

INFANTS' PERCEPTION OF CAUSAL CHAINS

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RUNNING HEAD: INFANTS' PERCEPTION OF CAUSAL CHAINS

Abstract

Three experiments examined infants' and adults' perception of causal sequences of events. In the causal chain sequence, the first action causes a second action that then causes a final outcome; in the temporal chain sequence, the first two actions are independent and the second action causes a final outcome. Infants and adults were shown the same event sequences; infants were tested using a visual habituation paradigm, whereas adults were given a questionnaire. Experiment 1 indicated that 15-month-old infants perceive the primary cause of the final outcome to be the first action in a causal chain but the second action in a temporal chain. Experiment 2 showed that adults interpret the causal sequences similarly to the 15-month-olds. Finally, Experiment 3 showed that 10-month-old infants do not yet perceive causal sequences in the same manner as the 15-month-olds and the adults. These results are interpreted both in terms of infants' developing knowledge of causal events and adults' attributions of causality in complex events.

Infants' Perception of Causal Chains

It is considered a hallmark of sophisticated reasoning, across both development and culture, to be able to look deep into the past to find the causes of events. Such reasoning skills obviously may be of great value, and as many researchers are fond of noting, understanding causal relations is what allows us to predict and control our world (e.g., Alloy & Tabachnick, 1984; Cheng & Novick, 1990; Crocker, 1981; Young, 1995). Often several factors contribute to an outcome, but how do we make causal attributions among those factors? Some researchers have found that when two or more sequential events result in an outcome, adults view the earliest event as most causal (e.g., Johnson, Ogawa, Delforge, & Early, 1989; Vinokur & Ajzen, 1982; Wells, Taylor, & Turtle, 1987). Others have found that adults view the latest event as most causal (e.g., Miller & Gunasegaram, 1990; Sherman & McConnell, 1996). Miller and Gunasegaram tried to reconcile these findings by arguing that in true causal chains, when the first event causes the second event and the second event causes the outcome, attributions are made to the earliest event; whereas in temporal chains, where the causal events act in sequence but are independent of each other, attributions are made to the latest event.¹

Our goal in the present research was to determine whether infants are sensitive to the sequence of events leading to an outcome and attribute causality in the same way as adults. Examining causality with infants introduces two challenges: first, how to present an understandable causal chain scenario and second, how to ascertain the infants' causal attributions. The first problem has been solved using events similar to those developed by Michotte (1963). In his causal perception experiments, adults were presented with events consisting of simple visual stimuli colliding with one another. In the basic "direct launching" event, one stimulus moves across the screen and makes contact with a second stimulus that then begins to move. Michotte found that adults perceived this event as "causal", but if a temporal delay was inserted from the time the stimuli make contact until the second stimulus begins to move, they now perceived the event as "non-causal". Using

Michottean type of events, researchers examining infant causal perception have presented similar causal scenarios to very young infants.

The other challenge is to determine how infants actually perceive these events. The primary method used by researchers has been the "habituation paradigm" which operates on the principle that infants will look longer at novel than at familiar stimuli. When the procedure is applied to early causal perception, infants are repeatedly shown the same causal (or non-causal) event and their looking times are measured. Once these looking times decrease to a predetermined habituation criterion, familiar and novel test events are presented. The relevant issue is whether infants will increase their looking times (i.e., dishabituate) when there is a change in the causality of the event from causal to non-causal or vice versa.

Previous research indicates that by 7 months of age infants not only can perceive causal relationships between objects (e.g., Cohen & Amsel, 1998; Leslie, 1984; Oakes, 1994), but also perhaps the role of agency in simple causal sequences (Leslie & Keeble, 1987). Oakes and Cohen (1990) extended these findings, showing that by 10 months infants are able to respond on the basis of causality even when complex, realistic objects are used.

Thus, convincing evidence exists that infants will respond to events based on whether the objects involved are causally related. A slightly different issue is whether infants have some idea of agency; that is, do infants understand that in a causal launching event the first object is the agent and cause of the second object's (patient's) movement? Early studies of agency (Golinkoff, 1975; Golinkoff & Kerr, 1978) suggested that infants may distinguish between agent and patient, but the results were ultimately inconclusive since the studies did not include a non-causal control condition. In these studies, it was unclear whether infants were responding on the basis of agency or to a change in which object first moved. Leslie and Keeble (1987) did include the non-causal control, finding that infants are less interested in the reversal of a non-causal event in which agency roles remain constant, than in the reversal of a causal event in which roles of agent and patient are exchanged. These findings

provide evidence that infants as young as 7 months attend to the roles of agent and patient when the objects are simple. In addition Cohen and Oakes (1993) found that 10- to 12-month-old infants associated a particular object used as an agent with the type of action (i.e., causal or non-causal) whereas they did not associate the object used as a patient with the kind of action, suggesting that agents and actions are afforded some special status or “deeper bond” as opposed to patients and actions.

