SLOW-MOTION TUNNEL EFFECT: AN INQUIRY INTO VERTICAL ORGANIZATION OF PERCEPTUAL EVENTS

Giovanni Bruno Vicario and Yoshie Kiritani

1. Introduction

Let us consider the stimulus situation depicted in figure 1, where a small square (*a*: 5x5 mm) is in motion (40 cm/sec) toward a big standing rectangle (*x*: 40x80 mm), and when in contact with it, progressively disappears. After a while (100 msec), a similar square (*b*) appears on the opposite side, in motion on the same course at the same speed. In figure 1, on the left, we have the typical sketching of the situation; on the right we have another sketching, where the space of the fronto-parallel plane (*s*, on the abscisse) and the temporal dimension (*t*, on ordinate) are represented. In this latter sketch we see that *x* is lasting in its place over time, where *a* is moving toward *x* and *b* is moving away from *x*.
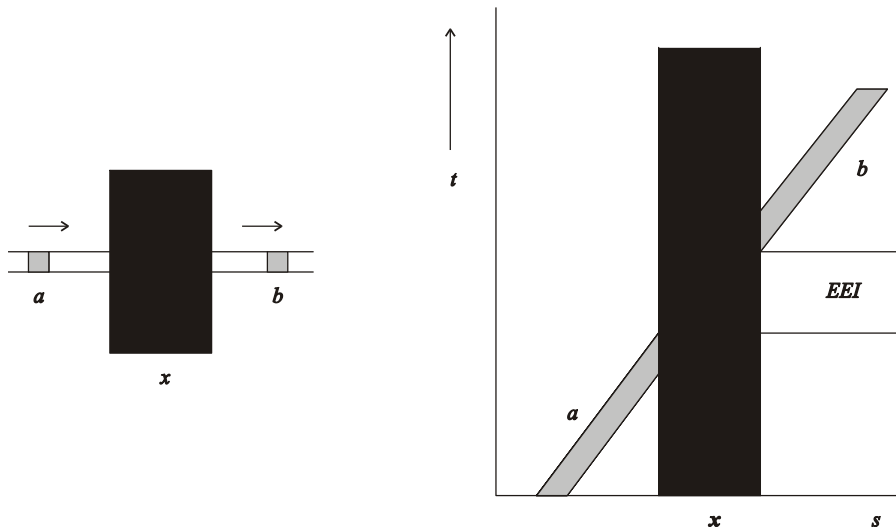

Figure. 1: Tunnel effect. At left its traditional sketching; at right a representation of it that can account even for the dimension of time. (*a* = the first mobile; *b* = the second mobile; *x* = a screen covering the trajectory of the two mobiles; *t* = axis of physical time; *s* = one-dimensional representation of frontoparallel plane; *EEI* = entry-exit interval of time, from the disappearing of the first mobile to the appearance of the second mobile.)

In looking at the situation, the observer perceives just *one* object, displaying an uninterrupted motion in open field and behind the big rectangle that is experienced as a screen: this is *tunnel effect*. (On this point, see also METZGER 1975, p. 584.) The motion of the small square in open field has of course the character of a full perception, where the motion behind the screen, although compelling, shares the character that MICHOTTE and BURKE (1951; see also METZGER 1975, chapter XIII, and KANIZSA 1991) call *amodal* ("modes" would be sense functions, like vision, audition, haptics *etc*.). To understand the meaning of the term "amodal", put a pencil horizontally on the three triangles depicted in fig. 2, so to cover both the gap and the crossing lines: you will see three perfectly alike triangles, which visible parts "amodally complete themselves" behind the pencil. By the way, the picture was devised by MICHOTTE, THINÈ and CRABBÉ (1964), in order to demonstrate that there is no use in knowing what is really there behind the screen: amodal completion takes place only on the basis of emerging parts of the "hidden" object.
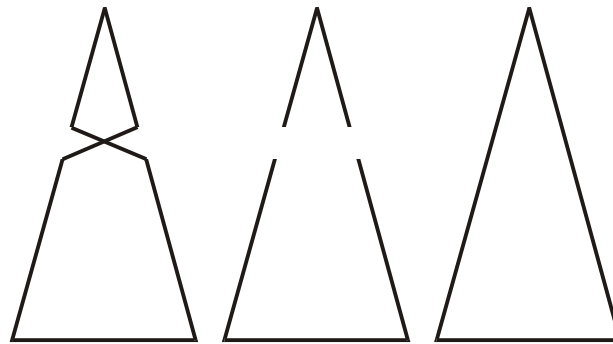

