Physical, Psychological, and Emotional Causality

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Abstract

Previous studies have suggested that adults and infants learn about causal relationships through Bayesian structure learning rather than through associative learning (e.g., Griffiths, Sobel, Tenenbaum, & Gopnik, 2011; Sobel, Tenenbaum, & Gopnik, 2004). This view ostensibly garners support from research that has used a blicket detector, which is a machine that lights up and plays music when certain objects are placed on it (e.g., Sobel et al., 2004; Sobel & Kirkham, 2006). Although a large database exists on physical causal inference, there is a dearth of causality research in other domains, such as psychological and emotional causality, particularly among adult populations. Because little research on causal inference has been conducted with adults in a blicket-detector-like context, this study investigated whether adults reason about causal events through Bayesian inference or associative learning and whether adults are capable of making physical, psychological, and emotional causal inference in a blicket detector paradigm. The results supported the hypothesis that adults are able to make physical, psychological, and emotional causal inference but failed to support the hypothesis that adults use associative learning to reason about causal relationships and showed that adults use Bayesian structure learning.

Physical, Psychological, and Emotional Causality

As humans, we have a large database of knowledge about the causal relations around the world among various objects, persons, and events. This is particularly important because it enables us properly to perceive, understand, and reason about cause-and-effect relationships in the world. Through such reasoning, adults and children build knowledge about the causal structures of the world and become skillful at learning new causal relations. Although many different theories have been suggested to explain causal reasoning, associative learning and Bayesian inference have been the two main competing theories. Researchers, however, have yet come to an agreement on whether an associative mechanism or a Bayesian inference mechanism underpins infants', children's, and adults' causal reasoning abilities.

An associative model is a learning mechanism of which Rescorla and Wagner (1972) model is one of the most well-known model. Associative causal learning model suggests that people track predictive statistics in causal events and use those statistics to make causal decisions. In other words, this model suggests that people determine associative strengths and compare these associations to make appropriate causal relationships. For instance, if people see that object A makes something react while object B does not, they will assign appropriate associative strengths to object A and object B. One of the competing models is the causal graphical model perspective, particularly the Bayesian structure learning model. Gopnik et al. (2004) suggested that learning mechanism behind causal learning in children is in accord with Bayesian model. They explored various studies, a few of which are discussed below, that support the hypothesis toward Bayes net representations. Bayesian structure learning suggests that people construct causal maps called Bayes nets in their minds and use a simple form of Bayes' rule to combine prior probability with likelihood information to make causal decisions.

To investigate the learning mechanism behind causal inference, many researchers have conducted studies on causal inference with the use of *blicket detectors* (e.g., Gopnik, Sobel, Schulz, & Glymour, 2001; Sobel et al., 2004). The Blicket detector is a machine that lights up and plays music when *blickets* (typically wooden blocks) are placed on it. Blickets are thus particular objects that activate the blicket detector and cannot be determined based on shape or color. With respect to the studies with the blicket detector and blickets, researchers have used four different conditions to understand how people, mostly children, reason about causal events. These four tasks are one-cause, two-cause, indirect inference, and backward blocking task (see Appendix A; Gopnik & Schulz, 2004), and they will further be explained in relation to the studies conducted by different researchers.

Gopnik et al. (2001) investigated whether young children can infer causal relations using a *one-cause* and a *two-cause* task. One-cause task refers to a condition in which block A is placed on the blicket detector and the detector activates, but when block B is placed on the detector, the detector does not activate. When both blocks are placed on the detector, the detector activates. The detector activates again when both blocks are again placed on the detector (see Figure 1a). The two-cause task is also demonstrated using two different blocks. When block A is placed on the detector, the detector activates. Block A activates the detector again in the next two consecutive trials. When block B is placed on the detector, the detector does not activate. However, block B activates the detector in the next two consecutive trials (see Figure 1b). In the one-cause task, children as young as two years of age were able to respond that block A, which activated the detector when alone and with block B, was a blicket. In the two-cause task, which included one negative trial of object B, however, two-year-olds were equally likely to choose block A or B as a blicket. The results of this study suggested that children as young as two years of age are able to make causal inferences in the physical domain.

Gopnik et al. also suggested that there may be a relation between these results and Bayes net causal models.

Sobel et al. (2004) conducted a similar study with young children using an *indirect inference* and a *backward blocking* task. Such tasks were used because they bear importantly on the associative model and Bayesian model debate. Indirect inference (henceforth, II) task refers to a condition in which object A and B were placed on the blicket detector, and the detector activated. When object A was placed on the detector by itself, however, the machine did not activate (see Figure 1c). The backward blocking (henceforth, BB) task is identical to the II task, but the detector activates when object A alone is placed on the detector (see Figure 1d). Sobel et al. (2004) bolstered Gopnik et al. (2001)'s claim that young children can make causal inference. When three-year-old and four-year-old children were asked to watch patterns of objects and the detector's activation, they were able to acknowledge that only certain objects cause the blicket detector to activate when those objects are placed on the detector. They also found that while children at four years of age can accurately infer causal relations in BB task, three years of age cannot accurately do so, which they explained to relate to the learning mechanism in children's ability to make causal inference. The study showed that the mechanism behind children's causal inference is beyond what associative models, such as the Rescorla and Wagner (1972) model, can explain. According to Rescorla and Wagner, the associative strength of object B should be equal in both II and BB conditions because object B was never illustrated by itself that allowed any associative strength to be assigned to it, but there was a significant change in the frequency of categorization of object B as a blicket in the II condition compared to that in the BB condition. Sobel et al. (2004) thus indicated that children use Bayesian inference and not associative models to reason about these events.

