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Perception and conceptualization of intentionality in children

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In the present study, comprising four experiments, we evaluated the development of the child's ability to theorize about intentionality. Children (N = 176) and adults (N = 28) were shown short films about two small moving geometrical forms. The stimuli were replications of those created by Michotte (1946) and Kanizsa & Vicario (1969). The participants' descriptions and explanations were examined. The causes of movement were divided into two categories: causality and intentionality. Our prediction was that the distinction between these two categories would be mastered at an early age, but only at a much later age would participants theorize about them. Results show three stages to this development.

Research on the development of the concept of intentionality in the child ('theory of mind') has generated many publications over the last 10 years (Astington, Olson & Harris, 1988; Baron-Cohen, 1995; Butterworth, Harris, Leslie & Wellman, 1991; Feldman, 1992; Frye & Moore, 1991; Leslie, 1994; Wellman, 1990; Wimmer & Perner, 1983). Broadly speaking, this line of research has brought to the fore children's precocious ability to attribute mental states to other people: at around the age of 3, the child knows that other people think, that they have ideas and beliefs, but they assume that these thoughts are the same as their own. Between the age of 4 to 5, however, a qualitative change takes place such that children are able to attribute to others mental states different from their own.

The experiments in theory-of-mind (TOM) research have mainly consisted of verbal presentations. Children are told stories about people, and must react by making a prediction about one of the protagonist's next actions or thoughts. The experiments have also been restricted for the most part to the investigation of preschool children. Studies, however, on the attribution of second-order beliefs (Miller, Kessel & Flavell, 1970; Perner & Wimmer, 1985; Schwanenflugel, Fabricius & Alexander, 1994; Sullivan, Zaitchnik & Tager-Flusberg, 1994) and our previous research on perception and intentionality attribution (Thommen, 1991, 1992) have not been so restricted. This research has shown that the child's theory of mind builds up progressively; the development of a 'TOM' continues well past the age of 7.

In the present study, we set out to contribute to understanding the child's theory of mind using a very different approach. Children were asked to describe simple movements

* Requests for reprints.

of geometrical forms, and we used various movement parameters to simulate either intentional or physical interaction. Previous research using simple moving geometrical figures has shown that physical causality can be simulated by temporally and spatially related movements (Michotte, 1946) while intentional relations can be simulated by self-propelled movements (Dasser, Ulbaek & Premack, 1989; Heider & Simmel, 1944; Kanizsa & Vicario, 1969). Our stimuli are replications of those created by Michotte (1946) and those slightly modified (to simulate intentional reactions) by Kanizsa & Vicario (1969). These authors argued that all participants responded in a similar manner, and compared the stimuli to the 'good forms' of Gestalt theory.

The perception of causal interaction has also been studied in children by Olum (1958) and by Piaget & Lambercier (1958). Young children (6 to 8 years old) were compared with adults and were found to differ in two ways; they produce less uniform descriptions, and they perceive causal relations only when they report a contact between the figures (whether the contact has really taken place or not).

On a more theoretical level, there is currently much debate about the nature of the ability to attribute 'mind' to others (Carruthers & Smith, 1996; Feldman, 1992; Gopnik & Wellman, 1994). There are many positions that researchers have used to explain what this unique ability involves, ranging from radical simulationism (Gordon, 1996) to simulation–theory mix (Perner, 1996). In the interest of simplification, we adopt the approach of Carruthers (1996) and distinguish two positions: the *theory-theorists* (Wellman, 1990) who assume that we employ some theory of the psychological to make judgments about the psychological states of others which will allow the prediction of their future behaviour; and the *simulationists* (Goldman, 1989; Harris, 1989) who argue that we possess no such theory but simulate other's minds, by projecting ourselves imaginatively into their perspective.

In our research, when we ask the participants to describe what they see — even if the situation is very simple — we call on a complex reasoning activity. The ability to transcribe perception into a verbal form in order to communicate it to the experimenter is underpinned by a reasoning activity: the ability to theorize about mind and causality. This reasoning activity seems nearer to the theory-theory approach than to the simulation approach. Gopnik & Wellman (1994) define theoretical constructs as follows: 'Theoretical constructs are designed to explain (not merely type and generalise) those empirical phenomena. So, one characteristic of theories is their abstractness. Theories postulate abstract entities and laws that explain the data but are phrased in a different vocabulary than the data themselves' (p. 260). A theory must then enable the individual to formulate the underlying principles of certain observed phenomena. The theory's explanatory power will grow as it takes more and more relationships between observed events into account.

The Piagetian position (Piaget & Inhelder, 1966) is that the ability to theorize changes with age. In common with this position we speak of theorizing abilities and not only of theories. The changes can be followed over time, and finally lead to becoming part of the adult folk psychology.

We assume that a first step in the building of a theory takes place when the child can report in a differentiated way events perceived as different. The theory will get more elaborate as the child becomes more and more able to infer relations and to formulate explanatory hypotheses about observed events. It is important then to delineate the important characteristics of intentional beings:

1. They are agents, and are therefore capable of autonomous movement (they are 'self-propelled objects'; Premack, 1990).
2. They have internal states such as mental states and emotions that are sometimes invoked by the observer to justify autonomous movements.
3. They can act on others through speech acts, i.e. without any material means.
4. They have mental states that are concerned with the mental states of others.

