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Can 6-month-old infants process causality in different types of causal events?

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Two experiments investigated 6-month-old infants' processing of causal and non-causal events with the habituation/dishabituation technique. Experiment 1 was carried out with the usual launching events. Results showed that 6-month-old infants can recognize the presence of causality embedded in a direct launching event. Experiment 2 was carried out with a previously univestigated type of causal event: the entraining event. Results showed that 6-month-old infants could not process causality through a direct entraining event. Findings are discussed in terms of compatibility with a modular or an information-processing framework.

Recent advances in understanding infants' processing of causality have been made with the use of Michotte's (1954/1963) launching events. Different types of events have been produced as animation sequences and presented to infants: (1) a causal *direct launching* in which one object moves and contacts a second object, which instantly moves away from the point of contact; (2) a *delayed launching* in which the second object only moves after a temporal delay following the impact; (3) a *launching without collision*, where the first object stops before it reaches the second object which moves immediately as if it had been hit; and (4) a *delayed launching without collision* which involves both a delay and a lack of physical contact.

Several investigations have used these events in different habituation of looking procedures. The most popular design consists in habituating the infant to a specific type of event, and then presenting him or her with a different type during test trials. If infants attribute a 'special' causal status to direct launching, they should dishabituate more if the test event differs from the habituation one in terms of causality compared to if it does not. For example, based on between-participants comparisons, Leslie (1984) found in one experiment that the amount of recovery of visual attention was greater for 6-month-old infants habituated to a direct launching and tested with a delayed launching without collision, compared to a group habituated to a delayed launching and tested with a launching without collision event. Similarly, other investigations provided data based, instead, on within-participants comparisons. For example, Cohen and Amsel (1998) and Oakes (1994) found that 6- to 7-month-old infants who had habituated to a noncausal event dishabituated more to a direct launching than to a novel noncausal event during test

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trials, when simple stimuli were involved moving on a linear path. With more elaborated stimuli (real objects), Oakes and Cohen (1990) found that 10-month-old infants could recognize the causal characteristic of direct launching, unlike 6-month-old infants. In Cohen and Oakes's (1993) experiment, 10-month-old infants did not respond to causality presumably because the objects varied from trial to trial.

Another design consists in habituating the infant to a specific type of event and testing him or her with the same type of event but run in the opposite direction. If infants of a given age can appreciate causal relations, the reversal of a causal event should produce more recovery of attention after habituation than the reversal of noncausal events. Indeed, the reversal of direct launching involves the reversal of three dimensions (causal direction, temporal priority and spatial direction), while the reversal of noncausal events involves the reversal of only the last two dimensions. With 6-month-old infants, Leslie and Keeble (1987) found that the reversal of a direct launching produced more recovery of attention after habituation than the reversal of a delayed launching. With $3\frac{1}{2}$-month-old infants, Desrochers (1999) did not demonstrate such a pattern of responding.

However, in the studies discussed above, launching events were the only stimuli used. The aim of the present investigation was to establish whether infants can recognize causality in another type of event never applied to young infants before: a direct entraining event (Michotte, 1954/1963). In this type of causal event, a first object moves towards and contacts a second object; then the two move along at the same speed, remaining side by side. According to adult viewers (Michotte, 1954/1963, p. 40), the first object apparently causes the second object to move. Similar to the different noncausal launching events described earlier, this direct entraining event can be modified in order to create noncausal entraining events.

Experiment 2 of the present investigation was designed to evaluate whether 6-month-old infants could process causality in a direct entraining event. Experiment 1 was first conducted with the usual launching events. Infants were tested with the reversal of the collision design. Therefore, the reversal of a causal event (direct launching or direct entraining), after habituation, should produce more recovery of attention than the reversal of their noncausal counterparts.

Experiment 1

The aim of this experiment was to confirm that 6-month-old infants can recognize direct launching as a causal event when simple stimuli along a continuous path are involved, as in previous reports (Leslie, 1984; Leslie & Keeble, 1987; Oakes, 1994). Leslie and Keeble used only delayed launching as a noncausal event with the reversal of the collision design. In this experiment, launching without collision was considered in addition to delayed launching as noncausal events.