When researchers tried to replicate the results of the two previous studies in younger children, Sobel and Kirkham (2006) found that infants can also infer causal relations. Again in the first part of this study, 19-month-olds and 24-month-olds were tested using blocks and a blicket detector with the II and BB tasks. It was found that when they saw an object activate the detector on its own, they determined the object to be a blicket. However, when they observed that object A activated on its own but object B needed object A in order to activate the detector, the children assumed object A to be a blicket and not object B. In the second part of the study, 8-month-olds were tested using an eye tracker to code the length of the baby's eye gaze when exposed to similar yet less complicated test trials of II and BB condition that were used in the first part of the study. When their eye gaze was analyzed, using an eye tracker, it was found that 8-month-olds looked longer at the expected event in the II condition but varied their looking times between the expected and the unexpected event in the BB condition. With these results, Sobel and Kirkham concluded that young children's learning mechanisms for causal inference are not based on associative strength. Data could not be explained using Rescorla and Wagner (1972) model because the associative model does not consider the associative strength of objects that are absent in the interaction but may be causal. Similar results were found when Sobel and Munro (2009) used the blicket detector with respect to the psychological domain, stating the event sequences in terms of an agent's desires. Instead of serving the blicket detector only as a machine, it was named Mr. Blicket and described to make children believe that the activation indicated his desires in some cases. When the detector just served as a machine that activated to blickets, children were able to infer causal relations as previously found in other studies (e.g., Gopnik et al., 2001; Sobel et al., 2004). When children were introduced to the blicket detector as an agent called Mr. Blicket, three-year-olds were found to be able to make causal inference. The results suggested that Bayesian inference best describes these inferences because children used their knowledge from the observed interaction in terms of base rate information to work out ambiguous data. This was significant because it showed that children are able to infer causality not only in physical domain but also in psychological domain.

Few other studies have also used the blicket detector paradigm but with the use of different objects (e.g., Griffiths et al., 2011; Schulz & Gopnik, 2004). For instance, Griffiths et al. (2011) used a “super lead” detector and pencils on adults and children to test the proposed Bayes net model on causal inference. In this study, the “super lead” detector served as a blicket detector and the pencils served as potential blickets. If the pencil was scanned on the “super lead” detector and the detector lit up with the words, “Super lead detected”, it was considered a “Super pencil”. If the detector did not provide any output, the pencil was categorized in the “Not Super pencils” box. The pencils made the detector activate at various times, and the participants were asked to sort these pencils and rate the likelihood of these to be super pencils. Griffiths et al. found that when adults are faced with ambiguous data, such as the variability in probability of pencils making the detector activate, they used base rate information to infer causal relations. The use of prior knowledge aligned with Bayesian model and suggested that people take the Bayesian approach to learn about causal systems, which again are consistent with the findings of the previous studies.

Similarly, Schulz and Gopnik (2004) conducted a causal study that did not require a direct involvement of the blicket detector and blickets. This study was a transition because it explored causal inference with respect to domains that were beyond physical events: biological and psychological. In some of the experiments they conducted, a monkey puppet and various flowers or a bunny and various plastic animals were used. The design of the study followed the blicket detector paradigm in that the monkey acted as a blicket detector and flowers were potential blickets, or the bunny acted as a blicket detector and plastic animals were potential blickets. In the biological domain, children were told that some flowers made the monkey sneeze while others did not, and they were shown various sequence of events with the monkey and flowers. After watching some interactions between the monkey and the flowers, children were asked to choose which flower made the monkey sneeze. Schulz and Gopnik found that children chose the flower that made the monkey sneeze when alone and with another flower over the flower that made the monkey sneeze only when with another flower. Similarly in the psychological domain, children were told that certain plastic animals make the bunny scared while others did not and asked to choose which plastic animal made the bunny scared. It was again found that children picked the plastic animal that made the bunny scared when alone and together with another animal over the plastic animal that only made the bunny scared when together and not alone. The results of this study not only supported the findings of previous studies that children can perform causal reasoning in the Bayes net model, but also suggested that they can do so in biological and psychological domains.