In this study, the simple perceptual event presented to participants can be considered on each of the four levels described above: it is possible to watch the event as the mere movement of geometrical figures; or one could attribute to the figures a motive that triggered the action; the action of a figure could be described as a consequence of the action of the other/response to the speech act of the other; or finally, one could explain the actions of a figure by an attribution of thinking about another figure's thinking.

Our prediction is that perception of the difference between the stimuli will be mastered at an early age, but that theorizing about these differences will be found only at a much later age. Our hypothesis is that the capacity to attribute intentionality is not sufficient to provide young children with a theory strong enough to allow them to conceptually differentiate these situations. We believe that the way that children differentiate the situations will change with age. Testing this should give us some information about how children build theories in general, and a theory of mind in particular.

Four experiments were performed in order to examine children's perception and theorizing of physical and psychological causation. In Expt 1, the participants' spontaneous descriptions were recorded and analysed. This procedure allowed us to distinguish categories of participants according to the way they described and discriminated the stimuli. Experiment 2 was used to validate the first experiment, and the participants were questioned according to the Piagetian method. Experiment 3 examined young children's ability to perceive the difference between the two kinds of stimuli; and Expt 4 was a replication of the first experiment but younger children were used as participants.

EXPERIMENT 1

Method

Participants

Eighty participants took part in the experiment and were equally distributed among 5 age groups: 16 were in the second year of kindergarten (mean age = 5:9), 16 were in second grade (mean age = 7:11), 16 were in fourth grade (mean age = 9:10), 16 were in sixth grade (mean age = 11:10) and 16 were students of the University of Lausanne (mean age = 25). Hereafter, these five groups will be referred to as, 6-, 8-, 10-, and 12-year-olds and adults. All of the children tested were in state schools in Geneva. There were an equal number of males and females in each group.

Stimuli

Each participant was seated facing a small computer screen that displayed short animated films. The stimuli consisted of two 1 cm long squares, one black and one grey, moving horizontally across the screen. The stimuli used were replications of stimuli created by Michotte (1946) and Kanizsa & Vicario (1969).

In the first film (see Fig. 1 Launching) the black square was on the left of the screen, and the grey square was 10 cm to the right, in the middle of the screen. The black square started moving towards the grey, and

stopped the moment it touched it. The grey square then moved immediately in the same direction, travelled 10 cm and stopped on the right of the screen. The grey square moved either three or nine times more slowly than the black square did.

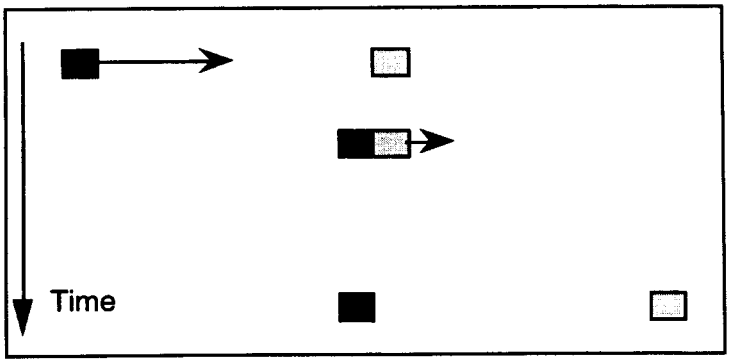

Figure 1. Sequence of a launching film (the horizontal arrows symbolize the speed of the squares).

In the second film (see Fig. 2 Reaction), the squares did not touch and the speed ratio was the reverse of that in the first film, the grey square moving either three or nine times faster than the black square. The initial display was the same as in the first film, but the grey square started moving when the black was still 1 cm away. The black continued its movement until it was 5 mm from the grey square's initial position, while the grey travelled 10 cm, as in the 'launching' film:

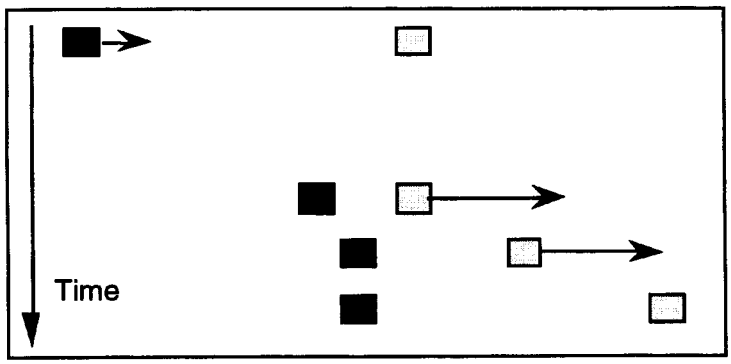

Figure 2. Sequence of a reaction film (the horizontal arrows symbolize the speed of the squares).

The absolute speed of the stimuli varied: half the participants watched 'slow' stimuli (from 4 cm/s to 36 cm/s), and the other half watched stimuli that went twice as fast (from 8 cm/s to 72 cm/s).

Procedure and experimental design

Each participant saw 12 films. Four practice films were shown to begin with, starting either with a 'launching' or a 'reaction' (practice stimuli). After the practice films, eight other films were shown (experimental stimuli). These were composed of two launchings and two reactions. Each film was shown twice, in one of four random orders. The order of presentation, the absolute speed of the stimuli and the

sex of the participant were counterbalanced across each of the five age groups. The sex of the experimenter and the film type of the first film shown were also counterbalanced.