Method

Participants

To achieve a final sample of 30 infants, 39 healthy full-term infants were recruited randomly from Paris birth records.

Parents were first sent a letter and were later contacted by telephone. All infants, accompanied by a caregiver, were seen at the University Paris-V laboratory where the testing session took place. Nine infants were excluded because of crying (3) or fussiness (6); all remaining infants habituated within the 24 allowed trials. The final sample consisted of 30 infants (15 boys and 15 girls) aged 6 months (mean age = 182.8 days, SD = 3.5 days).

Stimuli

All events involved the movement of computer generated images of a blue circle (4cm in diameter) and a yellow circle (also 4cm in diameter) across a video-screen. Three types of event were generated: direct launching, delayed launching and launching without collision. The delay introduced in the second event was 1s and the physical gap introduced in the last event was 4cm. The two circles were first presented stationary until the trial began. At this point, one circle moved either from the left or the right side, at a rate of 28cm/s, towards the second circle. After the collision, the second circle moved towards the other side at the same rate and disappeared at the edge of the screen. The first one continued its path at a lower rate (9cm/s) and disappeared also at the same location. This animation was repeated in a continuous loop until the trial ended.

Design

Participants were assigned randomly to one of the three events, with eight infants in each condition. A control group of six infants was added, with two in each of the three previous conditions. The initial direction of the event was counterbalanced between participants and within groups.

Apparatus

Lécuyer, Humbert, and Findji's (1992) apparatus was used. A computer was linked to a TV-screen (85cm diagonal) oriented horizontally in front of the infant. A one-way mirror was placed above the video-screen with a 45° angle. This setting allowed the infant to see the reflected stimuli generated by the computer, as he or she would normally see them on a standard screen. The infant sat alone in a baby-chair, approximately 100cm from the stimuli. A camera, located behind the one-way mirror, allowed an image of the infant's face to be displayed on a monitor.

Procedure

An infant control procedure was used. The experimenter looked at the infant's face on the video monitor. The computer mouse button was depressed when the infant was looking at the stimuli and held as long as the infant's attention remained there. A trial began when the infant looked at the stimuli for at least 0.5s, initiating the continuous production of the event until the infant looked away for more than one continuous second. At this point, the trial ended and the two objects regained their original stationary positions. The habituation phase ended when the average duration of looking of the last three trials was less than 50% of the average duration of looking of the first three trials. A minimum of six trials was thus required and a maximum of 24 trials was allowed for habituation. Immediately after the habituation criterion was reached, the same type of event was presented to the infant but run in the opposite direction; for those in the control group, the same non-reversed event was maintained during the test trial.

The computer program controlled the complete session: random selection of the event, stimuli animation, measurement of the different temporal parameters, calculation of the habituation criterion, transition to the test trial, and data storage. With this form of control, the experimenter was unaware of the type of event being presented to the infant and the moment when the habituation phase was terminated. A second observer coded 50% of the sessions from video-recordings. Inter-observer reliability on infants' total duration of looking per session was high (r = .99).

Results and discussion

Table 1 shows the mean durations of looking during habituation and the recovery score (the difference between the duration of the test trial and the last habituation trial).

Because none of the durations had a normal distribution (Shapiro–Wilk test) and given the small sizes of the samples, non-parametric statistics were used (Siegel & Castellan, 1988). These non-parametric analyses possess the specific advantage of neutralizing the effect of long lookers on the mean looking time of their specific group. A significance level of .05 was used for all statistical tests.

Test of a priori *preferences*

Kruskal–Wallis one-way analyses of variance (ANOVA) by ranks revealed no significant differences in durations of looking between the three experimental groups on any of the habituation scores. Therefore, there is no indication that infants rather look at a specific type of launching event. If infants demonstrate greater recovery of attention to the reversal of direct launching than to the reversal of noncausal events, it could not be explained in terms of a general preference for looking at this type of event.