Although prior studies had examined the reasoning behind physical causal inference, there have not been many studies on psychological and emotional causality, especially with adults. Schulz and Gopnik (2004) did study non-physical causality of items, but as previously described, they did not investigate causal inference in the emotional domain and conducted the study only with children. There is one causal study that was conducted with respect to psychological causality on adults (Steyvers, Tenenbaum, Wagenmakers, & Blum, 2003). This study directly explored whether people can learn causal inference from covariational data. Participants were shown several interactions of three aliens for which they were told the alien communications only follow two patterns as follows: only the two outer aliens can read the mind of the middle alien or only the middle alien can read the minds of the two aliens. For each trial, participants were asked to indicate the correct generating model. Steyvers et al. found that adults are able to infer and differentiate causal structures after passively observing just a few interactions. The researchers then increased the number of options of causal structures from which participants can reference and choose to reason about what they observe in the interactions. It was again found that adults are capable of making causal relationships after watching various psychological interactions between aliens. The responses from these experiments suggested that adults are able to make causal inferences in the psychological domain through Bayesian structure learning.

Researchers like McClelland and Thompson (2007) suggested associative models as a learning mechanism that is used to perceive and reason about causal events. They asserted that people acquire knowledge of the causal structure from witnessing interaction of objects and the consequences of such interactions. When people observe an event which involves an object interacting with others that leads certain order of sub-events to occur, we use this information to shape our understanding of and expectation about these objects. Thus, when they encounter these objects in new events, we expect the objects to be represented in a particular way. Through this reasoning, McClelland and Thompson suggested that children use associative learning and not Bayes nets model. This view garnered support from Van Hamme and Wasserman (1994), who conducted a study during which adult participants were asked to make causal ratings of three foods on the experimental sheets. When these ratings were analyzed, it was found that when the outcome occurred, the rating of a presented item increased while that of an absent item decreased. When the outcome did not occur, people rated the presented item lower than the absent item. The results suggested associative inference was being used to infer causal relations with a modified Rescorla-Wagner model (1972). The modified model is different than the traditional model because it asserts the associative strength of an absent item to have negative salience than no salience. In the BB task, for example, when object A and B activated the detector and object A alone activated the detector, people rated object B lower. The traditional model could not explicate these results because the associative strength put on object B should be equal across the experiment, since the interaction of object B alone was not observed. The modified model, however, is able to account for this phenomenon by suggesting that people considered object B with negative salience than no salience, reducing the associative strength. Thus, even though Rescorla and Wagner failed to account for the BB paradigm with its model, this modified associative model successfully explains the phenomenon. These research studies suggest that associative learning mechanisms follow the predicted statistics in events of causal relations and that adults make decisions using the statistics.

Despite an abundant number of research studies on causal inference, there is a dearth of research that investigates the reasoning mechanism behind causality of adults in a blicket-detector-like context. The present study investigated whether adults are capable of making physical, psychological, and emotional causal inference and which learning mechanism adults use to reason about such causal events in a blicket-detector-like setting. This study was particularly important because there have not been many research studies on non-physical causal reasoning with adult participants in such context. We hypothesized that adults are able to infer physical, psychological, and emotional causal relations in a blicket-detector-like context. Moreover, contrary to the majority of the prior blicket detector studies on physical causal reasoning, we predicted that associative learning underpins causal reasoning abilities because adults have failed to show BB and this failure was explained by Rescorla and Wagner (1972) model.

Method

Participants

Participants were recruited via Carnegie Mellon University Psychology Department Research Requirement Experiment System and flyering. The only requirement for participation was to be at least 18 years of age. Participants received course credit or were compensated $10 for their participation.

The sample (*N* = 60) was composed of 58.3% females with a mean age of 20.78 years (*SD* = 2.93; age range: 18-29 years). The majority of the sample (61.7 %) reported their ethnicity as Asian or Asian American. The remainder of the sample’s ethnic breakdown was as follows: approximately 18.3% Caucasian, 11.7% Hispanic or Latino, 6.7% African or African American, and 1.7% mixed.

Materials

Video clips that were constructed particularly for this study were used in this experiment. All of the videos consisted of three aliens: a mommy alien and two baby aliens (see Appendix B). In relation to the previous blicket detector studies (e.g., Gopnik et al., 2001; Sobel et al., 2004), the mommy alien acted as a blicket detector, and two baby aliens were potential blickets. The baby aliens were named “youbsters” to prevent any previous knowledge or experience the participants may have about blickets. In the videos, these aliens were used in four different tasks: one-cause, two-cause, backward blocking, and indirect inference. The baby aliens varied in color (light blue, dark blue, pink, yellow, orange, green) per each task condition across participants, while the mommy alien always remained consistent because she only served as a detector. The order of events was counterbalanced across participants.

Procedure

All participants were tested by a female experimenter. Participants were brought into a private room with a computer screen that can display several video clips. When the participants were seated in the room, they were asked to complete a demographics questionnaire. After the demographics were collected, participants were introduced to the concept of the blicket detector and blicket detectors, using the term, “youbster”. Mommy alien and baby aliens were then introduced, and participants were told the conditions in which baby aliens could be called “youbsters”. Participants were followed through the training and test phase and debriefed after they completed both phases.