Figure 2: Amodal perception. Put a pencil horizontally on the figure so to hide the crossing lines and the gap: the three triangles will be perceived as perfectly alike, despit the fact that the observer perfectly knows what is hidden behind the pencil (from MICHOTTE, THINÈS and CRABBÉ, 1964).

BURKE (1952) performed a detailed study on tunnel effect, varying the speed of the object, the length of the tunnel and the EEI (entry-exit interval: entry of the first object and exit of the second one). The main results of his inquiry can be summarized as follows: (1) when all the conditions are favourable, one perceives one single object in motion at uniform speed, in open field and behind the screen; (2) when the EEI and the length of the tunnel are discordant (*e.g.*, a tunnel too short combined with a long EEI, or a tunnel too long combined with an EEI too short), two objects are seen in motion, acting as independent events; (3) when the EEI and the length of the tunnel are not too discordant, several half measures take place: the moving object is one, but it slowes down its motion, or stops just a while behind the screen; the moving objects are two, but the second one begins its motion in perceived connec-

tion with the arrival of the first, *etc*.; (4) the optimal EEI for the vision of a single movement at uniform speed is shorter than the time a real object would take in order to overcome a real tunnel of a given length. (The last point reminds of the "phenomenal shrinkage" discovered by KANIZSA, 1975, in the amodal completion of static object. See also VICARIO and TOMAT, 1992.)

MICHOTTE (1962; see also BUTTERWORTH 1991) treated the tunnel effect as an example of what he called *phenomenal permanence*, that is the phenomenal existence of objects *after* they disappear from view (in tunnel effect, this concerns the first mobile) or *before* they are coming to light (in tunnel effect, this concerns the second mobile). Phenomenal permanence should be granted by the *screen effect*, that is by the impression that in the progressively hiding (or emerging) of a moving object behind a screen, the parts of the object that are already hidden (or going to appear soon) are perceptually, even if amodally, present (see KNOPS, 1962). As a matter of fact, MICHOTTE is considering tunnel effect as the combination of two screen effects, the one giving rise to a *succeeding permanence* (for the first mobile) and the other giving rise to a *preceding permanence* (for the second mobile): in the aforesaid favourable conditions, the joining of the two effects would lead to the perception of a unique object and of an unique movement. MICHOTTE's view of the tunnel effect as a general feature of the perception of events is supported by the fact that we have the same experience in auditory domain. If we substitute a part of a long tone with a white noise, we hear a continuous tone going behind the noise and then to surface uninterrupted at the end of the noise (provided that the noise level is at least 40 dB over the level of the tone, and that the noise is lasting not over 700 msec: see VICARIO, 1960, or 1982).

However, there is the well grounded claim that tunnel effect could also be considered as a problem of *phenomenal identity*, since the very fact emerging from the situation is that for optimal EEI and tunnel lengths, the second mobile is perceived as *the same* that first appeared on the opposite side, and then ran behind the screen (see PETTER, 1957, or BOZZI, 1969, pp. 214-264; the problem of phenomenal identity was treated in depth by METZGER, 1934). Tunnel effect would be nothing more than a sort of stroboscopic movement, where the first mobile represents the first light, and the second mobile the second light. (In fact, tunnel effect was first described by WERTHEIMER, 1912, in his inquiries on apparent movement.) In this sense, the main feature of both stroboscopic movement and tunnel effect should be the *constancy of identity*, where the apparent movement and respectively the welding of the actual movements behind the screen are the side effects of object constancy: (1) there is a light at a certain place and at a certain moment; (2) after a while and just a little apart in visual field, there is another light that shares with the first the same features, like size, brightness, and so on; (3) perceptual hypothesis is that the second light is the *same* first light; but (4) in order to materialize the perceptual hypothesis, the first light *has to move* from first to second position; (5) we *see* the movement. In tunnel effect things go likewise: the second mobile is recognized as the first mobile, but this sort of identification requires the movement behind the tunnel, from the entry to the exit point. By the way, there is a problem of millise-
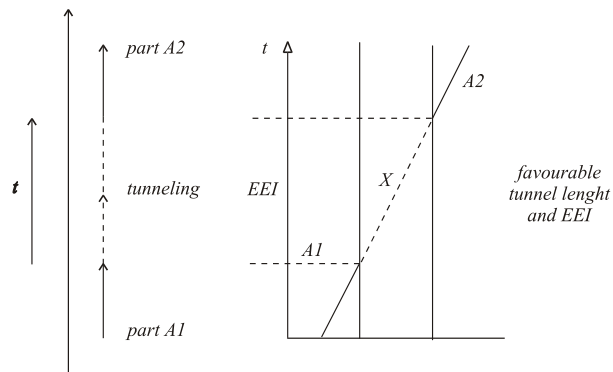
conds, in the sense that certain intervals favour both stroboscopic movement and tunnel effect, where other intervals destroy both the kinetic structures.

