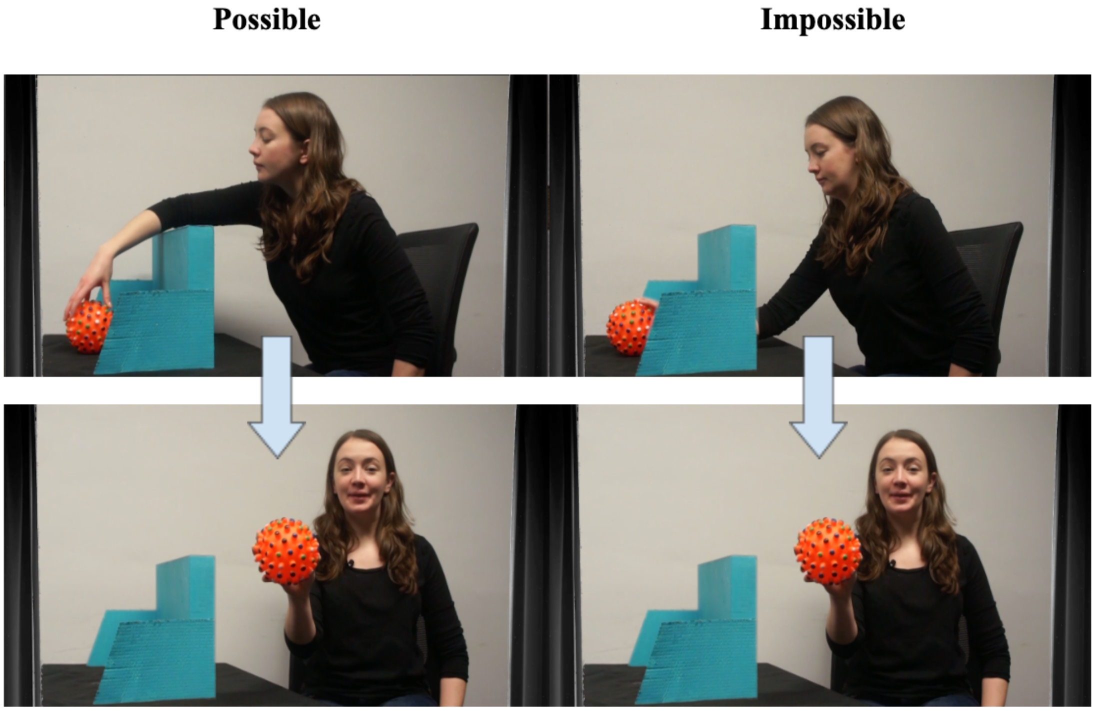
Familiarization Phase of the Experiment



First, an agent was trying to grab a target object, either a red cube or an orange ball, to familiarize infants with the agent's goal. Next, a solid blue wall was introduced by an arm knocking it. The target object that infants saw previously was placed behind the wall.

