

MOTION BRAKING AND THE PERCEPTION OF CAUSALITY*

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SUMMARY

The aim of this research was to find out whether it would be possible to produce specific, genuine, causal impressions of motion braking, in the visual field, which could compare with causal impressions of pushing, launching, tracing a.s.o. as described by Michotte, in his work «La perception de la causalité».

For this, we tried to determine the simplest conditions of stimulation which induced observers to mention in their responses a causal influence of braking.

The experiments consisted mainly in suddenly slowing down the movement of an object moving along a slit. This was taking place either without any accessory background structure, or at the moment the object was reaching a different coloured part of the background, or again when it had reached another, stationary, object over which it passed.

It was in this latter case that causal responses were most frequent, whilst they were sporadic in the former. The passing of the object over a different part of the background proved to be completely ineffective, under various time conditions, since the results were of the same order when the colour of the background was uniform. On the contrary, passing over another object was more efficient, especially when the duration of the slowmovement was limited to the superposition period of the two objects.

Changes in the stimulation system thus exerted a considerable influence on the *frequency* of the causal responses, but on the other hand had none on their *content*.

The analyses of their content clearly showed that the braking in-

* Cette contribution est publiée ici pour la première fois.

fluence was not perceived, but inferred from the perceptual data, permitting «understanding» on the basis of acquired knowledge.

The main interest of our research seems therefore to be that it established the possibility of using an objective criterion justifying the distinction between responses corresponding to specific impressions of causation and responses corresponding to inferences. In the first case alterations of the stimulus system brings about parallel changes in the content of the responses, whereas in the latter the responses remain practically unchanged; only their frequency varies.

RÉSUMÉ

Le but de ces recherches était de tâcher de provoquer chez des observateurs des impressions visuelles de freinage d'un mouvement, présentant un caractère originel et spécifique comme celles du lancement, etc., décrites par Michotte.

A cet effet on a tenté de déterminer les conditions de stimulation les plus simples qui amenaient les sujets à mentionner dans leurs réponses une influence causale de freinage au cours des expériences auxquelles ils étaient soumis.

Ces expériences consistaient essentiellement à ralentir brusquement le mouvement d'un mobile qui se déplaçait le long d'une fente. Ceci se produisait soit en l'absence de tout accessoire, soit au moment où le mobile atteignait un niveau à partir duquel le fond devant lequel il se mouvait présentait une autre couleur, soit au moment où il atteignait un objet immobile devant lequel il passait.

C'est dans ce dernier cas que les réponses causales ont été les plus nombreuses alors que, dans les premiers, elles étaient sporadiques. La coïncidence du ralentissement avec le passage devant une autre zone du fond s'est montrée tout à fait inopérante dans diverses conditions temporelles, les résultats étant du même ordre que pour un fond uniforme. Par contre le passage devant un autre objet était beaucoup plus favorable, et cela principalement lorsque le ralentissement se limitait à la durée de superposition des objets.

Les modifications du système de stimulation ont donc exercé une influence très nette sur la *fréquence* des réponses à signification causale.

D'autre part, elles semblent n'en avoir eu aucune sur leur *contenu*. Celui-ci manifestait de façon constante que l'action de freinage n'était pas perçue, mais seulement inférée à partir des données

perceptives dont il fournissait une explication empruntée à l'expérience acquise.

L'intérêt majeur de nos recherches réside, semble-t-il, en ce qu'elles indiquent expérimentalement la possibilité d'utiliser un critère objectif pour distinguer les cas dans lesquels il y a une impression causale spécifique, de ceux dans lesquels l'influence causale est inférée.

Dans la première éventualité, les modifications que l'on fait subir au système des excitants entraîne des altérations parallèles et systématiques dans le contenu des réponses des sujets.

Dans le second cas au contraire, le contenu des réponses demeure semblable et ce n'est que leur fréquence qui varie.