Test of recovery of attention

A Wilcoxon matched-pairs signed-ranks test revealed that infants in the three experimental groups showed a recovery of duration of looking between the last habituation trial and the test trial ($T = 300$, $z = 4.29$, $p < .001$). Infants in the control group showed no significant recovery between the last habituation trial and the test trial. Given the small sizes of the control group, it is possible that the failure to find evidence of a dishabituation for the control group could be attributed to a lack of statistical power. However, the raw data are not consistent with such an interpretation; indeed, they even showed a negative mean recovery score. Therefore, reversing the launching events did produce a reaction to novelty and this reaction cannot be explained in terms of a random fluctuation of attention.

Table 1. Mean durations of looking and standard deviations (in parenthesis) in seconds to the different launching events at 6 months

	Groups			
Scores	Direct launching $N = 8$	Delayed reaction $N = 8$	Launching without collision $N = 8$	Control $N = 6$
First trial	54.3 (47.1)	31.9 (20.9)	35.6 (32.2)	53.2 (53.1)
First 3 trials	84.9 (38.7)	87.3 (45.8)	86.9 (86.2)	89.8 (50.5)
Mean duration	18.3 (7.1)	22.3 (15.3)	16.8 (14.1)	18.8 (6.9)
Peak look	62.0 (42.8)	65.4 (49.1)	63.3 (76.0)	80.7 (40.5)
Total duration	123.9 (39.1)	157.0 (124.3)	113.0 (75.9)	129.0 (43.6)
Last trial	4.9 (4.01)	5.3 (2.1)	3.0 (0.9)	5.5 (2.9)
Recovery	25.5 (21.2)	14.8 (9.4)	8.5 (12.9)	−1.8 (3.8)

$N = 30$, mean age = 182.8 days.

Moreover, a further Kruskal–Wallis one-way ANOVA by ranks revealed a significant treatment effect between the three experimental groups on the recovery score ($H(2,24) = 6.56$, $p < .05$). Direct launching produced the highest recovery score, followed by delayed launching and launching without collision. But only the difference between direct launching and launching without collision reached statistical significance (Rdl-Rlwc = 9, $p < .05$), the critical difference being 8.46.[1] Although there can be interpretative difficulties arising from any comparison to last habituation trial's duration when a habituation criterion has been used (Cohen & Menten, 1981), this is unlikely to have affected the present results because mean durations of the last trial were very similar across conditions.

As observed by Leslie and Keeble (1987), 6-month-old infants dishabituated more to the reversal of direct launching than to the reversal of noncausal events, although only the comparison with launching without collision reached statistical significance in the present experiment. Other examples in the literature demonstrated that infants differentiated the causal event from noncausal events but not significantly in every comparison. For example, Oakes and Cohen (1990) showed that infants, when habituated to a causal event, dishabituated significantly ($p < .05$) to only one type of noncausal event. Similarly, Oakes (1994) obtained results which revealed that infants, when habituated to a causal event, dishabituated to both noncausal events; however, when infants were habituated to one type of noncausal event, they did not dishabituate significantly to a causal event ($p = .07$).

The impossibility to reach a statistical difference between direct launching and delayed launching in Expt 1 might also be attributed to a lack of statistical power, given the small sizes of the samples. Besides, because the level of dishabituation to the reversal of the delayed launching was intermediate between the level of dishabituation to the other two types of events, it is possible that continuous movement plays an important role in very young infants' processing of launching events (Cohen & Amsel, 1998). Obviously, one should only speculate about non-significant differences and additional research is needed in order to confirm this hypothesis.

Experiment 2

The aim of this experiment was to test if infants would react in the same way towards entraining events as they did towards launching events in Expt 1. In other words, the reversal of a causal direct entraining should produce more recovery of attention, after habituation, than the reversal of noncausal entraining events. Again, entraining without collision was used in addition to delayed entraining as noncausal events within the reversal of collision design.

Method

Participants

In order to achieve a final sample of 42 infants (21 boys and 21 girls, mean age = 184.1 days, SD = 5.4 days), 52 healthy full-term infants were seen. Seven were excluded because of fussiness (5) or crying (2), and

[1] For the nonparametric statistics, differences were calculated on the mean ranks obtained by the groups and not on the raw mean durations of looking that are presented in Tables 1 and 2.

three for exceeding the 24 trials allowed in habituation. Participants were recruited through advertisements in papers, with the collaboration of provincial medicare and through Quebec's birth records. All infants, accompanied by a caregiver, were seen at the University Laval Laboratory.