Training Phase

During the training phase, the participants watched video clips of two types of tasks regarding physical causal inference: one-cause and two-cause task. In the one-cause condition, when baby alien A moved to the mommy alien and touched her leg (henceforth, physically interacted), the hexagon on the mommy alien’s chest lit up and blinked. When baby alien B physically interacted with the mommy alien, the mommy alien did not react. When both baby aliens physically interacted with the mommy alien, the mommy alien responded with light. This successful interaction was repeated one more time. Participants were then asked if they understood the role of the aliens. If they were confused, they were instructed of the role of youbsters and a youbster detector again. In the two-cause condition, when baby alien A physically interacted with the mommy alien, the mommy alien reacted. This interaction was repeated two more times. Then, when baby alien B physically interacted with the mommy alien, the mommy alien did not react. When baby alien B physically interacted with the mommy alien again, however, the mommy alien responded with light and sounds. This successful interaction was demonstrated once more. Participants were again asked if they understood the role of the aliens. If they were confused, they were instructed of the role of youbsters and a youbster detector before the start of the test phase. Participants were not asked to fill out any questionnaire about the interactions during the training phase.

Test Phase

Following the two practice clips in the training phase, video clips of physical, psychological, and emotional causality using BB and II task were used in the test phase. The order of these events varied across participants, but all of the participants watched a total of six video clips: BB and II task for each of the three causality conditions. The possible combinations of conditions were physical-psychological-emotional, physical-emotional-psychological, psychological-emotional-physical, psychological-physical-emotional, emotional-psychological-physical, emotional-physical-psychological. The order of BB and II task was counterbalanced within each causality domain, resulting in two counterbalanced clips for each combination and a total of twelve combinations of video clips. BB task of physical causality was portrayed as follows. When alien A and B physically interacted with the mommy alien, the mommy alien reacted. When alien A alone physically interacted with the mommy alien, the mommy alien also reacted. The II task of physical causality was portrayed as follows. When alien A and B physically interacted with the mommy alien, the mommy alien reacted. When alien A alone physically interacted with the mommy alien, the mommy alien also did not react.

BB task and II task of psychological causality were identical to that of physical causality except the baby aliens lit up and blinked the light bulbs on top of their heads instead of moving to the mommy alien's leg. Similarly, BB task and II task of emotional causality were identical to that of physical causality except the baby aliens moved their mouths instead of moving to the mommy alien's leg. For each of the six video clips, participants were asked to answer questions on Youbster Rating Scale (see Measures for more details) before watching video clips as *Baseline* ratings and after watching video clips as *Test* ratings.

Measures

Demographics

A demographics questionnaire was administered at the beginning of the study. Demographic characteristics included gender, age, race/ethnicity, English as first language, education, major, participation in previous blicket studies.

Youbster Rating Scale

Participants' responses to the likelihood for aliens to be youbsters were collected using a two-item questionnaire. The first item read, "Please rate how likely either of the two aliens are youbsters on the 0 to 100 (0 = definitely not a youbster; 100 = definitely a youbster)." The second item read, "Which of the two aliens do you think are youbsters?". Participants were asked to record their answers to these items, using pen and paper copies of this rating questionnaire provided by the experimenter.

Results

A general linear model repeated measure ANOVA was performed with Baseline II of alien A and Test II of alien A for physical, psychological, and emotional causality. If the rating of Baseline II for alien A is greater than that of Test II for alien A, it indicates that participants were attentive and on task. In other words, the results from this comparison served as a control analysis. There was a main effect of indirect inference for physical causality task. Participants rated Baseline II to be greater (M = 53.50; SD = 18.00) than Test II (M = 15.92; SD = 30.95),

$F(1, 59) = 69.72$, $p < .001$. There was a main effect of indirect inference for the psychological causality task. Participants rated Baseline II to be greater (*M* = 54.25; *SD* = 14.87) than Test II (*M* = 31.25; *SD* = 40.28), $F(1, 59) = 19.13$, $p < .001$. There was a main effect of indirect inference for emotional causality task. Participants rated Baseline II to be greater (*M* = 58.08; *SD* = 15.89) than Test II (*M* = 28.33; *SD* = 40.17), $F(1, 59) = 27.44$, $p < .001$. These data indicate that participants successfully understood the concept of youbsters in physical, psychological, and emotional domains (see Figure 3).

To determine which learning mechanism the participants used to infer causal relations, a general linear model repeated measure ANOVA was performed with Baseline BB of alien B and Test BB of alien B for physical, psychological, and emotional causality. Decrease in the rating from Baseline BB to Test BB provided partial evidence that participants used Bayesian inference than associative inference. Main effect of backward blocking was found for physical causal inference tasks. Participants rated Test BB to be lower (*M* = 44.92; *SD* = 24.86) than Baseline BB (*M* = 53.25; *SD* = 12.68), $F(1, 59) = 7.07$, $p < .02$. This suggested that participants inferred causal relations in the physical domain through Bayesian structure learning. There was also a main effect of backward blocking in the emotional causality domain. Participants rated Test BB to be lower (*M* = 43.50; *SD* = 28.53) than Baseline BB (*M* = 52.58; *SD* = 16.68), $F(1, 59) = 6.42$, $p < .02$, which indicated that participants understood emotional causal relationship through Bayesian inference. A main effect of backward blocking was found to be marginally significant for psychological causality, $F(1, 59) = 2.95$, $p = .09$. Such results give some evidence that adults use Bayesian structure learning in physical and emotional conditions, but further analyses need to be done to draw a conclusion that Bayesian model is the learning mechanism behind causal inference (see Figure 4).