In his experiments on «The perception of causality» (1, 2, 3) Michotte was able to demonstrate the existence of many kinds of perceptually given causal impressions, like pushing, kicking, throwing, tracing, erasing, etc. According to Michotte these impressions are primary ones, i.e. they should be conceived of as specific perceptual responses directly elicited by a definite system of stimuli.

Theoretically Michotte reduces them to one basic perceptual scheme called «ampliation», essentially a particular kinetic structure corresponding to a stimulus system which includes two stimulus objects moving in the same direction.

It follows that it would be impossible to induce causal impressions by stimulus conditions which don't fit in with this basic scheme. Examples of these negative cases are «braking» (causally determined slowing down of movement) (1, p. 217) or «attraction» (1,p.216). Indeed in some experiments where braking or attraction were displayed, it was found that subjects did not report causal impressions (1, pp. 99, 154). For example one could expect braking responses in some of his pushing experiments: An object A moves in the direction of a stationary object B. After reaching it, both move with equal speed, i.e. juxtaposed in the same direction of A's original movement. When the velocity of A and B after their junction is much less than A's original velocity (1, p. 156), one could have the impression that A's speed is braked by B. In this case however, nobody observed that the encounter with obstacle B caused the slowing down of A.

Basing oneself on Michotte's ampliation theory one could not

expect braking answers in this case. When B's movement has to be the cause of A's slowing down, object B has to be the «centre de référence» of A's movement after their meeting, for it is the essence of ampliation that the dominant movement (the movement of the «centre de référence») expands over the patient (the other object). In that case only does one have a causal impression. It is however clear that A's movement, and not B's, will exert the dominance once the junction completed, a dominance it necessarily obtains during the period A moves alone. This is also the case in all other imaginable braking situations (1, p. 99); the object that causes the braking cannot be endowed with the dominant movement, therefore there is no ampliation and one cannot have a causal impression in the sense of MICHOTTE.

One may wonder however, if Michotte's theory does not conflict with the current opinion that we can very well perceive visually that a car is being braked or that some iron object is being attracted by a magnet. The question arises then, whether conditions different from those stipulated by Michotte might not also produce causal impressions. The only study along these lines which is known to us is that by Kanizsa and Metelli (4) who claim to have found a visual effect of attraction that would be immediately given as such. However, since the authors neither mention any quantitative results, nor even make it clear whether or not their subjects knew beforehand what they were supposed to see, this experiment cannot be considered as conclusive.

Our experiments are dealing with the braking effect only.

Let us suppose that subjects are shown a rotating disc which is brought to a standstill by the action of a brakeblock; when asked what they have seen, most subjects would probably answer that they saw a «braking» of some kind. However, our problem is: does this refer to a specific perceptual structure of «checking the movement», or should one say that these subjects saw something (the approach of the block and the slowing down of the wheel) which they then interpret as braking? Such an interpretation could be based on previously acquired knowledge. Moreover one should not forget that the word «braking» can be used in a wide variety of situations: the skater comes

to a stop by altering the position of his skates, a cart gets stuck in the sand, a driver puts on the brakes (in which latter case one cannot even see how the brake works), etc.

In our experiments we have made an attempt to reproduce the essential component of braking situations like those just mentioned, using a very simple and schematic stimulus system. We expected that the role of previous experience might thus be eliminated as much as possible. Also it might then be possible to discover by systematically changing the stimulus conditions, which perceptual structures would induce our subjects to mention causal impressions in their protocols.

We made use of Michotte's rotating disc device (1, p. 25-32). This consists of a circular cardboard disc, with a diameter of 50 cm. On these discs are drawn arcs of circles having the same center as the disc, as well as Archimedian spirals. The disc could be rotated behind an opaque screen with a horizontally radial slit of 5 mm width and a variable length. Under these conditions an observer will perceive arcs on the rotating disc as unmoving rectangles in the slit, whereas spirals will be seen as moving rectangles. In this way a number of moving and stationary figures can be produced in the slit. The velocity of the moving figures depends on the characteristics of the spirals as well as on the rotation speed of the disc. A more complete description of this technique can be found in 1 *loc.cit.*, 5, p. 186 and 6 (p. 183-185).