Figure 2

Pretesting Phase of the Experiment

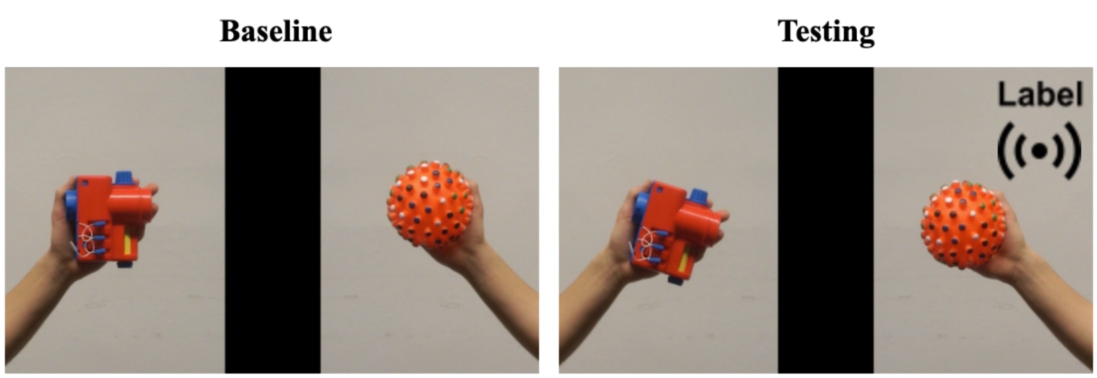


In the Possible condition, the agent grabbed the target object (the graph only shows the example of an orange ball; some infants saw another object, the red cube) by passing around the wall. In the Impossible condition, the agent's hand was impossibly passed through the wall to grab the object. In both conditions, after gaining the object, the agent would teach infants a label ("gombie" or "blicket").

For the posttest, there were two sections. Each section had two components: baseline and testing. The section was arranged in order of one baseline trial followed by one testing trial. Infants would see a baseline trial first in each section, which was the picture of the target object (e.g., an orange ball) and a picture of a new distractor object (e.g., a red cube) shown side by side on the screen silently (5s). The baseline trials would let us know whether infants have a preference for the agent based on the looking time at the target. Next, the same two objects were on the screen for testing, but they were shaken by two hands continuously (10-11s). Meanwhile, in one testing trial, we played the audio of the learned familiar label from the pretest (10-11s). In the other testing trial, we played an unlearned novel label (10-11s). If infants choose to learn from the agent, they would look longer at the target object when the familiar label was played, but not when the novel label was played. The order of playing labels was random (see Figure 3).

Figure 3

Posttesting Phase of the Experiment



Infants would see the combination of a baseline trial first and then a testing trial together twice. The baseline trials were pictures of the target object and the distractor object shown silently. For two testing trials, the hands were shaking the objects. One trial played the familiar label; another trial played the novel label. The order of the audio was random.

Coding and data exclusion

The recorded videos were from Lookit. The videos were coded on Datavyu (https://datavyu.org/), a software for manual coding. Two research assistants and I coded the time infants were not looking at the screen during the familiarization and pretest. For the posttest, infants' gazing directions were coded. During coding, we were unaware of what action condition infants were in or what target object they saw. The gazing directions during the posttest were coded as left, right, center, unclear, and not looking. Unclear and not looking were both considered infants did not look at the screen. We excluded infants who did not look for 4 or more seconds during baseline and did not look for 8 or more seconds during testing. We also excluded infants who were interfered by others like parents, siblings, etc. For outliers, if infants' percentage score of looking time at the target in either baseline or testing was 2.5 SD above or below the mean, they were rejected. These ranges were the same as Colomer & Woodward's (under review) study.

Data manipulation

In each trial, the percentage score (PS) of looking time was calculated as the time infants looked at the target divided by the total looking time at the target and the distractor. The PS was calculated separately for baseline and testing. The PS at 0.5 means that infants looked at both objects for an equal time. A PS above 0.5 means infants looked longer at the target object than the distractor.