Instructions

The purpose of the practice films was to make the participants familiar with the stimuli and to instruct them in the kind of responses that were expected. The experimenters followed a clinical interviewing technique, adapting their questions to the participants' answers, in order to make sure that participants saw the stimuli correctly. First, they made sure that the two figures involved were correctly perceived and distinguished. Second, they asked participants about the differences between the two films. Third, they asked them to give a reason for the grey square's movement. This last question was omitted only in the case of five of the older participants who gave spontaneous explanations. During the presentation of the experimental stimuli, the experimenter refrained from any comment, except to encourage the participant to describe what he or she saw.

The excerpt[1] in Table 1 was taken from the dialogue between the experimenter and an 8-year-old girl (Kar, 7:10).

The participants' utterances were recorded, and an unabridged version transcribed on a computer database (EXCEL), so that a content analysis could be performed.

Results

The participants' discrimination capacities and the kind of criteria used by them were analysed.

Discrimination between the two kinds of film

In order to evaluate the participants' discrimination capacities, two raters classified each of their responses in one of three categories: launching, reaction and undifferentiated. The rates' task was to decide which film was described by the participant (only in 3 per cent of the cases were the two raters in complete disagreement, one classifying the description as a launching and the other as a reaction; 8 per cent of the cases were classified as undifferentiated by only one of the raters). There was a 90 per cent inter-rater agreement, and 80 per cent of the responses corresponded to the film that the participant actually saw.

Generally speaking, we may therefore conclude that the films were perceived as expected. In order to evaluate the development of this ability with age, each participant was assigned a score between 0 and 8, corresponding to the number of film descriptions that were correct. An ANOVA was computed using these scores and there was a significant difference with age ($F(4,75) = 4.175, p < .005$). A *post hoc* analysis was then performed, showing that 6-year-olds' results ($M = 5.3$; SD = 2.4) were significantly worse than those of both the 8-year-olds ($M = 7$; SD = 1.4) and the adults ($M = 7.6$; SD = 0.7). The 6-year-olds also scored lower than the 10-year-olds ($M = 5.8$; SD = 1.9) and 12-year-olds ($M = 6.1$; SD = 2.3) but the difference was not significant.

These results show that, although adults describe the films as expected, this is not always the case as far as 6-year-olds are concerned. Young children of this age show some inconsistency in their ability to describe perceptual events of this kind accurately.

[1] Our study was conducted in French. For the example, we give the French discourse with an English translation of ours. Of course, we do not know what an English speaker would actually say.

Table 1. Dialogue excerpt

Practice phase	
On va te montrer plusieurs petit films, tu verras, ils sont très courts. Puis on te demandera juste de nous dire ce qui se passe à ton avis dans le film. Alors je vais te montrer le premier film. Tu regardes bien puis tu me diras ce que tu as vu. (Réaction). Alors tu as vu? qu'est-ce qu'il s'est passé?	We are going to show you several little films. As you will see they are very short. Then we shall ask you to tell us what you think happens in the film. I'm now going to show you the first film. Just watch it and tell me what you see. (Reaction). You saw it? What happened?
y'avait des petits carrés, y'avait un là pi un là, pi après i sont allés de ce côté.	*There were little squares, one there, one there, then they went that way.*
Oui c'est bien et puis c'était comment?	That's right, and then how did it go?
i s'arrêtaient un p'tit moment après i r'allaient, pi après i sont parti de ce côté.	*They stopped a while, then they moved again, then they went that way.*
d'accord, je te montre le deuxième.	Ok, I'll show you the second.
(Lancement) *Là i'en avait un ici pi un autre ici. Pi celui-là il est allé taper contre celui-là, pi après ils sont allés ici.* [. . .]	(Launching) *There was one here, and another one here. Then this one there went and bumped against this one there, then they went here.* [. . .]
(Réaction) *Là y'en avait un ici, pi l'autre ici pi quand celui-là il voulait aller là, l'autre il est allé là-bas.*	(Reaction) *There was one here and one there, and when this one wanted to go there, the other one went down there.*
ah d'accord! Pourquoi il est allé là-bas l'autre? Qu'est-ce qu'on pourrait dire?	I see. Why did he/it[2] go down there, the other one? What shall we say?
(hésite, 5 secondes) *ben, qu'il avait peur de lui.*	*well, he/it was afraid of him/it.*
D'accord. Je te montre le suivant	Ok, here's the next film.
Experimental phase	
(Réaction) [. . .] *pis après il a voulu le toucher, mais il l'a pas touché, parce que . . . ç'ui qu'avait les p'tits points il allait là-bas au fond*	(Reaction) [. . .] *then afterwards he/it wanted to touch him/it, but he/it didn't touch him/it because the one with little spots goes over there*
Oui, bien nous regardons le suivant.	Yes, O.K. We'll look at the next one
(Lancement) *pis après il l'a touché, pis l'autre il a encore avancé un petit peu.*	(Launching) *then after he/it touched him/it then the other one he/it went forwards a little bit.*
Ok, très bien.	Ok, very good.

The criteria of differentiation of the stimuli

Qualitative analysis of data. In order to understand the age-dependent differences more thoroughly, we performed a qualitative analysis of the differentiating criteria used by the participants. The qualitative analysis was carried out using a step-by-step method in a completely explicit manner.[3] The method itself is a development of Gardin's discourse analysis (1974, 1981) and of Gillièron's morphological analyses (1985). The participants'

[2] In French, the pronoun 'il' does not specify whether it is a 'he' or an 'it'.
[3] Details of the step-by-step analysis may be obtained by writing to the authors.

responses were divided into utterances comprising a predicate for each action of either the black or the grey square, using the criteria of Ghiglione, Matalon & Bacri (1985).