2. Horizontal organization of events

Tunnel effect may be viewed also in the light of the overall problem of the perception of events. As VICARIO (1994 and 1995) tried to establish, following the setting out of KOFFKA (1962), perception of events needs a clarification of conditions or of processes that lead to mutual segregation of events themselves within the unceasing flow of anonymous and unrelated physical stimuli. In static arrangements of visual stimuli, where the concern is limited to the mutual segregation of objects (WERTHEIMER, 1923), there is only a problem of spacial conditions, since the stimulation of all the points of the field is simultaneous and invariant. In visual kinetic displays, as in auditory domain, we must take into account even the temporal dimension, since the stimulation changes here and there in a perceptual field running over time. Adding the new dimension means that the problem of mutual segregation of visual events seems to have now two faces: the one concerning the segregation in space, the other the segregation over time. (On this problem, see MÜLLER, 1963, or even VICARIO, 1965.) We think that in this difficult situation, two concepts may be of some use: *horizontal* and *vertical* organization of events.

Horizontal organization refers to the fact that (a) in some cases events are perceived as following each other but are experienced as mutually independent, where (b) in some other cases events are perceived as linked together, that is as parts of a unique event. We observe the first possibility considering the words in an utterance, or the phrases in a melody, or even in a movement that stops and then recovers after a substantial time interval: this is *horizontal segregation*. We observe the second possibility considering vowels and consonants in a single word, the notes in a melody or even in movements occurring in strict succession, like in pendular motion: this is *horizontal integration*. As to tunnel effect, horizontal segregation refers to the fact that with tunnels too wide, or with EEIs too long, the event *A* (a mobile approaches the screen) has nothing to do with event *B* (a mobile leaves the screen), and therefore we perceive *two* events and *two* objects; horizontal integration refers to the fact that with a proper width of the tunnel, associated with a proper EEI, we see just *one* movement of *one* object, where the whole kinetic structure is articulated in three parts: the approaching of a mobile (*A1*) to the screen, the tunneling (*X*) and the leaving of the mobile out of the tunnel (*A2*). In figure 3 the two different results of horizontal organization (integration, segregation) in tunnel effect are depicted.