Our first experiments were to find out whether subjects would give causal responses when presented with the simplest possible stimulus pattern.

Experiment I.

The background behind the slit is in two parts: white at the left (75 mm) and black at the right (25 mm). Left of the separation line a red rectangle (5×10 mm) is visible, its right side being at a distance of 60 mm from the separation of black and white. Eventually this rectangle starts moving to the right (313.3 cm/sec.). At the precise time the left side of this rectangle coincides with the separation line, the velocity changes to 4.7 cm/sec. The object then moves at this constant speed over the black part of the background until it disappears behind the screen on the right.

The stimulus was presented to 50 «fresh» subjects, i.e. subjects who had no knowledge of the purpose of the experiment and who were merely requested *to describe what they saw* (the instruction was given this way in all experiments, which were always made on fresh observers).

Basing ourselves on Michotte's theory, we could not expect reports of primary causal impressions in this experiment.

Only seven subjects (14%) used causal expressions. A response is called a causal one when the subject does not only mention the slowing down of the movement, but also explains it by reference to something linked with the black that opposes resistance to the red object. For instance: «It looks like the red being held up by something on the separation between white and black». Four subjects mentioned a friction between red and black as cause, and two subjects a greater density of the surroundings on the black.

In this experiment two changes occur simultaneously: a) a sudden slackening of the movement, b) the object arrives in front of a different background. It would perhaps be possible to heighten the frequency of causal reports by altering the time relations between the two events.

Experiment II.

Three different discs were used:

1. As in Exp. I the background of a white part at the left and a black part at the right. The red object's (5×10 mm) right side is initially 85 mm to the left of the separation line. Then it moves to the right at a speed of about 20 cm/sec. When it is 25 mm *at the left* of the separation line, its speed changes to about 3 cm/sec. and at this speed the object moves on until it disappears on the right of the slit.
2. Like 1., except that the object is initially 45 mm on the left of the boundary line and only changes speed when it is clearly *upon* the black background; i.e. when its left side is 5 mm over the boundary line.
3. Like 2., with the difference that the object changes speed *still later*, i.e. when its left side is 35 mm on the right of the separation line.

All subjects were shown the three patterns successively in all

presentation orders. Using four subjects in every order, 24 subjects in all were involved.

The results were very similar to those of Exp. I. Only three subjects (12%) mentioned braking impressions. One of them with all three displays, and two others with display N° 2. We were not able to establish any influence of the different time conditions. It would thus seem as though the relationship between the slackening of the motion and the passing of the object in front of a different background were, for the practical purposes, irrelevant to our problem.

So far, some interesting conclusions may already be drawn:

1. The immense majority of observers described the slowing down of the movement and its location and considered the slackening as spontaneous; only very few subjects did mention a causal relationship (in accordance with Michotte's theory).
2. In the few cases of causal reports, the supposed cause was always something *which was not given* in the display, e.g. a sort of resistance or viscosity where the background was black.

It seems thus as though the background played practically no role at all, the main thing being *the change of speed itself, which in some cases induce observers to think of, or to infer, a possible cause and to formulate different hypotheses concerning their nature*. In these conditions therefore, no specific, genuine causal impressions are reported. It might seem at first glance that such a result should have been expected, owing to the schematic and artificial character of the display. But, and this is an essential point that should be borne in mind all the way through when discussing investigations of this kind, in the case of experiments on «pushing» etc., the display is equally schematic and artificial and besides, the observers may know, and in fact do generally know that the display consists only of spots of colour painted on paper and that there is no «real» pushing at all. Nevertheless, this does not prevent them from reporting that they *actually see one object pushing the other*.

The negative results obtained up to this point induced us to try different changes in the display in order to produce another

kind of structure of the perceptual field which could possibly alter the nature of the responses. Since the background had proved to be ineffective, we tried to bring in a *second object* in front of which the first would move after reaching it, its motion being slackened at that moment.

Experiment III.