In sum, previous research indicates that by 10 to 14 months, infants perceive the causality inherent in a simple launching event involving two objects, and they also seem to be particularly sensitive to the object that plays the role of agent in these events. The next logical step in understanding infants' perception of causality, therefore, is to examine their reactions to more complex events: sequences in which multiple events follow one after another, each possibly caused by the preceding event, and resulting in a final outcome.

Experiment 1

In our first experiment 15-month-old infants saw event sequences involving two possible causes (moving toy vehicles) leading to one outcome (a puppy popping its head out of a doghouse). Fifteen-month-olds were chosen because at this age the infants should have little difficulty perceiving the causality of simple launching events involving two objects (e.g., Oakes & Cohen, 1990). In fact the initial portion of the events used in the present experiment were similar to the entire events used in previous research in that two vehicles were shown moving across the screen in either a direct or delayed launching relationship with one another. However, unlike that research, a third object (the doghouse) was added with which the second vehicle came into contact and resulted in a puppy's head popping up from the roof.

In our extended direct launching sequence (i.e. with the doghouse at the end) it was assumed that the first vehicle would be regarded as the primary agent in the resulting outcome and the second vehicle would be regarded as an instrument. It was therefore predicted that infants habituated to this extended direct launching event would dishabituate

more to a test event when the first vehicle, rather than the second vehicle, was replaced by a novel vehicle, because infants seem to attend most to objects that serve as agents (Cohen & Oakes, 1993). However, in our extended delayed launching event, in which the two vehicles are not causally related to each other, it was assumed that the second vehicle would be regarded as the primary agent of the outcome because it appears to have independent agency and it acts last. It was therefore predicted that infants in the delayed condition would dishabituate more to the test event in which the second vehicle had been replaced by a novel vehicle.

Method

Participants. Fifty-three healthy, full-term, 15-month-olds participated. Twenty-one infants' data were excluded from final analysis: 16 for fussiness, 3 for failure to habituate, and 2 for maternal interference. The final sample consisted of 16 males and 16 females (M age = 65.52 weeks, range = 63.14 to 67.14 weeks). All infants were recruited from birth announcements published in the local newspaper.

Stimuli. In order to counterbalance order of presentation and direction of movement of the two vehicles as well as to run direct launching versus delayed launching conditions, a total of 28 event sequences were needed. Each sequence involved two brightly colored toy vehicles and a small jack-in-the-box shaped doghouse. In all events, one toy vehicle moved onto the screen and made contact with a different stationary vehicle that was located at the center of the screen. On contact, a "clunk" noise occurred and the vehicle that was initially moving stopped. The stationary vehicle then began moving; it stopped, with another "clunk" noise, upon contact with the doghouse. At the moment of impact, a "boing" sound occurred, and a puppy's face popped up out of the doghouse chimney and bounced slightly vertically several times before coming to rest.

Two types of event sequences were presented: In the extended direct launching event which lasted approximately 4 s, the stationary toy began to move immediately after it was hit by the first toy. In the extended delayed launching event, which lasted approximately 6 s,

the stationary toy began to move after a 2 s delay from the time the first toy made contact. Selected frames from habituation and test events are shown in Figure 1.

Insert Figure 1 about here.

Design. Infants were randomly assigned to either the direct or delayed condition. In the habituation phase, infants repeatedly saw one event involving Elmo and Dino. In the test phase, all infants first saw the familiar Elmo and Dino event they had seen during habituation. Then they saw two test events that were identical to the habituation event in terms of condition (direct or delayed) and direction of motion but that contained a novel object, Rhino, that replaced either Elmo or Dino. The order of these two tests was counterbalanced. Finally, as a control, all infants saw a novel event in which new toys, Big Bird and Cookie Monster appeared. This novel test was the same as the habituation and test events in terms of condition (direct or delayed) but the direction of motion was opposite.