HORIZONTAL INTEGRATION

part A2

t

tunneling

EEI

X

A2

A1

*favourable
tunnel lenght
and EEI*

part A1

HORIZONTAL SEGREGATION

B

*tunnel
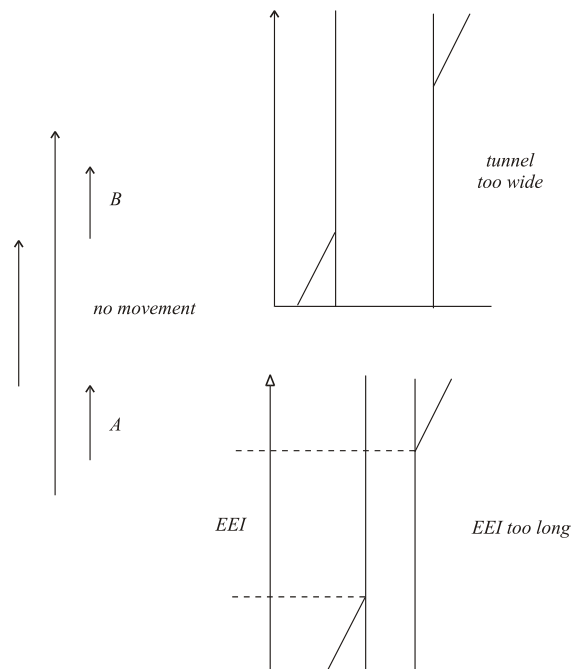too wide*

no movement

A

EEI

EEI too long

Figure 3: Horizontal organization in the tunnel effect. According to the stimulus condition, we can have integration (one event, on top), or segregation (two events, at bottom).

In fact, the work of BURKE (1952) consisted in a plain investigation of the conditions of the horizontal organization of events. That is, he simply accepted the fact that in some cases the separation in physical domain involves the perception of two successive events, and in some cases allows of the perception of a single event. As one can see in figure 4 on the left, we have two distinct events as to the distal stimulus (*a* and *b*: two distinct groups of pixel are successively activated on the screen of the monitor) and the proximal stimulus (two areas of the retina are successively stimulated), but the perceptual outcome does not always correspond to the physical reality nor to the peripheral sensory facts. With some combination of velocities, lengths of the tunnel and EEI intervals (figure 4, on the upper right) we see two squares (*A* and *B*) and two independent movements succeeding each other; with other combinations of the same factors we see just one movement in three phases, organized in the motion of just *one* object (*A1-X-A2*, see figure 4 on the lower right). In the first case the perceptual organization of events goes to the *horizontal segregation*; in the second case it goes to the *horizontal integration*.
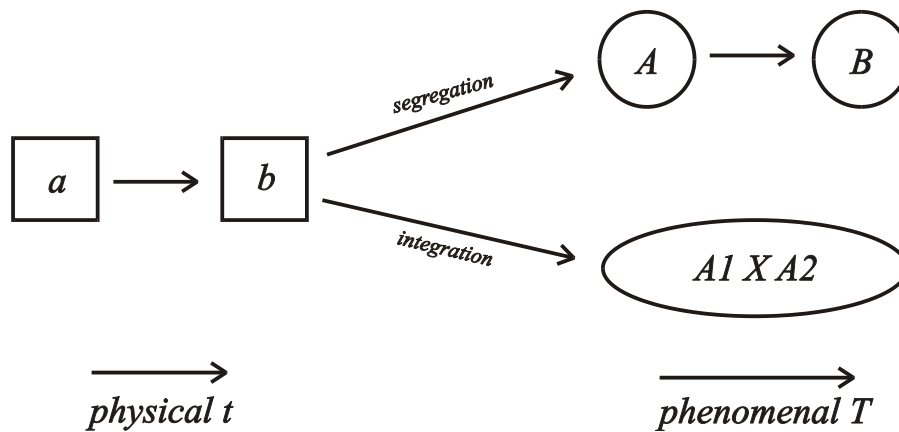

Figure 4: The same occurrence in physical time can give rise to two different events in phenomenal time (according to segregation or to integration).

3. Vertical organization

Vertical organization refers to the fact that events are also perceived as simultaneously but separately present, *e.g.* voices in cocktail party effect, melodies in musical counterpoint or independent movements in the same kinetic structure (for instance, a person going upstairs on a sliding scale). Now, tunnel effect may be employed even to clarify and to investigate vertical separation of events, even if we