Stimuli

All events involved a yellow square (4cm × 4cm) and a blue rectangle (4cm × 3cm) with a triangle (1cm × 1cm × 1cm) on the top (see Fig. 1). Stimuli differed in their shapes in order to ensure that infants would process two distinct objects instead of a united one when they were side by side. Three types of event were created. In the causal *direct entraining* event, one object moved and contacted the second one; then the two remained side by side and moved along at the same speed. In the *entraining without collision* event, the second object started to move before the first object had reached it (there was a 4cm gap between the two objects). In the *delayed entraining* event, a delay of 1s was introduced between the moment of impact and the start of entraining. Besides obvious differences in stimuli, the animation was conducted within the same parameters as in Expt 1.

The results of an experiment with adults in the laboratory confirmed that they rated the direct entraining as more causal than the delayed entraining or the entraining without collision events. The methodology was exactly the same as Oakes and Kannass's (1999) Expt 3 with adults. Eighteen undergraduate and graduate students at the University Laval participated. The three entraining events were the stimuli. Adults received a preview of the stimuli in a random order. After that, each participant had to judge each event as (1) not at all causal, (2) somewhat noncausal, (3) somewhat causal, or (4) definitely causal. Participants could view each event in a repeated loop as long as they wished; the order of presentation of the different entraining events was counterbalanced between participants. Friedman two-way ANOVAs by ranks revealed a significant treatment effect ($F_r = 17.69$, corresponding χ^2 corrected for ties $= 21.59$, $p < .001$). Multiple comparisons showed that direct entraining (mode = 4) was judged as more causal than delayed entraining (mode = 2; $R_{\text{direct}} - R_{\text{delayed}} = 20.5$, $p < .05$) or entraining without collision (mode = 2; $R_{\text{direct}} - R_{\text{without collision}} = 23.0$, $p < .05$), the critical difference being 14.45. These were the only statistically significant comparisons.

Design

Experiment 2 differed from Expt 1 in only one respect: the size of the experimental groups. In Expt 2, more infants were included in the experimental groups in order to diminish the influence of a possible statistical power error, proposed earlier as part of an explanation of Expt 1 results. There were 12 participants for each of the three experimental conditions (direct entraining, entraining without collision and delayed entraining). The control group was composed of six participants, two for each of the previous conditions.

Apparatus and procedure

These were the same as in Expt 1. Inter-observer reliability was high ($r = .99$).

Results and discussion

Table 2 shows the mean durations of looking during habituation and the recovery score. The same analyses as in Expt 1 were conducted.

Test of a priori *preferences*

Kruskal–Wallis one-way ANOVAs by ranks revealed no significant differences in durations of looking between the three experimental groups on any of the habituation scores. Recall that establishing the absence of such differences was a necessary condition for the subsequent analyses.