To analyze data as in Gopnik's studies (e.g., Gopnik et al., 2004; Sobel et al., 2004), a general linear model repeated measure ANOVA was performed with Test BB of alien B and Test II of alien B for physical, psychological, and emotional causality. If the rating of Test II for alien B was greater than that of Test BB for alien B, this served as another evidence to indicate that the participants used Bayesian structure learning than associative learning because if they used traditional associative model, these two ratings should not differ. Main effect was found in the physical causality task. Participants rated Test II to be greater (*M* = 84.58; *SD* = 24.20) than Test BB (*M* = 44.92; *SD* = 24.86), $F(1, 59) = 91.32$, $p < .001$. Main effect was found in the psychological causality task. Participants rated Test II to be greater (*M* = 80.83; *SD* = 29.86) than Test BB (*M* = 46.25; *SD* = 23.71), $F(1, 59) = 47.17$, $p < .001$. Main effect was found in the emotional causality task. Participants rated Test II to be greater (*M* = 84.17; *SD* = 26.44) than Test BB (*M* = 43.50; *SD* = 28.53), $F(1, 59) = 73.85$, $p < .001$. Through these analyses, the results serve as additional evidence that allow the conclusion to be made that participants use Bayesian structure learning than associative models (see Figure 5).

No significant interaction was found between gender and physical, psychological, or emotional causality. This suggested that gender did not have an effect on the ratings participants made for causal structures in all three conditions. No significant interaction was found between race and physical, psychological, or emotional causality. No significant interaction was found between English as first language and physical or emotional causality, but a significant interaction was found between English as first language and psychological causality, $F(1, 58) = 4.34$, $p < .05$. Participants who stated English to be their first language (*N* = 39) rated Test BB to be lower (*M* = 39.87; *SD* = 23.13) than Baseline BB (*M* = 52.31; *SD* = 16.30), while participants whose English was not their first language (*N* = 21) rated Test BB to be higher (*M* = 58.10; *SD* =

20.40) than Baseline BB (*M* = 54.05; *SD* = 20.47). This suggested that the participants' ratings for the psychological causal inference were dependent on whether English was their first language or not. No significant interaction was found between education and physical, psychological, or emotional causality. This suggested that level of education attained by participants did not have an effect on the ratings participants made for causal structures in all three conditions. No significant interaction was found between assigned condition physical, psychological, or emotional causality. This suggested that the order of events shown to participants did not have an effect on the ratings participants made for causal structures in all three domains.

Discussion

To our knowledge, this study is first to investigate whether adults use Bayesian network or associative mechanisms to reason about physical, psychological, and emotional causal events in a blicket-detector-like context. The results reveal that adults are capable of making causal inference in physical, psychological, and emotional domains as predicted. However, contrary to our hypothesis, the results support the claim that adults use Bayesian inference to reason about causal relations and not associative learning in all three domains. Although the findings diverge from the hypothesis made about the learning mechanism, the current data are consistent with previous studies that showed that people use Bayes nets to reason about causal relationships (e.g., Gopnik et al., 2004; Sobel et al., 2004). This may be explained by Rescorla and Wagner (1972) model, which fails to account for the learning mechanism behind causal inference particularly for the BB and II task. According to Rescorla and Wagner, the associative strength of object B should not differ between baseline rating and test rating because object B was not shown on its own for any further association to be made. People, however, tend to rate object B lower in the test rating than in the baseline rating, a phenomenon that cannot be explained through the traditional associative model. In this study, we also found that people were rating baby alien B lower after seeing a BB interaction of the baby aliens and the mommy alien. Such finding bolsters the claim that the traditional associative model cannot account for the learning mechanism behind causal inference in physical, psychological, and emotional domain.

Researchers who suggested the learning mechanism behind causal inference to be Bayesian structure learning compared the ratings between II and BB task for object B (e.g., Gopnik et al., 2004; Sobel et al., 2004). In this study, similar analyses were administered on the data. Since this study collected baseline and test ratings for II and BB, we analyzed the differences between the ratings between II and BB of baby alien B for the test ratings to mimic the analyses of Gopnik et al. (2004). The analysis of these results suggested the same conclusion as other Bayesian studies that people use Bayesian model to infer about causal relations. This is because participants rated baby alien B more likely to be a youbster in the II task than baby alien B in the BB task. If participants were using the traditional associative model, these ratings should not vary since they did not observe any interaction of baby alien B on its own, but the data suggested that these ratings varied and depended on prior probabilities. We, however, believed that we could not solely look at such analyses to make conclusion about the learning mechanism behind causal inference. We determined that it was also important to look at the data analyses that compared the baseline and test ratings of BB task for baby alien B to determine the learning model used by participants to make causal inference. This was because if participants' ratings of baby alien B dropped after seeing BB interaction (test rating) compared to before seeing BB interaction (baseline rating), it would suggest that people use Bayes nets to reason about causality. On the other hand, if the ratings of baby alien B did not change in both ratings, it would suggest the use of associations to reason about causal inference. Thus, we believe that both styles of these analyses of the ratings need to be administered to get an accurate picture of and draw a correct conclusion as to what learning model adults use to infer causal relations.