have to deal with a special sort of tunnel effect: a "slow-motion" one, where we can see at the same time the *screen effect* (the same in action in ordinary tunnel effect) on both sides of the central rectangle. Let us consider the stimulus situation depicted in figure 5, where we have a standing rectangle *y* (18x53 mm), an area *c* progressively shrinking at a speed of 10 mm/sec (of its tail side) and an area *d* progressively expanding at the same speed (of its head side). In figure 5, on the right, the situation is represented even in its temporal dimension.
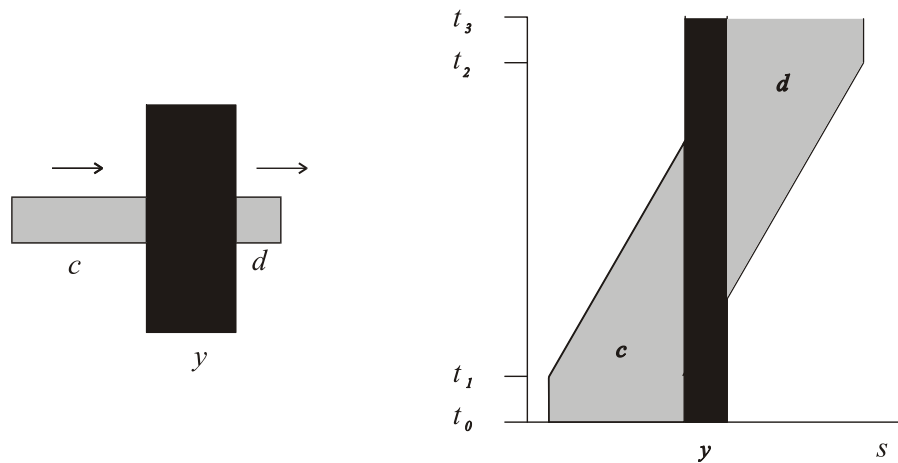

Figure 5: Slow-motion tunnel effect. At left a traditional sketching of it; at right the re-presentation that accounts for the dimension of time. (*c* = a surface slowly decreasing in size; *y* = a stationary surface; *d* = a surface correspondingly increasing in size; see also figure 1.)

What one sees, is a lying rectangle smoothly sliding behind a standing screen. As we have just said, the perceptual outcome is due to the linking of two screen effects acting in the same direction, that is from the left to the right. Nevertheless, there is to point out that the *unicity* of the perceived object is grounded on the identification of the perceptual event occurring on the left (the rectangle progressively disappearing behind the screen) as a part of a larger perceptual event that includes the perceptual event occurring on the right (the rectangle progressively emerging out of the screen) and the "amodal" presence of the third part of the rectangle behind the screen. We have to understand that the description of distal stimulus (what occurs on the surface of the CRT, provided that we employ a videographic computer to display the situation) and the description of the proximal stimulus (what occurs on the retina, at the periphery of the central nervous system) involves *two* distinct physical events: a group of pixels lighting off on the left, and another group of pixels lighting on on the right; otherwise, a decreasing number of neurons firing for the

left, and an increasing number of neurons firing for the right. The fact that the two distal or proximal events are simultaneous does of course not guarantee the unicity of the perceived event: they take place in different regions of the CRT and of the retina. Figure 6 may help to realize the argument.
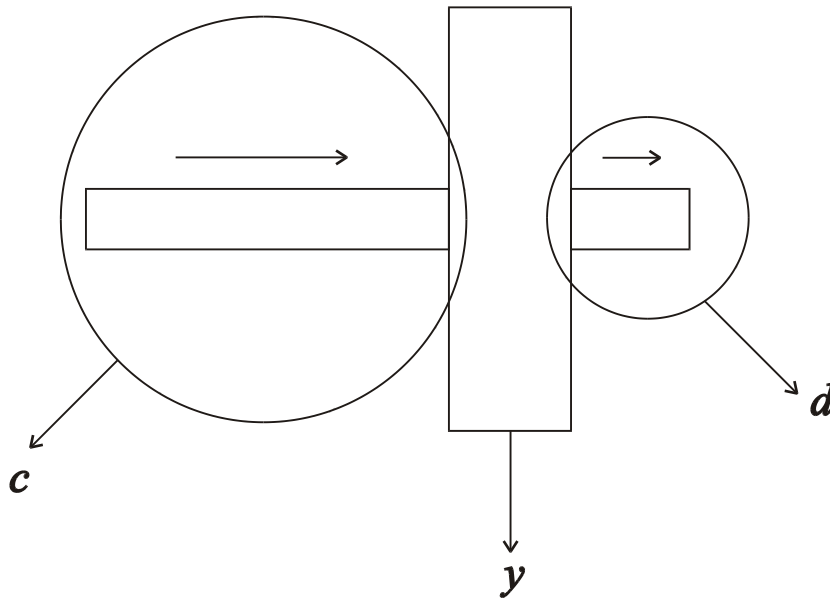

Figure 6: In slow motion tunnel effect there are two physical occurences: *c* on the left and *d* on the right, simultaneous and parallel in physical time.