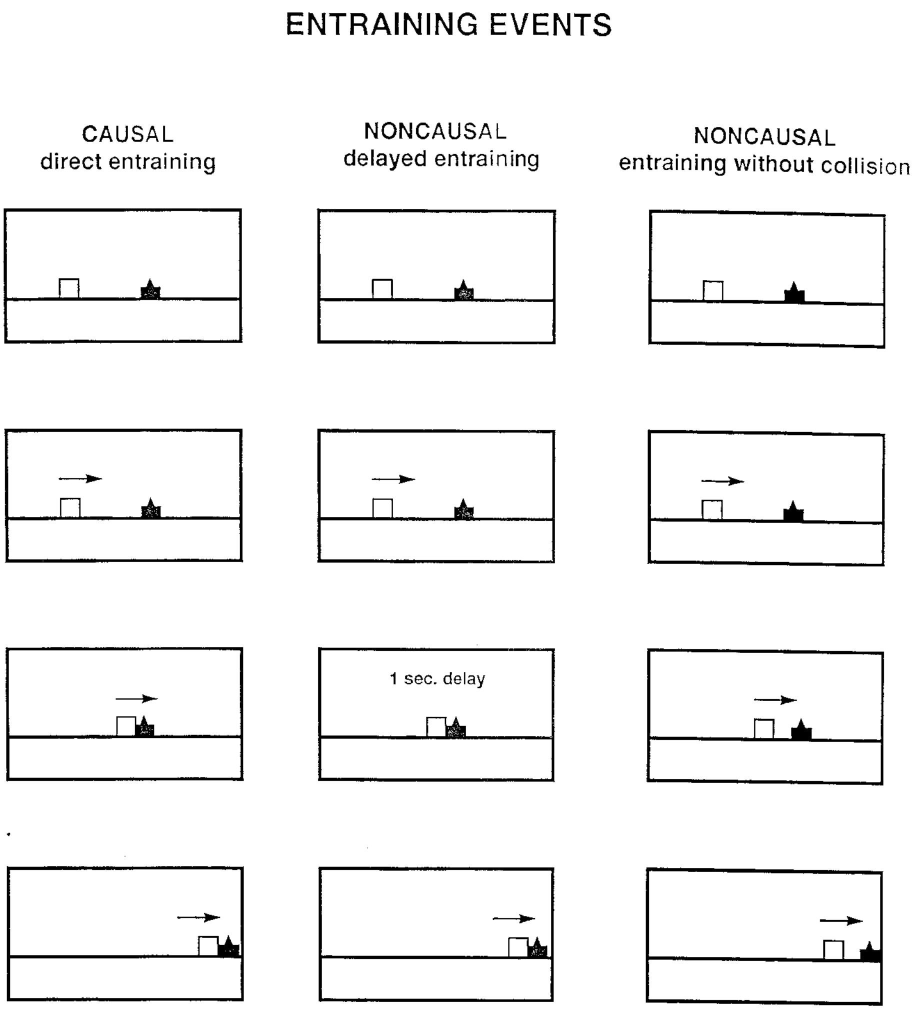

Figure 1. Illustration of the different entraining events used in Expt 2.

Table 2. Mean durations of looking and standard deviation (in parenthesis) in seconds to the different entraining events at 6 months

	Groups			
Scores	Direct entraining $N = 12$	Delayed entraining $N = 12$	Entraining without collision $N = 12$	Control $N = 6$
First trial	47.7 (43.5)	35.2 (22.9)	31.8 (20.9)	46.2 (67.5)
First 3 trials	70.4 (44.2)	67.2 (47.6)	78.9 (40.6)	81.5 (67.1)
Mean duration	16.2 (9.7)	16.3 (12.1)	19.1 (10.3)	18.8 (12.8)
Peak look	49.9 (41.4)	43.5 (27.1)	56.7 (30.5)	66.2 (63.0)
Total duration	112.6 (58.3)	122.3 (85.1)	148.0 (83.2)	123.4 (78.1)
Last trial	4.5 (3.1)	4.9 (5.2)	4.3 (3.1)	5.0 (3.1)
Recovery	7.8 (6.7)	7.5 (11.9)	12.5 (22.7)	−.6 (3.2)

$N = 42$, mean age = 184.1 days.

Test of recovery of attention

A Wilcoxon matched-pairs signed-ranks test revealed that infants in the three experimental groups showed a recovery of duration of looking from the last habituation trial to the test trial ($T = 600$, $z = 4.19$, $p < .001$). Infants in the control group showed no recovery between the last habituation trial and the test trial; they even showed a negative mean recovery score. Obviously, as in Expt 1, the failure to find evidence of a dishabituation for the control group cannot be attributed to a lack of statistical power. Therefore, reversing the entraining events did produce a reaction to novelty and this reaction cannot be explained in terms of a random fluctuation of attention.

However, a Kruskal–Wallis one-way ANOVA by ranks showed no treatment effect between the three experimental groups on the recovery score. The reversal of the direct entraining event did not produce more recovery of attention than the reversal of its noncausal counterparts. Infants habituated to all entraining events and dishabituated to their reversals equally.