As a first step, the utterances were classified according to the following qualitative variables: the semantic category of the predicate (movement, to touch, to be afraid, to pursue, to try to touch); the figure that carries out the action; whether an explicit attribution of causality or intentionality is made or not; and the kind of conjunction that may relate one utterance to another. The categorization of the utterances in the variables of the first step was validated by an inter-rater agreement of over 90 per cent.

In the second step, we defined two typologies of the participants' utterances, grouping different patterns of variables according to the contrast between present and absent patterns. A first typology captures the semantic aspects of the utterances (see examples below). The second gives an inference about the stimuli described by the utterance.

In the third step, from these typologies we took note of each participant's differentiation criteria (characteristic descriptions) for one type of film or the other (launching or reaction). A differentiation criterion is an accurate and specific description, applied to one type of film only. For example, if the participant describes correctly one or more launchings by mentioning a contact between the two figures, this description is a differentiation criterion for launchings; but if, in addition, they mention a contact in a reaction film, contact is no longer considered as a differentiation criterion for launchings. A participant can describe one type of film using more than one differentiation criterion. These five differentiation criteria (corresponding to the typology of descriptions) are presented below, from the least to the most complex. All of the criteria, except for the first, imply the presence of an inference on the part of the participant because he or she reports some non-visible features of the event.

(1) The *contact criterion* is the least elaborate. The participant merely mentions the presence or absence of contact, without making any inferences. They may only talk about the action of the black square, describing it as 'pushing' the grey square, e.g. 'the black one pushes the grey' or 'the black square didn't touch the grey'.

(2) The relation between the figures is described in terms of *weak intentionality*, e.g. 'the black one tries to touch the grey'. Attribution of intentionality such as desire, motivation, or a description of movement in terms usually employed only to describe movements of living beings, show a first degree of inference. The participant grants meaning to non-visible features of the event. Most of the participants do use descriptions containing weak intentionality although they often do not function as a differentiation criterion, because the same description is used for both types of film.

(3) The relation between the figures is described in terms of *relative speed*, e.g. 'the black square goes faster than the grey'. This description indicates an analysis of the whole situation. The comparison shows that reasoning activity about the event is on the level of the physical, observable features of the event.

(4) *Strong intentionality* attribution is the sign of a passage to a complex theorization capacity, where the movements of the two figures are linked and a psychological explanation about their space–time relation is inferred, e.g. 'the grey square runs away from the black one' or 'the grey square is scared of the black one'. The participant attributes not only simple internal states to the figures but describes also the psychological relation between the two figures. Both figures are considered as intentional beings explicitly or implicitly (in the case where the action or mental state mentioned for one

figure implies that the other figure must be an intentional being in the context of the stimuli). In addition, the action (or internal state) of one figure is motivated by the existence of the other figure.

(5) Finally, *physical criteria* imply the capacity of inferring an invisible physical cause to explain the observed movements. An example is to explain the reaction film in terms of the interaction between two magnets. Such an explanation means the participant can produce a complex inference. The relation between figures is described explicitly in *physical* terms, e.g. 'a magnet repels another magnet'.

We chose to arrange these five criteria in a linear order (one-dimensional hierarchy).

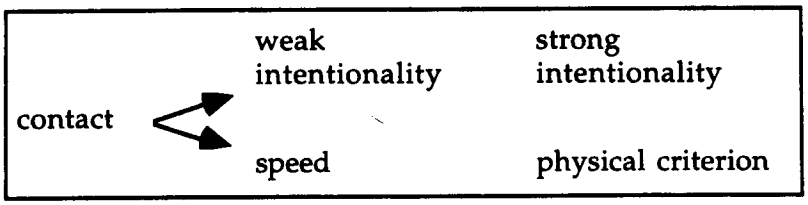

Figure 3. The hierarchy of criteria in the proper semi-order. *Note.* One branch concerns living beings, the other physical objects. The contact criterion can be used indifferently for living beings and for physical objects.

This way of presenting a semi-order is of course questionable (see Fig. 3), but we used it to allow us to define a quantitative score. We considered the first level of physical explanation (level 3: speed) as slightly higher than the first level of intentionality (level 2: weak intentionality), and the second level of physical explanation as slightly higher than the second level of intentionality (level 4: strong intentionality). The reason for considering physical explanation as superior to psychological explanation is that the attribution of intentionality is far more frequent and precocious. The attribution of causality seems to be a little less immediate and can therefore be considered at a slightly higher level. Table 2 gives some examples of the protocols for each level.

As children generally used more than one criterion, we first computed a score of differentiation which takes into account all the criteria. For each category of film, we counted the number of each sort of criterion used by the participant. We then calculated a 'theorizing score' for each category of film. This was achieved by multiplying the level of each criterion by the number of times it was used, and summing up these values. For example, if a participant used the speed criterion for a launching twice and the strong intentionality criterion for a reaction once, he or she received a score of 10 ((2 × 3) + (1 × 4)).

Results of the analysis. The counterbalanced variables of our design (order of the practice stimuli and experimental stimuli, absolute speed of the figures, sex of the participant and of the experimenter) had no significant influence on the results obtained on the differentiation score. The different groups were therefore combined for further analysis.