The background is 170 mm in length. At the left, 5 mm from the edge is a red rectangle (5×10 mm), and at a distance of 60 mm from its right side is the left of a black rectangle (5×25 mm). The white background extends then 70 mm further to the right. (As a consequence of the enclosure principle the black rectangle is seen in this case as a «figure» and constitutes thus the second object). Eventually the red object starts moving to the right (31.3 cm/sec.). The moment the red object's left side coincides with the black's left, the velocity changes to 4.7 cm/sec. and the object moves on at this constant speed until it disappears behind the screen on the right.

This experiment differs from Exp. I by the white part added to the right of the black.

Among 50 fresh subjects, 17 (34%) reported having seen the red object *being braked when it moved over the black part*. This number is significantly higher than the number found in Exp. I (chi-square: $p < .05$). Thus there is an important increase in the frequency of the causal responses, but their nature remains the same as in the previous experiments. An inspection of the individual protocols makes this clear enough. First, 13 subjects who reported a braking impression made use of expressions like: «It appears as if...it gives the impression that...one could believe that...» etc. So, it is obvious again that the stimulus system did only *suggest* the idea of «checking» the motion. Furthermore, 4 of our subjects did refer to examples taken from everyday experience. They thought of the black as of a tunnel through which the red object could only proceed with difficulty; or the red object was imagined as a cart coming from a highway on to a track, or as a rolling ball landing in the sand. One of them said: «The red falls into the butter»; 9 subjects did not refer to such specific points and only said that the red object appeared to be grating the black or got stuck to it, or called the black magnetic, all physical factors not present in the display.

This rise in number of causal reports stimulated us to stress still more the connection between the slowing down and the passing in front of the black. In the next experiment there is not only a slowing down of the movement of the red object when it arrives at the black, but this slackened movement is also restricted to the period the red passes over the black, so that the movement resumes its original speed once it is on the right white part of the background.

Experiment IV.

The difference with Exp. III is that the velocity of the red rectangle changes to 31.3 cm/sec. the moment its left side is on the black's right. So the movement proceeds in three phases: fast-slow-fast.

Out of 50 subjects 29 reported the red to be braked (58 %). This number is significantly higher than that found in Exp. III (chi-square: $p < .05$) and also obviously better than that in Exp. I (chi-square: $p < .001$). Our brake response criterion was the same as described in connection with Exp. I.

Here too, many (16) subjects who reported a braking, described the situation in terms of «as if», and 21 subjects referred to the influence of unperceived properties or factors (magnetic forces, grating, etc.).

It is noteworthy that in spite of the large increase in the number of causal responses, only 4 subjects were disturbed by the sudden acceleration of the red, after it had passed the black. They groped for all kinds of peculiar explanations for this acceleration, like «The black pushes the red away», «The black fires the red», «The red arrives upon a conveyor». The other observers satisfied themselves by simply saying that the red was being braked and afterwards just went on as before. Strangely enough, the subjects did not explicitly refer to a self-moving object, the motion of which would simply be temporarily restrained by passing in front of another object.

The following experiment is designed to establish further the necessity of a second object of some kind to be present in order to produce braking reports.

Experiment V.

The difference with Exp. IV is that the background is entirely white, so that the movement of the red object (fast-slow-fast) proceeds in front of a white background.

This display was presented to 15 subjects. Only three of them (20 %) said they saw the object being braked by something they could not see, but supposed to be working. This result differs significantly from that of Exp. IV (Fisher exact probability test: $p < .01$). Curiously enough, this temporary deceleration did not make our subjects think of a braking factor. If one compares the results with those of Exp. I and II, one notices that they are nearly equal (Fisher test: no significant differences), which proves once more that the structure of the background is not an important factor in producing braking reports.

It is clear that all these experiments point to the same general conclusions. We have altogether 59 (on a total of 189) records of causal responses given independently by fresh observers who had never taken part in similar experiments; and in all these cases the «causes» were always extrinsic to the perceptual structure (this refers of course only to our own research¹). None of the subjects ever reported seeing *one object checking the motion of another*, whereas in MICHOTTE's experiments on causation, observers constantly said that they saw *the moving object pushing the other ahead*.