Apparatus. The experiment took place in adjacent experimental and control rooms. In the experimental room, infants sat approximately 140 cm from a 31-in color television monitor that was 76 cm from the floor. Infants were filmed using a low-light video camera located below the monitor.

In the control room, infants' looking times were recorded by a Power Macintosh[®] computer. The experimenter observed the infants via a 13-in television monitor. The events were presented by a laser disc player controlled by the computer.

Procedure. Infants were seated on a parent's lap facing the video screen. Parents were instructed to remain neutral and refrain from attempting to direct the infant's attention.

At the beginning of each trial, a green light on a dark background flashed on the screen in order to capture the infant's attention. When the infant oriented towards the screen, the experimenter pressed a computer key that stopped the green attention-getter and started the first trial of the habituation event. The experimenter then pressed and held down a different

key as long as the infant fixated on the screen. As soon as the infant looked away from the screen, the experimenter released the key, the event disappeared, and the attention-getter resumed. Each trial lasted until the infant looked away for 0.5 s or continued looking for 30 s. A trial could include up to four repetitions of the event sequence. A blue screen gradually lowered and raised over a period of 2 s to separate individual presentations of the sequence within a trial.

During the habituation phase, infants repeatedly saw the same event sequence until their mean looking time for any four consecutive trials fell below 50% of their mean looking time for the first four consecutive trials. When this habituation criterion was met, the test phase began. Infants who did not habituate within 20 trials were excluded from final analysis.

Results and Discussion

We first wanted to confirm that infants were indeed habituated to the habituation event and that during test they responded to novelty. As expected, the mean looking time for the first four habituation trials ($M = 23.1$ s; $SD = 6.5$ s) was greater than the mean looking time for the familiar test ($M = 11.6$ s, $SD = 9.3$ s), $F(1, 31) = 37.955$, $p < .05$, indicating that the infants did habituate. Also as expected, infants looked significantly longer at the novel test ($M = 17.7$ s, $SD = 10.2$ s) than the familiar test indicating that they were responding to novelty, $F(1, 31) = 7.494$, $p < .05$.

Infants' mean looking times on the two test trials were analyzed using a 2 (Gender) x 2 (Habituation Event: direct or delayed) x 2 (Object Replaced: first or second) mixed ANOVA. A significant interaction was found between Habituation Event and Object Replaced, $F(1, 28) = 14.759$, $p < .05$. The interaction, shown in Figure 2, indicates that infants habituated to an extended direct launching event looked longer at a test event in which the first object was replaced by a novel object than an event in which the second object was replaced. In contrast, infants habituated to an extended delayed launching event looked longer at a test event in which the second object was replaced by a novel object than an event in which the first object was replaced.

Insert Figure 2 about here.

These findings suggest that 15-month-olds do indeed treat causal agents as special. When shown a causal chain, infants looked longer when the first object (agent) was replaced than when the second object (instrument) was replaced. In contrast, when shown a sequence in which the first and second objects appeared to be independent, infants looked longer when the second object (agent) was replaced than when the first (causally irrelevant) object was replaced. Thus the infants appear to have associated the events with their “causers”, so that when that causer is replaced, the resulting “new” event seems more novel. It remains to be seen, however, whether adults would make these same attributions if they were shown the same events.

Experiment 2

Experiment 2 was designed to validate our intuitions about the event sequences used in Experiment 1. Adults were shown the habituation events and asked to rate how important each of the toy vehicles was in causing the outcome. It was predicted that adults would rate the first vehicle as more causal in extended direct events and the second vehicle as more causal in extended delayed events.

Method

Participants. Participants were 38 male and female introductory psychology students participating in partial fulfillment of a course requirement. The study was conducted in three group-testing sessions.

Stimuli, design, and apparatus. Participants saw four left-to-right event sequences from Experiment 1: Elmo-Dino direct, Dino-Elmo direct, Elmo-Dino delayed, and Dino-Elmo delayed. The presentation order interleaved the direct and delayed events with half of the participants seeing a direct event first and half seeing a delayed event first. Events were presented on a 27-in color television monitor that was approximately 200 cm from the floor.