Results

Baseline

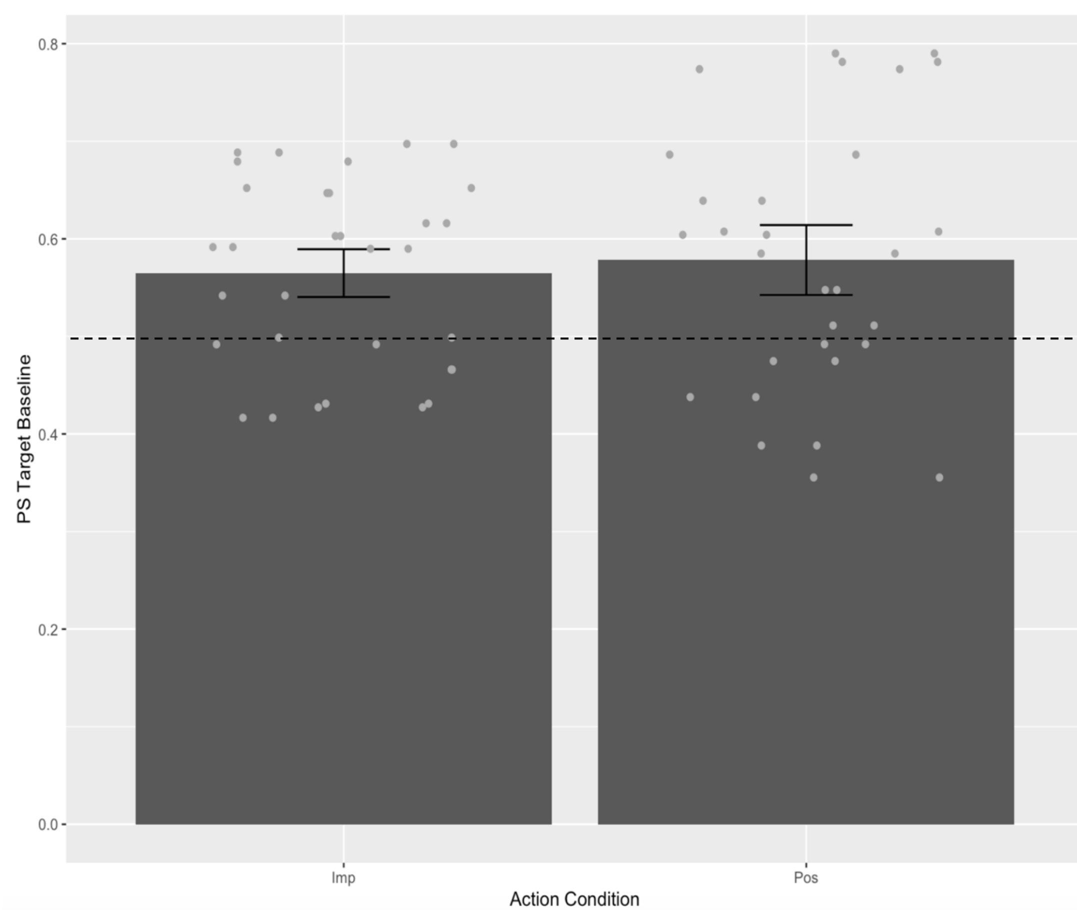
For two baseline trials, the mean percentage of looking time on the target object in the Possible condition was 0.5783 (SE 0.0359). The mean percentage of looking time on the target object in the Impossible condition was 0.5649 (SE 0.0245). A univariate ANOVA showed no significant difference in the percentage score of looking time on target during baseline between conditions ($F(1,29) = 0.10$, $p = 0.757$). Due to no significant difference, action condition was collapsed for the one-sample t-test. The looking time on target during baseline ($M = 0.57$, 95% CI [0.54, 0.60]) was significantly different from chance (0.5) ($t(61) = 4.8$, $p = 0.00001$; see Figure 4). This indicated that infants had a preference for the agent during baseline, independently of the condition.

Testing

For testing trials, the mean percentage of looking time on the target object in the Possible-Familiar label condition was 0.5888 (SE 0.0318). The mean percentage of looking time on the target object in the Possible-Novel label condition was 0.5820 (SE 0.0289). In the Impossible-Familiar label condition, the mean percentage of looking time on the target object was 0.5333 (SE 0.0306). The mean percentage of looking time on the target object in the Impossible-Novel label condition was 0.5399 (SE 0.0373). Next, we wanted to know if there was any looking preference in the looking time to target during testing based on action condition and audio type. We ran a mixed ANOVA with audio type as a within-participants factor (Familiar; Novel) and action condition as a between-participants factor (Possible; Impossible). However, we found no significant main effects or interactions (all $p > 0.05$). Since two types of audio were played during testing; even though there were no significant results, we also tested whether infants could distinguish between the familiar and novel audio in each action condition. For both Possible and Impossible conditions, infants did not significantly distinguish the familiar or novel audio label during testing trials (Possible; $F(1,14) = 0.05$, $p = 0.820$; Impossible; $F(1,15) = 0.06$, $p = 0.813$).