Results show a significant difference between the theorizing scores achieved by each age group ($F(4,75) = 3.3, p = .01$). As in the judgment procedure, the score increases significantly between 6- and 8-year-olds and between adolescent and adult. Figure 5

Table 2. Examples of protocols for each level

	Yli: 5:8 (no criterion)	
Reaction (R)		
	alors il y en a un qui est allé comme ça	So there was one that went like this
	et après hop et hop comme ça	and after hop and hop like this
	celui qui était derrière c'était le tout noir	the one that was behind was the black one
Launching (L)		
	il y en a un (le noir) qui a poussé l'autre	there was one (the black) that pushed the other
	il est allé en avant	it/he went forwards
R	il y en a un qui a poussé l'autre	there was one that pushed the other
	pis l'autre il est allé doucement en avant	then the other one it/he went slowly forwards
	Steph: 8:1 (contact criterion)	
R	y a pas touché	it/he didn't touch
	alors l'autre il est parti, comme toujours	so the other left, as usual
L	touché!	touched!
	pis l'autre il est parti	then the other one left
R	pas touché!	didn't touch!
L	touché!	touched!
R	pas touché!	didn't touch!
	l'autre il est parti	the other one, he left
	Walt: 12:0 (speed criterion)	
L	là le noir il allait un peu plus vite	here the black went a little bit faster
	et celui avec les pointillés un peu plus doucement	and the one with the spots a little bit slower
R	là aussi, le noir il allait doucement	here too, the black went slower
	et l'autre il est parti encore vite, celui avec les pointillés	and the other one left quickly again, the one with the black spots
L	là le noir il allait vraiment très vite	here the black one was going really fast
	et il a tapé celui avec les pointillès	and he/it hit the one with the black spots
	et il allait plus doucement	and he/it was going slower
	Kar: (7:10) (Contact and weak intentionality criteria)	
R	pis après il a voulu le toucher	then afterwards he/it wanted to touch him/it
	mais il l'a pas touché	but he/it didn't touch him/it
	parce que ... ç'ui qui'avait les p'tits points il allait là-bas au fond	because the one with little spots goes over there
L	pis après il l'a touché	then after he/it touched him/it
	pis l'autre il a encore avancé un petit peu	then the other one he/it went forwards a little bit
	Val: 12:0 (strong intentionality)	
L	c'est de nouveau le noir qui a voulu la place du gris	it's again the black one that wanted the grey's place
	il l'a fait partir avec un coup de pied, ou comme ça	he/it made him leave with a kick or something like that
	ben le gris il était obligé de partir	well the grey had to move
R	ben le gris dès qu'il a vu	well the grey one as soon as he/it saw
	approcher le noir	the black come near
	il est vite parti ...	he/it left quickly
	pour pas faire recevoir un coup de pied ou une gifle	so as not to get a kick or a slap

Table 2. *continued*

	Mir: 20 (physical)	
R	c'est-à-dire que ... le carré noir, enfin	that is to say that the black one, well
	s'approche du pointillé	approaches the spotted one
	qui ... qui lui heu (le gris) se retire	that ... that (the grey) leaves
	donc toujours un effect de répulsion	so again this repulsion effect
L	ben toujours heu ... cet effet d'impact,	well again this impact effect
	le premier qui pousse le deuxième	the first that pushes the second

represents this development graphically, with the participants of Expts 1, 2 and 4 combined.

This analysis does not taken into account the utterances about the four practice films. During the practice phase, the experimenter could interact more freely with the participants. Yet the results are similar to those of the eight experimental films. At 6 years of age, more than half of the children answered in such a way that it was impossible to know whether they saw a launching or a reaction. Children gave the same reasons for the grey square's movement (for example: 'he's afraid' or 'he's running away') no matter what kind of film was shown. These results thus confirm those of the experimental phase. They show that although young children will readily attribute intentionality to the figures, their explanations do not help them to point out the differences between the two types of films shown to them. The child's capacity to theorize clearly continues to grow after the age of 6. Experiment 2 tests the validity of these results by applying the same qualitative method to a different set of participants.

EXPERIMENT 2

Method

Participants

Sixty participants took part in the experiment, equally distributed among five age groups: 12 were in kindergarten (mean age = 5:5), 12 were in second grade (mean age = 8:0), 12 were in fourth grade (mean age = 9:9), 12 were in sixth grade (mean age = 12:2) and 12 were adults (academics from Lausanne and the surrounding area, working in various fields such as mathematics, literature, philosophy, theology; mean age = 35). The children questioned were all in Geneva public schools. The number of males and females was equal in each group.

Experimental design and procedure

The stimuli were identical to those used in Expt 1. The order of the experimental stimuli (three random orders), the absolute speed of the figures (slow or fast) and the sex of the participant were counterbalanced in a factorial design. The practice films, alternately a launching and a reaction, were always presented in the same order. All the participants were questioned by a female experimenter.

The procedure differed from the previous one only in the fact that, during the experimental phase, the experimenter had a much more active role and asked the participants to explain why the figures acted or moved in the way described.

Results

The data were analysed in exactly the same way as in Expt 1. There was no significant difference between the mean theorizing scores of the two experiments. The results were therefore combined for further analysis.

The main risk of this approach was that of an *ad hoc* construction. The fact that no differences were found between the two experiments, however, shows that the validity of our typology is not restricted to our first set of data. The automatic application of our typology to a second set of data was therefore important. This validation procedure is similar to the one used by Gardin (1981). The use of the same procedure with the new set of data did not yield any uncoded utterances (no description in the new set of data was left unanalysed using the method of the first set) and the level of each group was not significantly different. By closely adhering to the exact content of the participant's descriptions this method allowed us to show the change of content with age. Clearly stating the steps used in the creation of our typology allowed us to apply it in an objective manner to a new set of data.