Although this study is first to show the capability of adults to make physical, psychological, and emotional causal inference and the reasoning mechanism behind causality of adults in a blicket-detector-like context, there are limitations. First, the demographics of the participants were not representative of the community. Racial and ethnic makeup of the sample did not match that of the community. Most participants (78.3%) were undergraduate students whose highest level of education was high school. Similarly, the age of participants fell between 18 and 29 year olds, which is not representative of the community. Given all of these unrepresentative demographics, the results are not generalizable to public. Second, the premises that we established upon psychological and emotional causality may seem too artificial. Although we emphasized that baby aliens light up and blink the light bulbs on top of their heads as their way of thinking and move their mouth to express their emotions, the participants may not have considered these behaviors to represent psychological and emotional events. Since they both do not involve physical movement of aliens, participants may have considered both of these events to be psychological. However, the differences in the main effects and interactions for psychological and emotional domains indicate that participants did indeed make distinctions between the two, even though it is still unclear as to whether they correctly regarded them as psychological and emotional events. Lastly, unlike in the test phase, participants were not asked to make any ratings during the training phase. If the ratings were collected, however, it would have been beneficial in analyzing the data because these ratings would have served as a basis to inspect whether participants accurately understood the interaction between the aliens and the role of youbsters. Since we did not have such data, we compared the baseline rating and the test rating of alien A from II task to determine if participants were attentive and on task to serve as a control analysis.

In future studies, the motions that the baby aliens make for psychological and emotional causality should be clear enough for the participants to think in terms of psychological and emotional domain. In addition, participants should be asked to make ratings for the one-cause and the two-cause task in the training phase, which could be analyzed as control to determine if participants correctly understood the task. To conclude, this study demonstrates that adults are able to infer physical, psychological, and emotional causal relations with the use of Bayesian structure learning. Results of this study thus underscore the previous findings of the blicket detector studies that argue the learning mechanism behind causal inference to be Bayes net model.