Figure 4

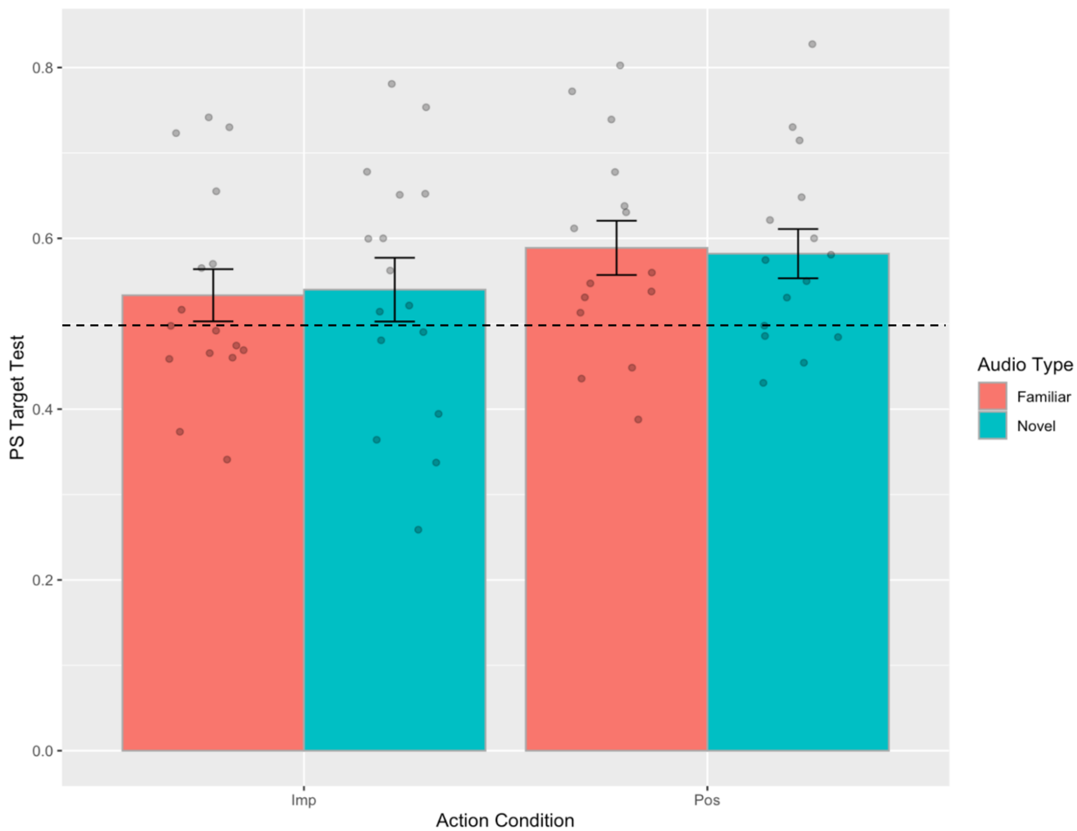
The Score of Looking Time on Target in Both Action Condition During Baseline



Mean percentage score (PS) of looking time on target as compared to distractor during baseline trials by action condition (Impossible vs. Possible). The bar graph represents the mean percentage of looking score with standard error. Each dot represents a participant's score.

