Cognitive Principles Central To Causality Understanding

Cristina Meini (cristina.meini@lett.unipmn.it)
Department of Human Studies, via Manzoni 8, 13100 Vercelli, ITALY

Monica Bucciarelli (monica@psych.unito.it)
Center for Cognitive Science and Department of Psychology, via Po 14, 10123 Torino ITALY

Giuseppe Maurizio Arduino and Francesca Vinai (arduino81@hotmail.com)
Center for Autism, ASL 16, via Torino 1, Mondovì (CN), ITALY

Abstract

Many studies in the psychological literature focus on the distinctive features of physical and psychological causality understanding. Our aim is a preliminary study from a different perspective, looking for similarities in the two domains. The results of Experiment 1 (38 adults participants) confirm our prediction: some features of the perceptual stimulus affect causality understanding in both the physical and the psychological domain. Also, the results of Experiment 2 (16 autistic children and 16 controls) confirm a clinical prediction deriving from our assumption. Autistic individuals, who are notoriously impaired in understanding psychological causality, turn out to be impaired also in understanding physical causality.

Keywords: Causality understanding; physical causality; psychological causality.

Introduction

The notion of causality is central in both the physical and the psychological domains. In the physical realm, the rotation movement of the Earth causes the alternation of night and day, while in the psychological domain the defying glance of a child causes her friend's wild reaction.

In the physical domain, particular attention was devoted to simple launching events such as a billiard ball colliding with and launching another billiard ball – i.e., the same kind of events notoriously studied by the philosopher Hume (1741/1978). Two centuries later, Piaget (1955) studied how children develop causality understanding. An important finding in the most recent literature is that individuals are sensitive to the *contingency* or *temporal contiguity* between pairings of a cause and an effect. In other words, cause and effect must be temporally contiguous in order to generate a judgement of causality. A 0.5 seconds delay between an action and its outcome suffices to decrease causality perception in young infants (see, e.g., Spelke, Phillips & Woodward, 1995). In adults, Michotte (1963) observed that the perceptual system assumes cause-effect relations in the absence of contradictory evidence such as the lack of temporal or spatial contiguity, even when there is no real object.

In the psychological domain, many studies attempted to understand which perceptual features trigger the perception of agents. Baron-Cohen (1995), for example, purported the existence of the Mindreading System, a cognitive mechanism detecting complex psychological causes of action. One component of the system is the Intentionality Detector (ID), a specialized perceptual mechanism detecting an agent's goal. Other studies evidenced that eyes are fundamental social and psychological stimuli. It is from the presence of eyes that we immediately recognize agents, and we spontaneously tend to "read" mental states in the eyes of someone. According to Baron-Cohen (1995), eye-like stimuli trigger the Eye Direction Detector (EDD) component of the Mindreading System, that computes the direction of the gaze, finding what the eyes are looking at. ID and EDD trigger SAM (Shared Attention Mechanism), which detects mutual attention and communicative situations. The assumption of specialized mechanisms involved in psychological causality is enforced by clinical data that can be read in terms of an impairment in such a mechanism. In particular, causal psychological understanding is notoriously impaired in autism (see, e.g., Klin, 2000, Klin, Volkmar & Sparrow, 1992). Autistic people generally do not understand the psychological state expressed by a particular glance, nor they understand that a person wants what she is looking at (Baron-Cohen et al., 2001). At a higher level, they do not understand that beliefs cause behavior. On the contrary, autism is not regarded as a syndrome that impairs physical causality understanding (Baron-Cohen, Leslie, & Frith, 1986).

Some studies revealed a precocious ability to differentiate agents from objects in causal events. For example, Woodward and colleagues (1993) found evidence that 7-month-old infants make a distinction between mechanical forces and animate sources of motion. On the whole, those experimental data show that people not only have precocious causal understanding in both the physical and psychological domains, but also know that the two realms are governed by different principles. An interesting question thus concerns the relation of the two domains of knowledge. Some authors tend to see causal understanding in the physical and psychological domains as completely separated. According to Leslie (1994), for example, the cognitive mechanism ToBy (Theory of Body Mechanism) allows us to understand the physical notion of force, while ToMM1 (Theory of Mind Mechanism 1) and ToMM2 (Theory of Mind Mechanism 2) are the bases of psychological understanding. Also, the Mindreading System proposed by Baron-Cohen (1995) is triggered by specifically agentive stimuli, such as eyes and self-propelled movement. Gelman, Durgin and Kaufman (1995) purport a different view. They claim that there exist numerous skeletal causal principles that organize attention to and learning about the animate-inanimate distinction. Perceiving a particular kind of movement is neither necessary nor sufficient to identify causal situations: other conceptual information, such as those concerning the transmission of force and the respect of specific naïve physical principles, are also considered (see also Leslie & Keeble, 1987; Spelke, 1994).