Null results are open to many interpretations. For example, delayed entraining may have much in common with many of human agency causal events. Therefore, the fact that there was no difference between direct entraining and delayed entraining might be because infants perceive causality in both rather than none of these events. However, if direct entraining and delayed entraining were processed as causal, infants should have differentiated those events from a clear noncausal entraining without collision, to which infants are never exposed.

A look at both experiments' results might support the idea that direct entraining was not processed as a causal event. Indeed, a Mann–Whitney U test revealed that the recovery score of direct launching was higher than the recovery score of direct entraining ($U = 17$, $z = 2.39$, $p < .05$). Thus, it seems that an additional property was processed in the direct launching event that was not processed in the direct entraining event. According to the reversal of the collision design, this property is probably the causal direction of the event.

General Discussion

Expanding on Fodor's (1983) ideas, Leslie (1986) suggested that infants possess an innate perceptual mechanism that allows them to extract the causal component of an event when this is appropriate. According to Fodor, modular processing should be domain specific, mandatory, insensitive to central cognitive processes, fast, informationally encapsulated, giving rise to shallow outputs, of fixed neural architecture, and of specific ontogeny and breakdown patterns.

Recent researchers, however, have shown that processing of causality is certainly not mandatory during infancy and changes over the months. For example, Oakes (1994) found that 6- to 7-month-old infants could process causality when two objects were involved on a similar trajectory, but not when they moved along a dissimilar trajectory, while this limitation is overcome at 10 months of age. Moreover, 6-month-old infants were unable to process causality when complex stimuli were involved, but were able to do so at 10 months (Oakes & Cohen, 1990). Finally, 10-month-old infants could not process causality when the objects changed from trial to trial during habituation (Cohen & Oakes, 1993). In addition, Cohen and Amsel (1998), Desrochers (1999) and Lécuyer and Bourcier (1994) showed that, before 6 months of age, infants could not process causality in a direct launching event. These studies clearly demonstrate that the processing of causality is certainly not inevitable during infancy and remains sensitive to specific characteristics at particular ages.

In the same vein, if the processing of causality is inevitable, participants in Expt 2 should have identified causality in a direct entraining event, as they did in the direct launching event. Indeed, according to an innate automatic module, events themselves should not be important. Only the presence/absence of causality should matter. Therefore, the present investigation does not support Leslie's hypothesis of the existence of a functioning module of causality at 6 months of age.

Cohen (see Cohen, 1988; Cohen, 1991; Cohen & Oakes, 1993; Oakes 1994) has proposed a different theoretical model. Before the age of 5 months, infants process the different parts of an object independently, as if they were not related to one another. Between 5 and 7 months they perceive relations between the parts of an object and they then start to integrate them as a whole. Between 7 and 10 months infants are able to process relations between objects and begin to integrate them as an event. Thus, the processing of causal relations should develop only during this last period. In the present investigation, the fact that 6-month-old infants could process causality in a direct launching event, but not in a direct entraining event, demonstrates that the notion of external causality is weak at 6 months and can be applied only in limited situations.

The results found so far with the visual habituation/dishabituation technique can only be adequately integrated within a developmental framework. The processing of causality would only begin at around 6 months and would gradually develop to become more flexible over following months—a very similar developmental sequence to what empirical studies of Piaget's (1937/1954) sensorimotor causality revealed (Desrochers, Ricard, & Gouin Décarie, 1995; Uzgiris & Hunt, 1975). Nevertheless, the fact that 6-month-old infants can process causality only in very restricted situations is certainly interesting. This ability appears to be highly domain specific and becomes mandatory when certain specific conditions are encountered. In fact, each time that simple stimuli were involved on a linear path, infants of that age recognized causality in direct launching events.

Could it be possible that Leslie's ideas of a functioning module of causality during infancy was inappropriate because of its broadness? A modular hypothesis could in fact be accurate, but needs to be more specific. If one is to suggest the existence of modular processing in infancy, one should propose a limited module which processes causality only in a direct launching event when simple stimuli are involved on a linear path. This type of event is, in reality, the simplest, most definite and identifiable kind of causal event an infant is likely to see in real-life experience. One could then propose the existence of an automatic module, applicable to and only to specific classes of launching events at given ages.

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