Procedure. Participants were seated in easy viewing-range of the monitor. A questionnaire was distributed and read aloud by the experimenter instructing participants to rate how important Elmo and Dino were in causing the puppy to pop up in the events they would be shown. Participants then saw each event twice; after each pair of presentations they were asked to write the number representing the causal importance of each toy using a rating scale from 0 (“not at all important”) to 5 (“extremely important”)

Results and Discussion

Causal importance ratings were analyzed using a 2 (Type of Event: direct or delayed) x 2 (Object: first or second) ANOVA. As shown in Figure 3, a significant interaction was found between Type of Event and Object, $F(1,36) = 53.632$, $p < .05$. As predicted, adults presented with the same stimuli as infants rated the first object as more causally important than the second object in the direct events and the second object as more causally important than the first object in the delayed events.

 Insert Figure 3 about here.

A significant main effect was also found for type of event, such that overall, adults rated objects in the direct launching event ($M = 3.826$, $SD = 1.46$) as more causal than objects in the delayed launching event ($M = 3.104$, $SD = 1.86$), $F(1,36) = 15.235$, $p < .05$.

Thus Experiment 2 confirms that with these event sequences, the looking behavior of 15-month-old infants in Experiment 1 shows the same pattern as the causal attributions made by adults.

Experiment 3

The findings from Experiments 1 and 2 prompted us to ask the question: at what age does this ability to perceive causal sequences first develop? To further investigate this question, Experiment 3 duplicated Experiment 1 with 10-month-old infants. Previous research has shown that by 10 months infants perceive simple direct launching events

between two objects as causal (Oakes & Cohen, 1990). Our goal was to examine 10-month-old infants' perception of the more complex three-step causal chain.

Method

Participants. Forty-five healthy, full-term 10-month-old participated. Thirteen infants' data were excluded from final analysis: 7 for fussiness and 6 for failure to habituate. The final sample consisted of 16 males and 16 females (M age = 44.29 weeks, range = 42.86 to 45.71 weeks). Infants were recruited as in Experiment 1.

Stimuli and design. Identical to Experiment 1.

Apparatus. The set-up of the experimental room was slightly different from Experiment 1: infants sat approximately 122 cm from a 25-in. color television monitor that was 91 cm from the floor. Everything else was the same as Experiment 1.

Procedure. Identical to Experiment 1.

Results and Discussion

As in Experiment 1, we first needed to ensure that the infants had habituated and were responding to novelty during the tests. As expected, the mean looking time in the first four habituation trials ($M = 24.7$ s, $SD = 8.9$ s), was significantly greater than the mean looking time in the familiar test trial ($M = 7.4$ s, $SD = 4.2$ s), $F(1, 31) = 149.097$, $p < .05$. Also as expected, a comparison between looking times in the familiar and novel test trials revealed that infants looked significantly longer at the novel test ($M = 12.7$ s, $SD = 9.0$ s), than the familiar test, $F(1, 31) = 8.036$, $p < .05$. These findings indicated that the 10-month-old infants, like their older counterparts from Experiment 1, did habituate and were responding to novelty during the test phase.

On the critical test trials, however, the 10-month-olds behaved quite differently from the 15-month-olds in Experiment 1. Unlike the 15-month-olds, the 10-month-olds did not always look longer when the primary causal agent was replaced by a novel toy. A 2 (Gender) x 2 (Habituation Event) x 2 (Object Replaced) mixed ANOVA was used to analyze infants' mean looking times on the two test trials. Unlike Experiment 1, there was

no significant Habituation Event X Object Replaced interaction, $F(1, 28) = .195$, $p = .66$. Instead the ANOVA revealed a significant main effect for Object Replaced, $F(1, 28) = 4.824$, $p < .05$. As illustrated in Figure 4, across both direct and delayed launching conditions, the 10-month-olds looked longer at the test events in which the first object was replaced by a novel toy than when the second object was replaced.

Insert Figure 4 about here.

Based on the results of Experiment 3, we can conclude that the 10-month-old infants' responses were clearly not governed by a change in the primary agent in the causal sequence, as we had concluded with 15-month-old infants and adults. Rather, it appears that these younger infants were focusing on the first object in the sequence whether or not that object was acting as the primary agent.

General Discussion

The results from Experiment 1 indicate, for the first time, that 15-month-old infants can perceive three-step causal chains, and that they also seem to be particularly attuned to the agent or initial cause of the outcome. In extended direct launching events, adults (in Experiment 2) rated the first object in the causal chain as the more important cause, and, for infants (in Experiment 1), replacing that object did in fact produce more dishabituation than replacing the second object. On the other hand, in extended delayed launching events, adults rated the second object in the temporal chain as the more important cause, and, for infants, replacing the second object produced more dishabituation than replacing the first object. The results from both Experiments 1 and 2 are consistent with Miller and Gunasegaram's (1990) proposal regarding causal attributions, namely that when a first event causes a second event and the second event causes the outcome, attributions are made to the earliest event, whereas when the two events are independent, attributions are made to the latest event. Thus one way of interpreting the results of Experiment 1 is that infants are making appropriate causal attributions.