Cognitive Principles of Causality Understanding

In line with Gelman and colleagues (1995), we assume that numerous factors contribute to causality understanding. From this perspective our study looks for possible factors playing a major role in both the physical and the psychological domains. We considered interactive situations more complex than those situations typically investigated in the literature; we explored both judgments of physical and psychological causality and, within the two categories, two further sub-categories. As regards physical events, we allowed for the possibility to judge it as an instance of either a chance event or an event of physical causality. As regards psychological events, we allowed for the possibility to evaluate them as instances of private psychological causality or communicative psychological causality. With private psychological causality we refer to a situation where the agents act on their own, with no communicative intent. With communicative psychological causality we refer to a situation where at least one agent acts with the intention to communicate something to others (Grice, 1989).

A main assumption of our investigation was that psychological causality judgements may be affected by the same features of the perceptual stimulus as physical causality judgements are. In particular, as contact and temporal contiguity, compared with no contact and no temporal contiguity, distinguishes between a physical causality event and a chance event, we expected them to distinguish between two different kinds of psychological causality judgment, i.e., communicative and private. From our assumption another important prediction follows. If some cognitive principles are central to both the physical and the psychological domains, then autistic people should also have difficulties in physical causality understanding.

Experiment 1: Evidence for Aspects Common to Physical and Psychological Causality judgments

The adults participants in the experiment were invited to watch some video-taped animations and to answer, for each animation, two questions (translated from Italian): 1) “Are those moving on the screen characters or objects?”, 2) “Do they move independently or they interact?”. We combined the answers to the two questions and we coded them as follows:

- Objects that move independently: *chance event*.
- Objects that move dependently: *physical causality*.
- Characters moving independently: *private psychological causality*.
- Characters moving dependently: *communicative psychological causality*.

Method

Thirty-six students at Turin University participated in the experiment (7 males and 29 females: mean age 23 years). They were students attending a course of General Psychology and voluntarily accepted to take part in the experiment. The experimental material consisted of 12 video-animations all sharing the same structure. Each animation involved two billiard balls of the same size (diameter: 110 pixels) and started with a ball standing at ¾ of the visible area (on the right side of the screen); let us call it the first ball. After 1 second another ball, let us call it the second ball, which was not visible at the beginning of the animation, arrived from the left side of the screen (speed: 18.1 cm/sec in a 14-inch television set). Only at this point the first ball moved through the right side of the screen and exited. Each animation ended with the ball that entered the screen resting in the place where originally stopped. The twelve video-animations differed according to the following variables: presence of eyes or not; ocular contact or not; physical contact or not; temporal contiguity of 0.5 seconds or not. In the “no contact” condition, the second ball stopped before arriving at the central part of the screen. Figure 1 illustrates a photogram of an animation (i.e., an instance of animation involving eyes, eye contact, physical contact).

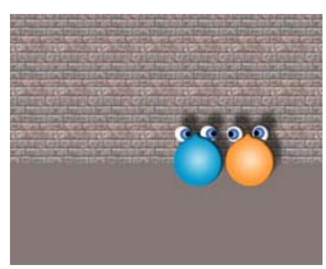

Figure 1. A photogram of an animation characterized by the presence of eyes, eye contact and physical contact.

The 12 animations were arranged in four different random orders and the participants were casually assigned to one of the four randomizations, for a total of 9 participants in each randomization. The experiment was carried out individually, in a quiet room. Participants were told that the experiment was concerned with how individuals judge brief animations. Each animation was presented twice; once after the first question, once after the second question.

Results and Discussion

For a conservative analysis, which allows us to consider how globally the variables we considered affected individuals' judgments, we carried out a series of log-linear analyses. If we consider all the variables with the exception of eye contact (the animations without eyes do not feature this variable), the STEPWISE log-linear analysis selects as the best model (LR χ^2 (df=12): 7.84, p=.80) the model in which judgments were affected by the variable eyes (see Table 1) and by the interaction between physical contact and temporal contiguity (Table 2).

Table 1. Contingency table eyes*judgment.