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Appendix A

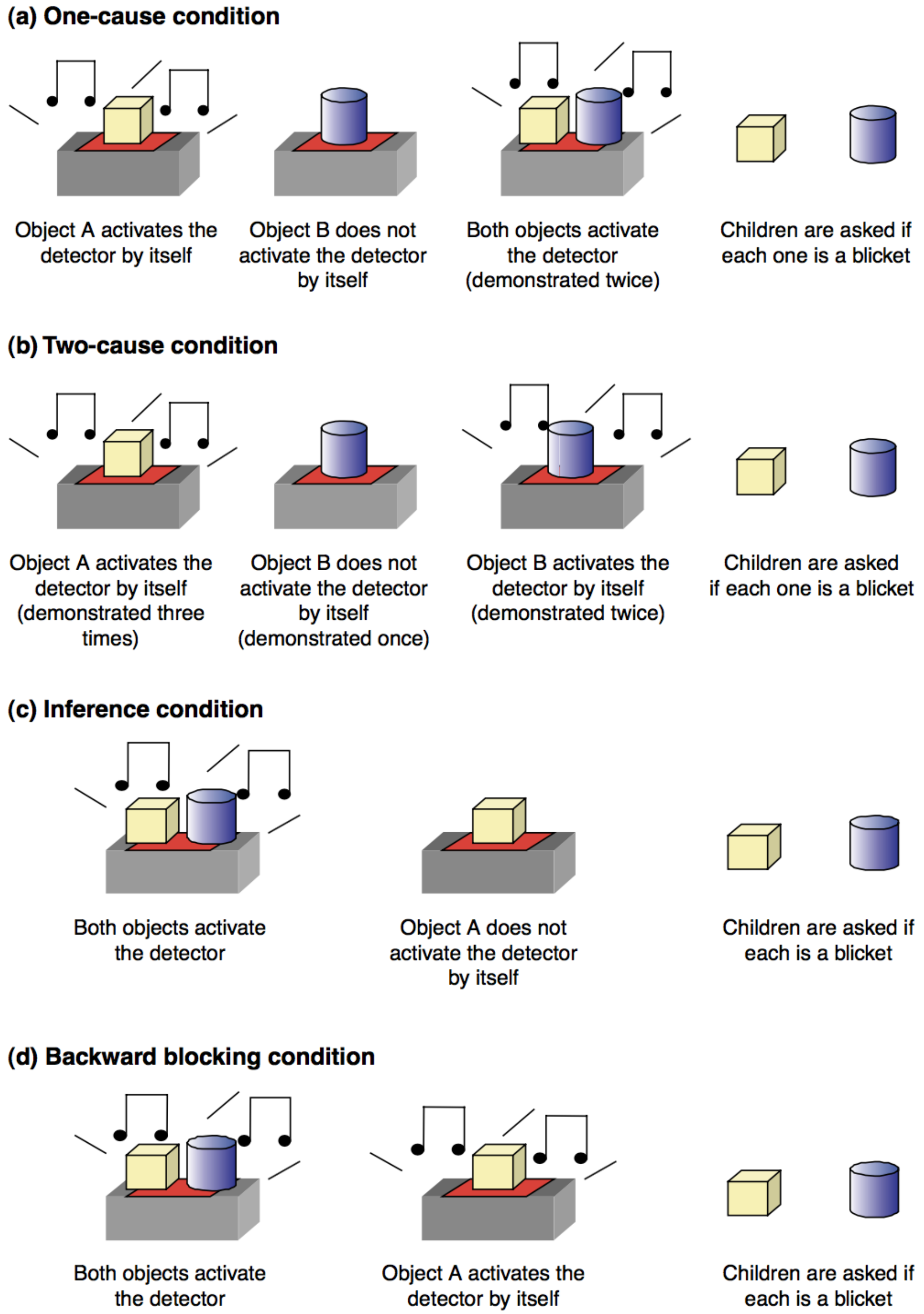
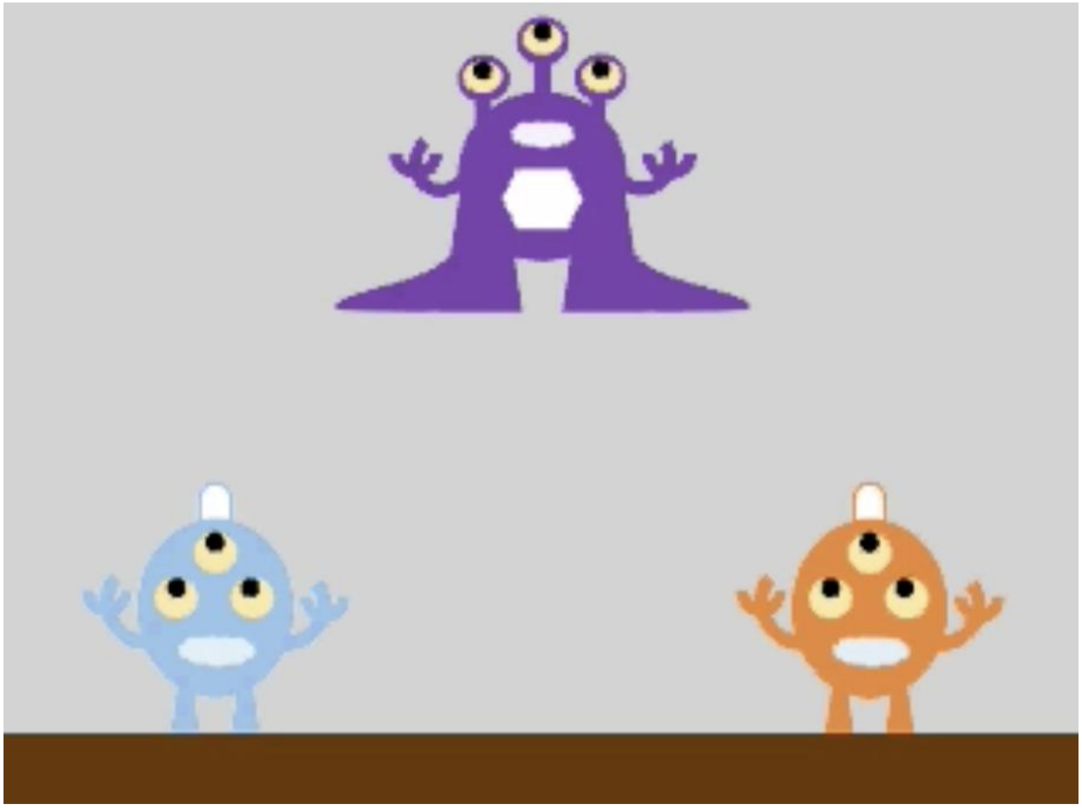


Figure 1. Four conditions that were used with the blicket detector and blickets. Retrieved

from Gopnik & Schulz (2004).



Appendix B

Figure 2. Screenshot of one of the video clips. Mommy alien referred to the purple alien on the top, alien A referred to the baby alien on the left, and alien B referred to the baby alien on the right. Color of the mommy alien remained unchanged, while color of the baby aliens differed for each condition.