Finally, Experiment 3 demonstrates that infants' perception of causal sequences develops between 10 and 15 months of age. The 10-month-olds dishabituated when the first object was replaced regardless of whether the first two objects represented a direct or delayed launching. It is apparent that at 10 months the infants were not focusing on the object that 15-month-olds and adults would treat as the cause of the outcome.

Why 10-month-olds in this study attended more to changes in the first object in the sequence rather than the causer of the outcome remains somewhat of a puzzle. We do know from previous research (e.g., Oakes & Cohen, 1990) that with simple launching events involving just two objects 10-month-olds are perfectly capable of responding differently to direct versus delayed launchings. One potentially important difference between the previous studies with 10-month-olds and the present study is that in the present one the events were more complex, involving three objects rather than two. Furthermore, the direct and delayed launching events used in earlier research are actually embedded components of the more complex causal sequences used in the present studies.

The developmental change we found between 10 and 15 months of age is consistent, however, with the information-processing principles proposed by Cohen (1988; 1991; 1998). According to this view, simple relationships between objects, that are perceived as unified wholes at one age, can be embedded into more complex events that will be perceived as wholes at a later age. However, if an event is too complex for an infant at a particular age, the infant will revert back to a simpler level of processing. These two principles may help to explain the differences in performance between 10- and 15-month-old infants. The older infants may be able to take relatively simple causal relationships between two objects such as direct versus delayed launchings and use them as components of more complex causal sequences. The younger infants, on the other hand, may be unable to do so. Indeed, the additional complexity of adding a third object to the event may force the younger infants into a more primitive level of processing in which they no longer even perceive the first two

objects as causal or noncausal, but instead key on the even simpler distinction of the temporal order in which the first two objects move.

The notion that with more complex three-step causal sequences the younger infants may revert to simpler processing has a parallel in the adult literature. Gilbert and colleagues (e.g., Gilbert, Pelham, & Krull, 1988) have found that adults, who often make automatic causal attributions but then are able to adjust those attributions in the presence of additional relevant information, lose the ability to make such adjustments when they are “cognitively busy”. Thus, it seems that throughout life, our causal reasoning ability, although quite important, is also quite fragile.

For now, the closeness of the link between the present results and adults' causal attributions remains highly speculative. However, the current findings make it clear that from 10 to 15 months of age, infants' perception of causality progresses beyond the simple phenomenon described by Michotte and reported previously for infants during their first year of life. The next steps should be to increase both the complexity and the uncertainty of causal chains, to present these more realistic events to infants older than 15 months of age, and to examine how and when the infants' understanding of causal events develops into the understanding of older children and adults.

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Author Notes

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Footnote

¹ Other researchers have argued that in causal sequences there is no simple first-last rule for determining causality but rather causality is attributed to the event that most covaries with the outcome (Mandel & Lehman, 1996) or that most increases the probability that the actual outcome would have occurred (Spellman, 1997; see Spellman, 1997, for a review). For the event sequences used in this paper, such analyses would agree that in direct launching the first object would be most causal and in delayed launching the second object would be most causal.

Figure Captions

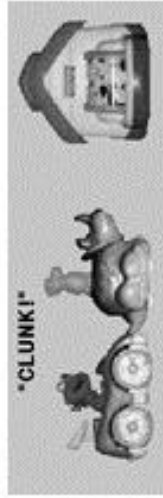
Figure 1: Selected frames from events used in Experiments 1, 2, and 3. Note that in Test 1, the first habituation object (Elmo) has been replaced by a novel object (Rhino), whereas in Test 2 the second habituation object (Dino) has been replaced by a novel object (Rhino).

Figure 2: Looking times of 15-month-old infants in Experiment 1 during the Test Phase in which either the first or second object has been replaced by a novel object.

Figure 3: Adult ratings of the degree of causality of first and second objects when the first two objects occurred either in a direct launching or a delayed launching.

Figure 4: Looking times of 10-month-old infants in Experiment 3 during the Test Phase in which either the first or second object has been replaced by a novel object.

Causal Chain -- Test 2



Causal Chain -- Test 1



Causal Chain -- Habituation