Nevertheless the slackening has been related to the second object, but this happened by means of a «hidden» property of this object, like viscosity and so on. These references to numerous unperceived factors show at once that in this case we are not dealing with a specific impression of «braking», but that the

¹ One may wonder what the results would have been if still other displays had been used, for instance displays using the more «natural» *gradual* deceleration. Trials to perform such an experiment showed that people experienced considerable difficulties in perceiving any difference between a sudden deceleration of the treble as well as a gradual deceleration of the same order. A still larger gradual decrease in speed is not easily practicable with the rotating discs device. Besides, a large number of subjects having actually described the sudden change in speed as gradual, we did not consider the graduality of speed change as an important variable.

perceptual data of the slackening of the first object during its passage over another object induce a number of observers to think of explanatory hypotheses of this fact, on the basis of knowledge acquired in the past. We have learned that a moving body does not change its velocity without the intervention of some cause and when we perceive a change of that kind, we are liable to look for such a cause, which in the case of our experiments could only be guessed.

Furthermore these experiments have clearly shown that even the awakening of the idea of the cause was dependent on the structure of the display — the cases, scanty in experiments I, II and V, became very numerous in III and IV, in which the system of stimuli was such that a strong connection was established between the slackening and the passage in front of the second object. Needless to say the latter displays are much more similar to daily life conditions under which a physical braking takes place, and thus also better fitted to recall the idea of such an event. This is easy to understand, because in most cases the slowing down of movement is produced by friction, when a body is moving over another. Furthermore, it seems that the most current concept of braking is that of a temporary slowing down produced by counteracting for a while a continuously working force, like gravity, a mechanical motor, or voluntary human movement. It is clear that our set-up corresponds perfectly to the sense that may be inferred from the above-mentioned situations. On the other hand, it appears that the 4 subjects who experienced some difficulties in reporting what they saw, due to the increase of speed after braking (Exp. IV), gave a somewhat different meaning to the word «braking» by taking only the inertia into account.

But one point ought still to be specially stressed, namely the fact that if a change in the system of stimuli had an influence on the *frequency* of the causal responses, it had none on their *kind* or their *nature*. They remained all the way through examples of: «It is as if», generally followed by a hypothesis about some physical features liable to check the motion.

Now this is something entirely different from what happens

in the experiments on «pushing» and the like, for in the latter cases, gradual changes in the system of stimuli bring about gradual changes in the kind of descriptions given by the observers. This shows, as MICHOTTE has repeatedly pointed out, a direct dependence of the responses upon the stimulus pattern. In our experiments, on the contrary, the description remained practically the same in spite of great differences in the displays. This is a fact which supports very strongly the conclusion drawn from the differences in the content of the verbal responses in the two cases.

Another experiment substantiates the same statement. We wanted to know whether the second object should be present in the field before it is reached by the moving one. This would seem probable, if any causal response were to be expected.

Experiment VI.

In the slit (170×5 mm) is a red rectangle (5×10 mm) at 5 mm distance from the left side. The background is entirely white. At a certain moment the red starts moving to the right (12 cm/sec.). When it has moved 60 mm, the black object suddenly appears in such a way that its left border coincides with the right side of the red object. At the same time the latter changes speed to 1.8 cm/sec.; it moves at this speed over the black part and at the moment it has altogether left it, the latter disappears again and the red object resumes its initial speed of 12 cm/sec., moving on until it disappears behind the screen.

This experiment is thus similar to Exp. IV, the only difference being that the second object appears suddenly at the moment of the slowing down of the movement and disappears when it resumes its former speed.

Using the velocities of Exp. IV this stimulus configuration appeared to be confusing; too many things happened together. Therefore we used slower speeds, maintaining their *ratio*. Only 12 observers took part in this experiment, but 7 of them (58 %) said that the red object was being braked at the appearance of the black. The difference in results with Exp. I is significant (Fisher exact probability test: $p < .003$).