In order to discuss how the ability to theorize develops with age we conducted a more simple qualitative analysis. We took into account only the highest level achieved by each participant and reduced the five levels of criteria to three: contact criterion; weak intentionality or speed criteria; strong intentionality or physical criteria. In addition, participants with no differentiation criteria were included in the first level (contact). The distribution with age clearly indicates the qualitative differences between participant groups ($\chi^2(8) = 23.2, p < .01$). Results of Expts 1 and 2 are shown in Fig. 6 combined with results of Expt 4. The contact criterion (or absence of criterion) decreases with age as strong intentionality and physical explanation increase. Older children give not only more criteria but also more sophisticated criteria. These changes explain the increase in the average theorizing score with age.

As in the previous experiment, 6-year-old children quite often gave the same kind of description whether they were shown a launching or a reaction. For example, the child might say 'the grey square was frightened' for both kinds of films. The reason why young children do not point out the differences between the different types of stimuli is, however, not clear. A simple lack of vocabulary cannot be a sufficient explanation, since young children are perfectly capable of attributing intentionality to moving figures. It is merely that they do not use these descriptions to make a distinction between different situations. Before assuming a lack of theorizing capacity on the young children's part then, it must be determined whether the young children actually perceive the stimuli correctly. Experiment 3 was devised for this purpose.

EXPERIMENT 3

There are two perceptual differences between a launching and a reaction: the contact between the figures, and the relative velocity of the figures. To make a distinction between the two kinds of films the participants could thus watch for two things: contact between the two figures, so as to recognize a launching when the two figures touch each other and a reaction when they do not; or speed differences, so as to recognize a launching when the black square moves faster and a reaction when the grey square moves faster. Two groups

of children were therefore tested. One group was asked to watch for contact, and the other for speed differences.

Method

Participants

Forty-eight children participated in this experiment, equally distributed in three age groups: 16 were in the first year of kindergarten (M = 4:7), 16 were in the second year of kindergarten (M = 5:6) and 16 were in first grade (M = 6:7). The number of boys and girls was equal in each group. The children were all interviewed in Geneva public schools.

Stimuli and experimental design

Each age group was divided into two subgroups: those in one subgroup were asked to see whether the figures touched each other, and those in the other were asked to watch for speed differences. The stimuli were the same as in Expt 1, but the design was simplified. The practice films, alternately a launching and a reaction, were always presented in the same order. In each subgroup the sex of the child and of the experimenter, the absolute speed of the figures (slow and fast) and the order of presentation of the experimental films (two random orders) were counterbalanced in a factorial design.

Procedure

Both subgroups of each age group were given different instructions: in one subgroup, children were asked to watch the stimuli to see whether the two squares touched each other or not; in the other, they were asked to watch the speed of both squares to see whether one went faster than the other. During the practice films the experimenter tried to make the child aware of the presence or absence of contact (or of speed differences between the squares), and questioned him or her actively to understand what was meant by contact (or higher speed). During the experimental phase, the experimenter refrained from any comment, except to encourage the child to say whether the squares touched or not (or whether one square went faster than the other).

Results

The number of correct responses for the eight stimuli were counted. Figure 4 shows the increase in correct responses with age for the different subgroups. This development was evaluated using the Kruskal–Wallis test. Results show no increase with age for the contact subgroup. This is in contrast to the speed subgroup in which older children gave significantly more correct responses than younger children ($H = 7.524, p = .0186$).

These results show that even young children can distinguish between the two kinds of films by pointing out the contact or absence of contact between the figures. Consequently, the fact that they seldom use this difference in order to distinguish the two kinds of films indicates that they fail to see the relevance of these facts when asked to give an account of what they see. This is in contrast to the recognition of the speed difference between the two squares. Children only master this skill at around 7 years of age. Specifically, children younger than this often responded to the experimenter's questions in the practice films (which are not included in the results) by confusing going faster with going further. Young children will thus often declare that the grey square went faster because it went further on the right than the black one did. It is important to keep in mind that this was

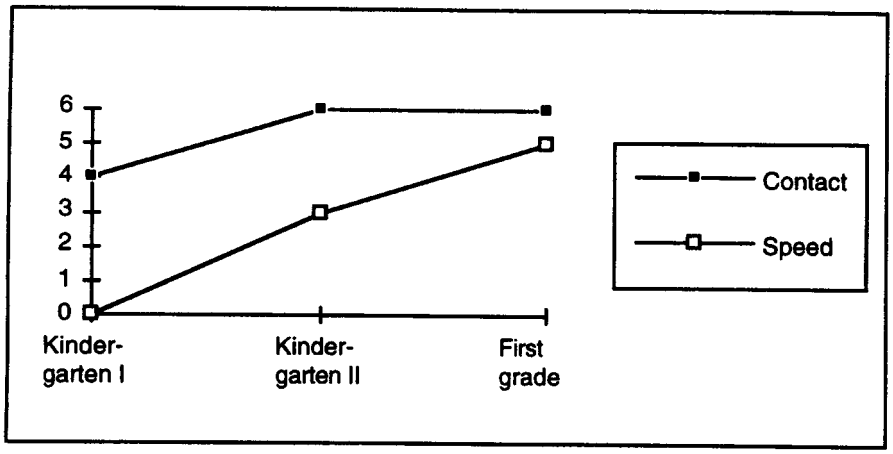

Figure 4. Number of children (N = 8 per age group and condition) who give the correct criteria for all eight films.

in response to a question about relative and not absolute speed. That is, the children had to take into account the speed of both squares in order to give a correct answer, and this is just the kind of integrated view that young children lack. The results of Expt 3 show that even very young children are capable of seeing the difference between the two kinds of films shown to them. It was therefore important to repeat our Expt 1 using younger children as participants. Experiment 4 was carried out for this reason.