Eyes	Judgment				Total
	Chance	Physic. Causality	Priv. Psych.	Com. Psych.	
-	67	67	9	1	144
+	30	25	111	122	288
Total	97	92	120	123	432

From Table 1 we can consider that animations without the eyes lead participants to judge the event as pertaining to the physical domain, whereas the presence of the eyes led to judge the event as an instance of causality in the psychological domain.

Table 2. Contingency table physical contact*judgment*temporal contiguity.

Temporal contiguity		Judgment				Total
		Chance	Physic. Causality	Priv. Psych.	Com. Psych.	
+ Physical contact	-	32	13	35	28	108
	+	1	51	7	49	108
Total		33	64	42	77	216
- Physical contact	-	38	6	47	17	108
	+	26	22	31	29	108
Total		64	28	78	46	216

Table 2 shows that, independently on the presence of the eyes, when there was temporal contiguity, and there was physical contact, participants judged the event as either physical causality or communicative psychological causality. When there was no temporal contiguity, and there was not physical contact, participants judged the events as either a chance event or private psychological causality.

Let us consider only the animations with eyes (for them we can consider the variable eye contact); the STEPWISE log-linear analysis selects as the best model the model in which judgments were affected by the interrelation between physical contact and temporal contiguity (LR χ^2 (df=16): 15.02, p=.52); see Table 3). In case of temporal contiguity and physical contact, participants tended to judge the event as either physical causality or psychological causality. In case of no temporal contiguity and no physical contact, participants tended to judge the event as private psychological in the psychological realm.

Table 3. Contingency table physical contact*judgment*temporal contiguity.

Temporal contiguity		Judgment				Total
		Chance	Physic. Causality	Priv. Psych.	Com. Psych.	
+ Physical contact	-	10	2	32	28	72
	+	0	17	6	49	72
Total		10	19	38	77	144
- Physical contact	-	10	1	44	17	72
	+	10	5	29	28	72
Total		20	6	73	45	144

We conclude that some features of the perceptual stimulus affected individuals' judgments of causality both in the physical and the psychological domains. In particular, our global results reveal that physical contact and temporal contiguity were essential to distinguish between a chance event and physical causality in the realm of objects (animations without eyes), and between private psychological causality and communicative psychological causality in the realm of agents (animations with eyes).

Experiment 2: Clinical Evidence

Experiment 2 was devised to test a clinical prediction. Autistic children, who are impaired in psychological causality understanding, ought to be impaired also in physical causality understanding. The experimental procedure of this study (see below) allowed us to overcome a limit of Experiment 1, which did not discriminate between communicative psychological causality and physical causality involving agents in animations with eyes. An agent could cause the movement of another agent unintentionally.

Method

The experimental group consisted of sixteen children (12 males and 4 females: mean age: 8;9) with a diagnosis pertaining to the autistic spectrum according to the DSM-IV and the ICD-10. In particular, 8 children were autistic, 4 had a pervasive disease of the development non otherwise specified, and 4 had Asperger syndrome. Their non verbal mental age - as measured by the Brief IQ (BIQ) Screening Assessment from the Leiter International Performance Scale Revised (Roid & Miller, 1997) - was 6;9 years, and their verbal mental age - as measured by the Peabody Picture Vocabulary Test Revised (Dunn & Dunn, 1981) - was 6;7 years. Children were all attending the Center for autism of the Local Sanitary Health Authority of Cuneo.

The control group consisted of sixteen non-autistic children attending the local schools of Cuneo. They were comparable to the autistic children for sex and verbal mental age (12 males and 4 females: mean verbal mental age: 6;7 years). We assumed also a match of the two groups of participants on non verbal mental age.

Children were presented with a theory of mind test and with the causality test we devised. The theory of mind test was intended to ascertain that our autistic children were impaired in theory of mind tasks like the autistic children described in the literature. We used the classical Sally and Ann test (Baron-Cohen, Leslie & Frith, 1985), presented through a series of 5 vignettes. There were two doll protagonists, Sally and Anne. Sally first placed a marble into her basket. Then she left the scene, and the marble was transferred by Anne and hidden in her box. Then, when Sally returned, the experimenter asked the critical Belief Question: “Where will Sally look for her marble?”. If the children point to the previous location of the marble, then they pass the Belief Question by appreciating the doll’s now false belief. If however, they point to the marble’s current location, then they fail the question by not taking into account the doll’s belief. These conclusions are warranted if two control questions are answered correctly: “Where is the marble really?” (Reality Question); “Where was the marble in the beginning?” (Memory Question).