However, it once again appeared that 6 out of the 7 causal

responses were of the «as if» type. The display made the observers *recall* braking situations. One of our subjects even said that it was not the black object that braked the red one, but something else not visible, hidden behind the screen. This is therefore another case in which a considerable change in the display did not affect the results accordingly, these being similar to those of Exp. IV. Finally, in order to verify our main conclusion that the causal responses given by our observers were not descriptions of what they actually saw, but were essentially hypotheses based on acquired knowledge and framed in order to explain the perceived changes, we carried out a last experiment, in which the speed ratio was inverted; this resulted in a situation practically never met in ordinary life.

Experiment VII.

The set-up is similar to that of Exp. IV, but the red rectangle moves to the right at the speed of 4.7 cm/sec. until its left side coincides with the black's left side. Its speed increases then suddenly to 31.3 cm/sec. to resume its former value when its left side coincides with the black's right. Thus we have the three steps: slow-rapid-slow.

This experiment is the «reverse» of Exp. IV. Whereas in the latter the object decelerated while passing in front of the black, in Exp. VII it accelerates, the ratio between the two velocities being the same.

In the above situation, the connecting factors of simultaneity and equality of duration and trajectory of the two changes (acceleration and passing) are thus also at work, but on the other hand, the situation shows little conformity with everyday events and common physical knowledge could hardly be applied to it. Among the 20 subjects taking part in the experiment, only 3 reported a causal connection (15%) between passing over the black and acceleration, and their reports were rather poor. One subject said that the black was protruding so that «the red tumbles from the black»; a second said that the red was being pushed by the black and the third one that «the red jumped over the black because it perceived the black as an obstacle».

The difference with the results of Exp. IV is striking (significant at the .02 level, Fisher test). Although the structural fac-

tors which tend to bind strongly together the change in speed and the passing of an object over another are the same, the number of the «causal responses» drops at once according to prediction, and this is quite natural since current life does not provide us with ready-made causal concepts fitting to such cases.

It is also interesting to compare this experiment with those of MICHOTTE on the «release effect», which takes place when an object starts moving after an impact, but at a greater speed than the object which hits it (1, p. 116). The reports of the observers are very different in this case from those obtained in the experiments on «pushing» and the like. There is no question of a shock «producing» the movement of the second object any more, this movement being reported as autonomous and just «released» at the moment of the impact; the observers explicitly stress the fact that they have an impression of direct «dependence» of the movement upon the impact — a crude unspecified type of causation. They also try to find out some possible explanations of the fact in the same way as in our experiments. Whether or not our subjects also had an impression of such an indefinite «dependence» of the change of speed on the passing over the second object, we have no reason to believe because they don't mention it, and this assumption is by no means required in order to understand our results.

GENERAL CONCLUSION

Considering all these data, it seems that the most interesting result of our investigations lies in the experimental evidence that an *objective criterion* may help to establish and justify the distinction between two classes of causal verbal responses elicited by visual situations:

- 1° Verbal responses corresponding to genuine, specific causal visual impressions.
- 2° Cases in which the causal bond is not actually perceived, but inferred from perceptual data of another kind (2, p. 389 sq.).

It has been shown that in these latter cases, the content of the verbal statements does not vary in nature, in spite of considerable changes in the patterns of the display, these bringing about mere differences in the frequency of the causal responses.

In the first case, on the contrary, as MICHOTTE has been able to demonstrate it, there is a close parallelism between changes in the displays and corresponding in the *content* of the responses.

Further research will be needed to find out how far this criterion may be applied to other causal situations, but it seems that one can reasonably believe in its general value.

ACKNOWLEDGEMENT

This study was made possible by a grant to the author from the «Gemengde Technische Commissie ter Uitvoering van het Nederlands-Belgisch Cultureel Accoord». The author is indebted to Prof. Dr. A. Michotte for his kind hospitality and constant support and to Prof. Dr. L. Knops for statistical and other advice.

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