EXPERIMENT 4

Method

Participants

Sixteen children took part in this experiment, equally distributed between two age groups: eight children were in the first year of kindergarten (M = 4:8) and eight were in first grade (M = 6:7). The number of boys and girls was equal in each group. The children questioned were all in Geneva public schools.

Procedure

The stimuli and the procedure were the same as in Expt 1, and the design was the same as in Expt 3.

Results

Half of the 5-year-olds gave no differentiation criterion at all and two children gave a contact criterion for only one type of film. Although the children of this age group responded in a less elaborate way than the 7-year-olds did, the difference was not significant.

Combined results of Expts 1, 2 and 4

When all of the participant groups of Expts 1, 2 and 4 were combined and the results analysed together, a significant development with age ($F(6,149) = 9.97$, $p < .0001$) emerged. Figure 5 shows the general trend of this development for the score of differentiation.

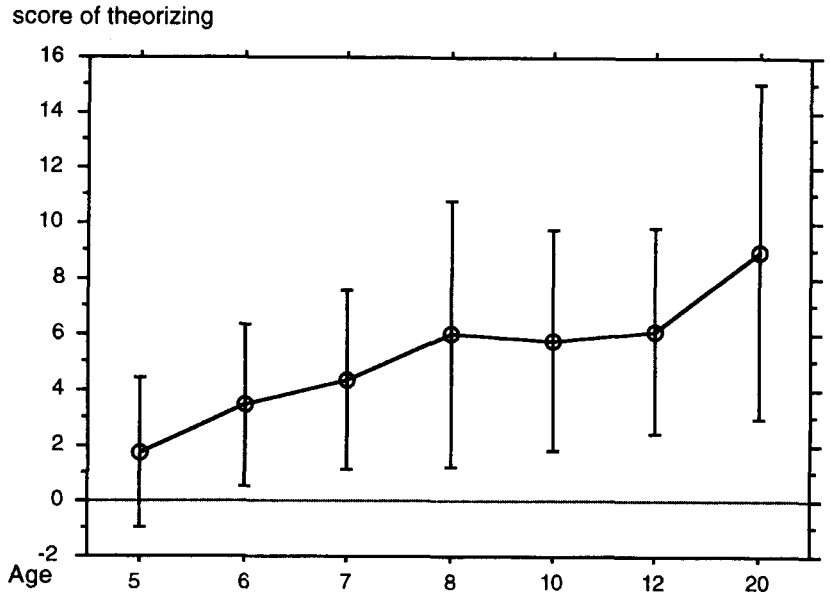

Figure 5. Mean and standard deviation for the score of theorizing by age (the participants of Expts 1, 2 and 4 pooled together).

Figure 6 shows the percentage of participants of each age, using each level, and classified according to the highest level used ($\chi^2(12) = 31.3$, $p < .001$). The most important difference between 5-year-olds and older children is that 5-year-olds are not capable of giving explicit criteria in order to distinguish the two kinds of films. Six-year-old children, however, do regularly attribute intentionality to moving figures. This is a finding that is consistent with previous results (Dasser, Ulbaek & Premack, 1989; Thommen, 1992). On the other hand, they attribute the same intentionality to different movements of the figures. It is between the ages of 6 and 8 years of age that children become capable of correctly using a differentiation criterion. The criterion most frequently used is that of presence or absence of contact; the simplest and most superficial criteria supposing no theoretical explanation.

At 10 years of age half of the children used the most sophisticated criteria, explaining events either by intentional or by physical explanations. At this age, children are capable of attributing intentionality to describe the differences between the different stimuli shown to them. Twelve-year-olds are similar to 10-year-olds, and several participants used the speed ratio criterion. Adults use the most sophisticated criteria and, unlike the children, five of them used the physical criterion to describe reaction films.

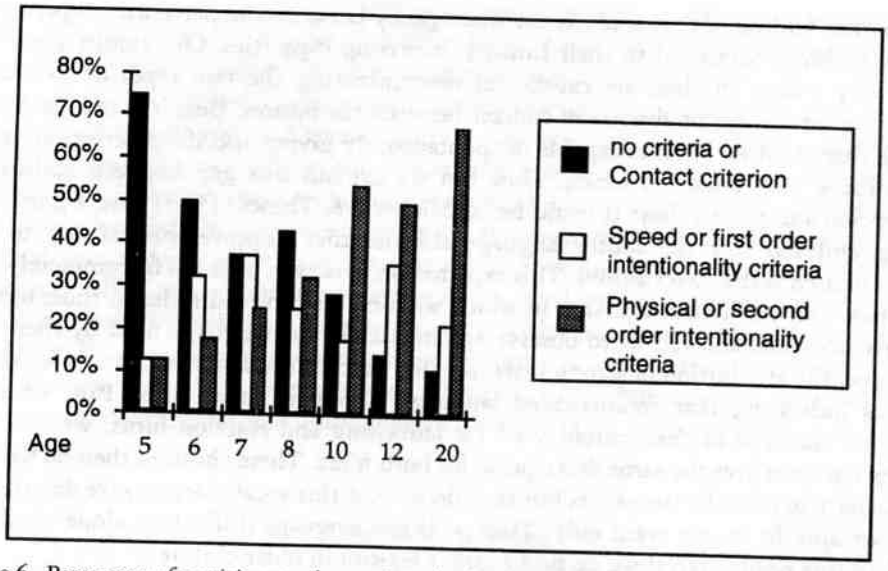

Figure 6. Percentage of participants who attain each criterion level by age (the participants of Expts 1, 2 and 4 pooled together).