The causality test consisted of 6 of the 12 animations used in Experiment 1. In particular, we focused our attention on the crucial animations for investigating the relationship between physical contact and temporal contiguity (see Tables 4 and 5). The experimental procedure was slightly different from the procedure used in Experiment 1. Participants were told that they were going to see characters when presented with animations with eyes, and they were told that they were going to see objects when presented with animations without eyes. This procedure was meant to detect situations in which, while knowing that animations involved agents, children still attribute physical causality. Each of the 6 animations was presented twice, but not on consecutive trials, for a total of 12 animations (12 trials). Also, each trial involving an animation with agents required the participant to answer two questions, and for this reason the animation was presented twice within a trial. Each question and each possible answer was written on a piece of paper and read aloud by the experimenter. The first question was common to both animations, with and without eyes: ‘Does one move the other or they move by themselves?”. In case of animations without eyes, the answer discriminates between physical causality and a chance event. In case of animations with eyes, the situation is different. Indeed, it is possible for someone to recognize two stimuli as agents and to interpret their interaction as physical causality, as when one person unwillingly pushes the other. Thus, in case of agents, the first question was followed by a second one: ‘Does the [COLOR OF BALL ON THE SCENE SINCE THE BEGINNING] ball move because the [COLOR OF THE BALL ENTERING THE SCENE AFTERWARDS] ball want it?’. Depending on the answers to the two questions, we coded participants’ interpretations of the animation involving agents as follows:

- Character/one moves the other/did not want: *physical causality*
- Character/one moves the other/wanted: *communicative psychological causality*
- Character/they move by themselves: *private psychological causality*

Results and Discussion

In the false belief task the participants behaved according to the literature in that autistic children performed poorly (see, e.g., Baron-Cohen et al., 1985; Leslie & Frith, 1988). Only 4 of the 16 autistic children answered correctly both the Reality and the Memory questions, and of these 4 children only 1 answered correctly the Belief question. As regards the control group, 7 of the 16 children answered correctly both the Reality and the Memory questions, and of these 7 children 6 answered correctly the Belief question. Hence, children in the control group outperformed children in the experimental group (Mann-Whitney test: $z=2.21$, $p<.04$). As regards the causality test, Table 4 and 5 summarize the percentages of typologies of judgment by the autistic and the control group, respectively.

Table 4. Percentages of typologies of judgment in the autistic group of Experiment 2 (kinds of judgment statistically more frequent than expected by chance in **bold**).

					Judgment by autistics			
Prob N°	Eyes	Eye contact	Temp. cont.	Phys. cont.	Chance	Phys. Causal.	Priv. Psych.	Com. Psych.
1	+	-	+	+	/	9	19	**72**
2	+	-	-	-	/	22	6	**72**
3	+	+	+	+	/	6	13	**81**
4	+	+	-	-	/	16	16	**68**
5	-		+	+	59	41	0	0
6	-		-	-	44	56	0	0

A series of bi-nomial tests (with an a priori probability of ½) reveals what follows for the animations involving objects (animations number 5 and 6), the only animations having normative correct judgments according to the literature. As regards the event in problem 6 (no physical contact, no temporal contiguity), the normative correct judgment is *chance*. As expected, children in the control group were more accurate with this problem than children in the autistic group (Mann-Whitney test: z= 1.86, tied p=<.05). Children in the control group judged the event in problem 6 as an instance of chance, whereas autistic children were divided between judgments of physical causality and chance, and there was no a difference statistically significant between the frequencies in the production of the two sorts of judgment (Wilcoxon test: z=1, tied p= .25). The event in problem 5 (physical contact and temporal contiguity) is prototypic of physical causality; the normative correct judgment is *physical causality*. Again, as expected, children in the control group were more accurate with this problem than children in the autistic group (Mann-Whitney test: z= 3.2, tied p=<.002). Children in the control group judged the event as physical causality. Autistic children, instead, divided themselves between judgments of chance and physical causality, and there was no a difference statistically significant between the frequencies in the production of the two typologies of judgment (Wilcoxon test: z=.71, tied p= .36).

Table 5. Percentages of typologies of judgment in the control group of Experiment 2 (kinds of judgment statistically more frequent than expected by chance in **bold**).