Figure 5

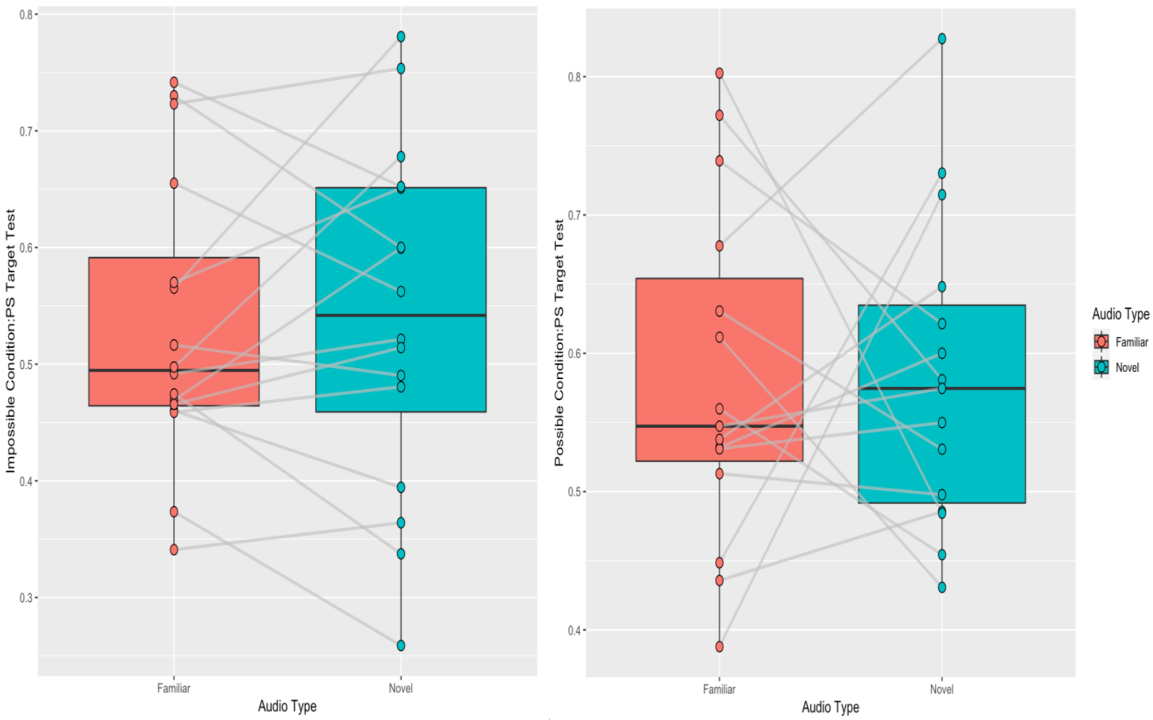
The Score of Looking Time on Target in Each Condition and Audio Type During Testing



Mean percentage score (PS) of looking time on target as compared to distractor during testing trials by action condition (Impossible vs. Possible) and audio type (Familiar vs. Novel). The bar graph represents the mean percentage of looking time with standard error. Each dot represents a participant's score.

Figure 6

Within-participant Difference on the Score of Looking Time on Target in Each Condition and Audio Type During Testing



Mean percentage score (PS) of looking time on target as compared to distractor during testing trials in each action condition and audio type. The horizontal line of boxes represents upper quarterly, median, and lower quarterly. Each dot linked with a grey line represents the difference of the same infant on score of looking time between familiar and novel audio in each action condition (Impossible vs. Possible).

Then, as exploratory analysis, we wanted to know for each action condition and audio type if the looking time on target was significantly different as compared to chance (0.5). One-sample t-test found that infants in the Possible condition who heard the familiar label during testing (*M* = 0.59, 95% CI [0.52, 0.66]) looked significantly longer at the target object ($t(14) = 2.8$, $p = 0.014$; see Figure 5, Figure 6) as compared to chance (0.5). Infants in the Possible condition who heard the novel label during testing (*M* = 0.58, 95% CI [0.52, 0.64]) also looked significantly longer at the target ($t(14) = 2.8$, $p = 0.013$; see Figure 5, Figure 6) as compared to chance (0.5). However, there were no differences as compared to chance (0.5) in the other two experimental conditions (Impossible-Familiar, Impossible-Novel; all $p > 0.05$). However, the looking preference found in the Possible condition was not significant after Bonferroni correction (all $p > 0.0125$).