Appendix C

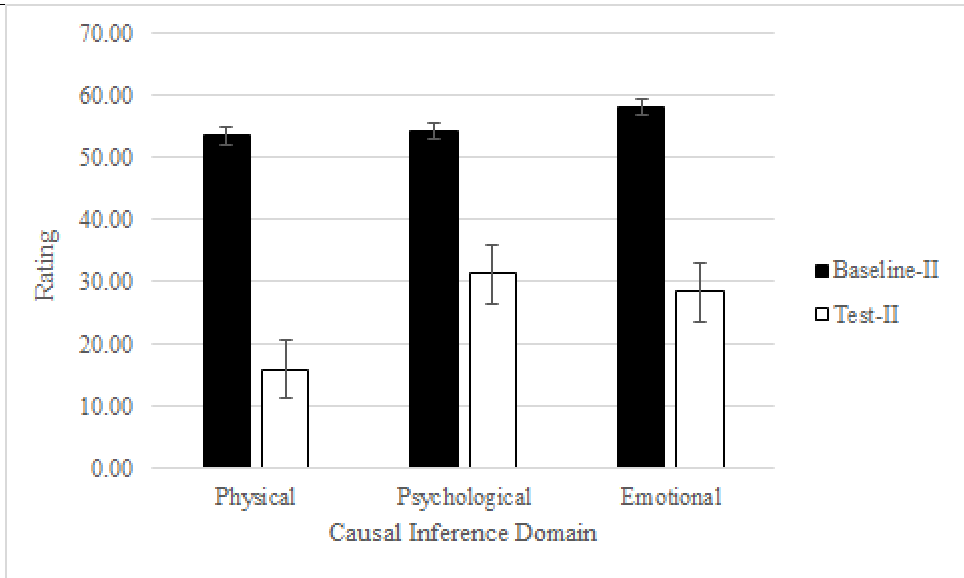


Figure 3. Difference in ratings between Baseline II of alien A and Test II of alien A.

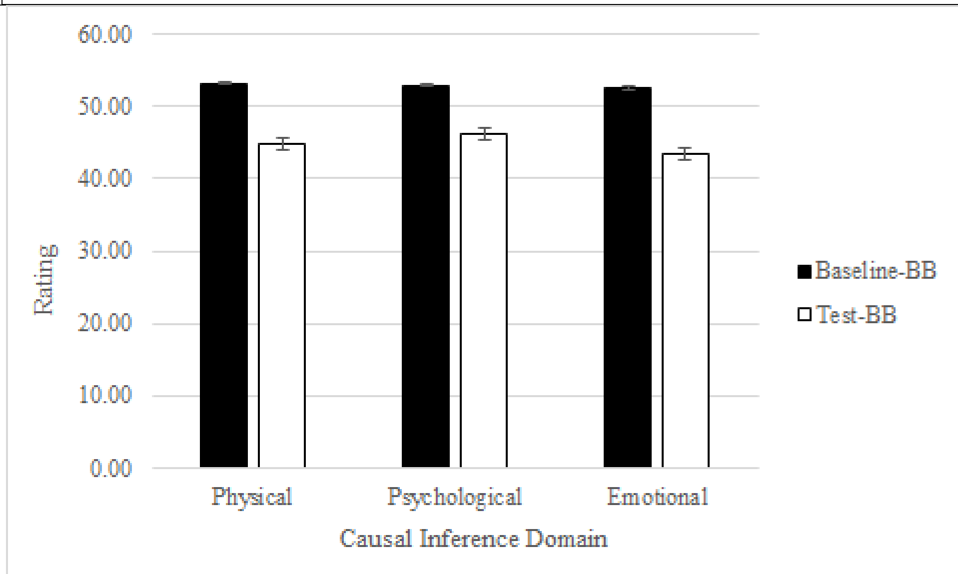


Figure 4. Difference in ratings between Baseline BB of alien B and Test BB of alien B.

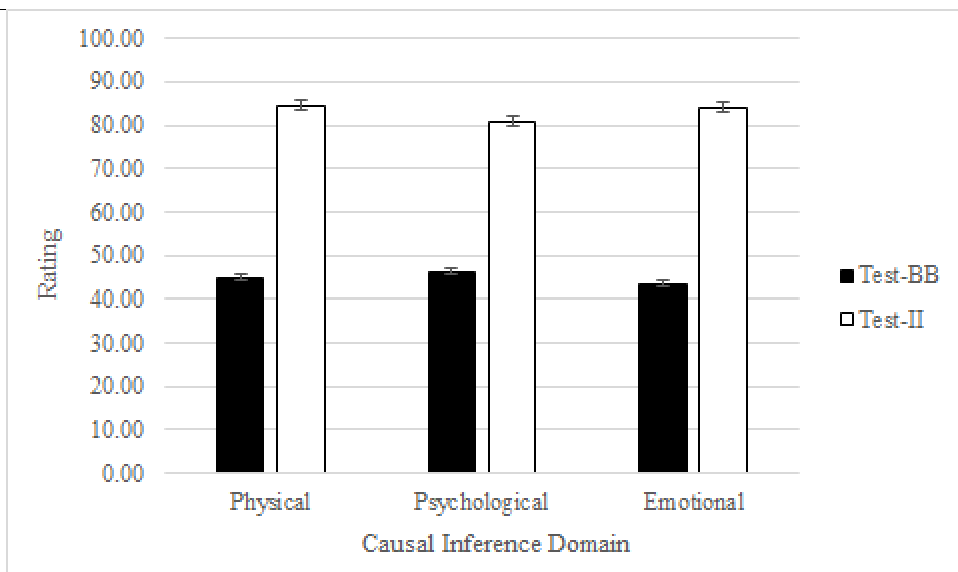


Figure 5. Difference in ratings between Test BB of alien B and Test II of alien B.