					Judgment by controls			
Prob N°	Eyes	Eye contact	Temp. cont.	Phys. cont.	Chance	Phys. Causal.	Priv. Psych.	Com. Psych.
1	+	-	+	+	/	3	**53**	44
2	+	-	-	-	/	19	9	**72**
3	+	+	+	+	/	0	**47**	53
4	+	+	-	-	/	19	6	**75**
5	-		+	+	6	**94**	0	0
6	-		-	-	**81**	19	0	0

As regards the animations involving agents (animations with eyes, i.e., number 1 to 4), a series of bi-nomial test (with an *a priori* probability of ¼ for judgments of physical causality and private psychological causality, and an *a priori* probability of ½ for judgments of communicative psychological causality) reveals what follows. Autistic children interpreted all the animations as instances of communicative psychological causality, whereas children in the control group did not. This result is new in the literature; it implies that autistic children, as compared to children in the control group, overrated causal interactions as communicative. In particular, this result holds for 'pure' autistic children, as well as for children with a pervasive disease of the development non otherwise specified, and children with Asperger syndrome (a mean of 2.9 and 2.8 judgments of communicative psychological causality, respectively). Children in the control group were sensitive to the interrelations of the variables temporal contiguity and physical contact. Only in absence of physical contact and temporal contiguity (see problems 2 and 4), children in the control group judged the event as an instance of communicative psychological causality. On the contrary, in case of physical contact and temporal contiguity (see problems 1 and 3), they judged the event as an instance of private psychological causality. These results reveal a pattern which is contrary with respect to that revealed by adults' results in Experiment 1. We have some tentative explanations (see the General Discussion).

The global results of the experiment confirmed the predictions deriving from our assumptions. First, differences in performance between the autistic children and the non autistic children were traceable in both causal domains. Most important, the autistic population was poor in physical causality understanding. Second, in the case of agents, with physical contact and temporal contiguity autistic children envisaged communicative intentions more than children in the control group did.

General Discussion

In our investigation we looked for possible factors that might interact in producing causality judgments in the physical and in the psychological domains. The focus of our investigation were launching events. The results of Experiment 1 confirmed our predictions: some features of the perceptual stimulus influence judgments of causality in both the physical and the psychological domain. In particular, physical contact and absence of temporal contiguity are essential to distinguish between chance events and physical causality among objects, and between private psychological causality and communicative psychological causality among agents. These results are not easily reconcilable with those of Woodward, Phillips and Spelke (1993). Their children had not specific expectation of contact with human agents. More in general, the authors purported that infants may have a separate set of principles to guide their reasoning about human action. In our view, it is possible that previous studies like the one by the authors failed to find similarities between judgments of physical and psychological causality because they focused on the role of single variables rather than on their interactions in producing causality judgments in the two domains.

Also the results of Experiment 2 confirmed our expectations: in the physical domain autistic children were poorer than controls in understanding physical causality. More in general, differences in performance between the autistic and the normal children were traceable in both causal domains.

The results of our experiments, along with those in the literature, let us envisage several ways to further investigate into causality understanding. First, both experiments suggest that the interrelation between physical contact and temporal contiguity is relevant to understanding causality in both the physical and the psychological domain. Nevertheless, in Experiment 1 the presence of physical contact and temporal contiguity lead to judgments of communicative psychological causality, whereas in Experiment 2 judgments of communicative psychological causality were produced in absence of those two variables. There are at least two possible explanations. One is the difference in the experimental procedures used in the two experiments, the other is the different age of the participants in the two experiments. A replication of Experiment 2 on subjects older than 7 years could discriminate between the two possibilities. Second, since the participants in our experiments had to provide simple Yes/No answers to questions about whether agents/objects were involved in the animations, and whether they moved dependently/independently, future studies should investigate how subjects spontaneously interpret similar situations. Finally, although in Experiment 2 neither autistics nor controls were affected by the variable eye contact, autistics seem to have noticed the presence of the eyes in the animations and to have taken this kind of stimuli as a cue of a communicative interaction. This results contrast with those in the literature (see, e.g., Klin, 2000; Klin & Volkmar, 1995, 1997). A possible explanation relies in the experimental material we used; we used simplified stimuli characterized by oversized eyes, but lacking other elements that constitute the human face: the nose, the mouth, the ears, etc. Also, such simplified stimuli are presented in dyadic, rather than complex, social interactions. Our simplified stimuli might have resulted in a more salient presence of the eyes for autistic children. It would be interesting to verify whether a specific training using such a stimuli could improve autistics' sensitivity to psychological interpretations in more complex and realistic communicative situations.

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