GENERAL DISCUSSION

The purpose of this study was to examine the development of children's capacity to theorize, as indicated by their descriptions of short animated films. We distinguish three stages: a first stage in which participants are incapable of spontaneously identifying differences between the two kinds of films, although they are able to identify them using the contact criterion *when prompted by the experimenter*; a second stage in which individuals use superficial clues such as presence or absence of contact in order to describe the differences in the stimuli shown to them; and a third and most sophisticated stage, in which people give complex descriptions of the stimuli, distinguishing between physical and psychological relationships by referring to *hidden* causes or beliefs.

A second finding concerns the perception of causality. The two forms of stimuli used in this study differed perceptually in two ways: the relative speed of the figures and the contact between the figures. Michotte (1946) and Kanizsa & Vicario (1969) argue that such differences are sufficient to create very different perceptions, of physical causality on the one hand and of intentional causality on the other hand. Our results show that, for each type of film, the participants gave more than one explanation belonging either to one or the other kind of causality. We cannot say that only one type of interpretative description can be given for the launching or for the reaction. Young children can spontaneously describe launchings by attributing psychological states to the figures, and adults sometimes describe reactions in terms of physical causality. Although these findings do not support the view of the perfect uniformity of perceptual structures held by Michotte and Kanizsa & Vicario, there is a certain uniformity of descriptions in a given model of attribution. For example, when a reaction is described in psychological terms, flight is almost always mentioned, and when it is described in physical terms, magnets are usually mentioned.

Another finding of this study is the discrepancy between the perceptual capacities of young children compared to their limited theorizing capacities. Our results show that even very young children are capable of discriminating the two types of stimuli by watching for contact or absence of contact between the figures. But, it is only at 7 years of age that children become capable of spontaneously giving specific descriptions of the films using the contact criterion. How can we explain this gap between abilities in perception and description? It could be, as Michotte & Thinès (1963) have argued, that young children lack the subtle language abilities that improve their ability to give differentiated verbal descriptions. This explanation, however, does not fit completely with our data. Our qualitative analysis, in which we used terms very similar to those used by our participants, allowed us to observe systematically the language used by them. For example, the attribution of strong intentionality reaches the same percentage for all age groups indicating that sophisticated language is present at all ages. But, when we compare the type of descriptions used for launching and reaction films, we note that young children give the same description for both films. These children then do have the vocabulary to describe the events but they do not use this vocabulary to give descriptions that are specific to one event only. Thus, it is not language difficulties alone which can explain this result even if we do find a larger lexicon in older children.

A second possibility is that the experimenter may interact in a different manner with younger children or use dialogue that can aid older children only. This is unlikely, however, as two experimenters interacted with the participants. One experimenter may have been a little more suggestive than the other but an ANOVA analysis showed no experimenter effects, nor any interaction between experimenter and participant age.

The third possibility, and the explanation that we subscribe to, argues that the production of differentiated descriptions involves the ability to transcribe perception to language. In the introduction to this paper we explained that the participants' task is to transcribe perception in a verbal form in order to communicate it to the experimenter. This activity is, relatively speaking, similar to the one of scientists communicating their observations to other people. The reports that they give will be related to the theories that are currently available to them. For the children in our study, the report that they give will depend to the same extent on the theories available to them, but in addition this transcription is also highly dependent on general operational abilities (Piaget, 1948).

When children become able to use spontaneously a simple differentiation criterion like contact, they demonstrate the development of a general ability to theorize. This is the point in development that corresponds to Piaget's concrete-operational thinking' which is reached by children at 7 years of age. Moreover, we have found more subtle differences in the descriptions given by children of 7 years of age compared to older children and adults. The description of 'hidden causes' can appear at 8 but is observed more often at 10 years of age. The contrast between children's capacities of perception and of attribution, and the fact that they do not use these capacities to give a differentiated account of various situations, show that the theorizing capacities of children under age 10 are still quite limited.

Finally, our results provide new evidence to contribute to the discussion about theory of mind. In accordance with the classical data about TOM, young children in our study attribute mental states to the figures in the film ('he tries to'). They recognize our stimuli as simulated actions of intentional beings. On the other hand, our results also indicate

that their TOM as a theory is not fully developed. Younger children cannot use their TOM to describe their observations in a differentiated way. Our results then support the argument for the development of second-order theories of mind (Miller *et al.*, 1970).

To conclude, we consider that the ability to describe and explain what we see is largely dependent on our general and specific theorization abilities. General abilities make it possible to transcribe perception into words, and specific theorization abilities such as knowledge of causality and psychology provide children with concepts necessary to understand what they see. Our methodological approach, through the role performed by the participant's theorization capacities (in attributing meaning to the films shown to that person), offers new arguments in favour of the development of theories of mind. Our findings support the view that it is progressively, with age, that the capacity develops to link objects that are distant in space and time in order to explain their movements. And our data show two vital developmental changes: from differentiated perception to differentiated description; and from superficial description to psychological or causal explanation.

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