Discussion

The thesis investigated how infants learn from others with actions that violate the principles of naïve physics. Seeing an expecting or unexpecting action does not influence 17- to 19-month-old infants' attention and learning differently. During baseline, infants showed an interest to look at the target object that the person previously labeled, independently of the action condition. Since there was no significant main effect or interaction of the looking preference to target during testing trials based on action condition and audio type, there was no evidence showing that expectancy violations of naïve physics in the social domain influence infants' subsequent learning from others. Previous studies have found that infants usually show a novelty preference in a visual preference task with two objects, suggesting that they have already encoded the familiar object (Hirai et al., 2022; Thiele et al., 2021). However, infants typically look longer at objects that other people have previously labeled (Twomey & Westermann, 2018). From the findings on the baseline window, infants showed an interest in looking at the target the person labeled in both action conditions. In Colomer & Woodward's (under review), only infants in the efficient (expected) condition showed a preference for the target during baseline. Infants in the efficient condition also learned the new label-object association, whereas infants in the inefficient condition, which presented an expectancy violation, did not showed any evidence of learning. Since in our findings infants showed a preference for the target during the baseline in both conditions, this could suggest that infants were interested to learn about an object that a person demonstrated even when the person previously violated infants' expectations. This could indicate that expectancy violations in the social domain only hinder learning when the violation is about the domain of naïve psychology, but not if it happens in the domain of naïve physics.

However, the current study found that there is no looking preference on target during testing, and no differences when hearing a familiar as compared to a novel label. The null results suggest that infants do not learn from people whether their actions violate the expectations of naïve physics or not. From exploratory analyses, we found no evidence of learning in any action condition and audio type. Infants did not look differently at the target as compared to chance when the familiar or novel label was played after they saw the possible action. These findings limit the conclusions that one can draw from these data. If there is no evidence of learning even in the Possible condition, it is difficult to interpret whether expectancy violations influenced learning in any way in the Impossible condition. However, these null results could be due to the small sample size. Increasing the sample size will help determine whether infants learn or not the label-object association in each action condition and audio type.

The null results could also indicate that infants had a hard time learning labels after just a short exposure (18s). Previous work using similar stimuli found that infants learned new labels when presented with an efficient person, but not with an inefficient person (Colomer & Woodward, under review). Although the authors interpreted the findings as indicating attenuation of learning in the inefficient condition, the findings could also indicate that seeing people who act efficiently induces infants' learning (Colomer & Woodward, under review), rather than seeing irrational (unexpected) actions hinders learning. Then, short exposure to labels may not be enough to show evidence of induced learning in Possible condition as compared to Impossible condition. If exposures to labels are extended, infants may be able to learn the label-object association and show learning preference subsequently.

The methodological issues could also be taken into account for the null results. The research was conducted online. Online research can give participants a convinient and comfortable enviroment while participating. However, it has limitations as well. For example, for our research, infants participated from their home, we did not have a same shared experimental set up. Enviromental differences like screens, audios, and rooms may add nosies to the measure. Infants are active learners and explorers and all of these conditions may change their attention. If the experiment was conduced in person with the same setting, the experimental conditions would be more consistent and the results be easier to interpret.

Taken together, no evidence shows that seeing someone performing impossible actions by violating the expectations of naïve physics influence 17 to 19-month-old infants' learning from that person. Due to the above reasons, cautious manipulation and larger sample size are needed to see if there is any significant difference on the looking time between action condition and audio type. From previous research, different learning preference based on the domain of core principles (naïve physics versus naïve psychology) and the type of subjects (objects versus human) is an interesting distinction to explore. The innate ability to screen the information greatly impact infants' choices of learning. Thus, exploring and understanding what specific information shapes infants' learning choice is critical to understand how infants begin to navigate their social environment. The current research is a first step to understand how infants interact and learn from strangers who perform expected versus unexpected actions, and may have interesting applications in pedagogical settings.

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