Now, as we shall see in figure 7, identification of *C* with *D* does occur not always. As we shall see later, in some cases the rectangle emerging on the right *is not the same* as the rectangle submerging on the left, owing to gross disparities between the two surfaces, their setting and their rate of evolution. In this way we realize that there is a problem of *vertical organization*, in the sense that some stimulus conditions lead to the perception of a couple of events (movements) that correspond to physical (and physiological) occurrences, and other stimulus conditions lead to the perception of a single event articulated in three simultaneous parts. In figure 7 the matter is conceptualized. On top we have the status of affairs in physical time *t*, where the decrement in area of *c* and the increment in area of *d* are obviously superposed, since they occur at the same time (see the interval t_1-t_2 in figure 5). At bottom we have the two possible perceptual outcomes in phenomenal time *T*: (1) *vertical segregation*, that is the perception of two simultaneous events, like two movements or two objects whose simultaneous movements are correlated; (2) *vertical in-*

tegration, that is the perception of just one single event, like a moving object whose parts are here visible, and there hidden behind a screen.
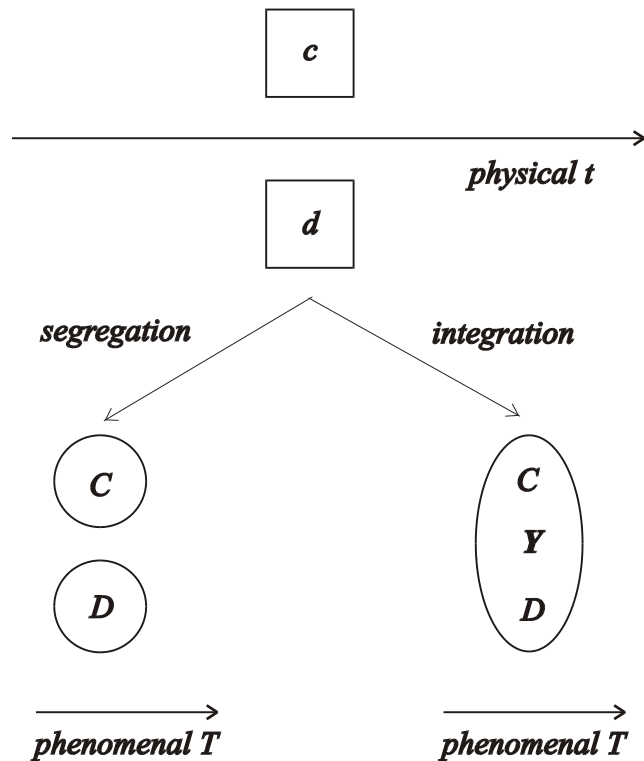

Figure 7: Vertical integration in the slow-motion tunnel effect. The same physical superimp-
osed occurrences in physical time can give rise to two different phenomenal
events (according to the parameters of the stimulation): two simultaneous inde-
pendent perceptual events (segregation, on left) or a single event (integration, at
right).

4. Preliminary remarks

We will now start analysing the slow-motion tunnel effect, in order to show the many aspects of it, some of which are useful for the general problem of formation of events in perceptual field, where some other deserve attention for their own. Our re-port will be rather qualitative than quantitative, given that in this step of the research is even difficult to focus single questions. As to the method, we made use of expe-

rimental phenomenology (on this topic see THINÈS, 1977 and 1991, or VICARIO, 1993a), postponing crude experimentation to a more defined state of affairs. We hope indeed to attract attention to a method that, during the flourishing of Gestalt psychology, assured to the study of perception a matchless number of facts.

As to the tools of our inquiry, we made use of short animations prepared by means of the programs MacroMind Director 3.1 and MacroMind Accelerator 3.1, performed by a computer Mcintosh IIfx on a 13" AppleColor monitor (refresh rate: 66.7 Hz; resolution 640x480 pixels; pixel = .35 mm). In all the animations the standing rectangle is black (0.826 cd/m²), the moving rectangle is light grey (51.977 cd/m²), and the background is white (78.015 cd/m²).

The animations have been proposed to five experienced observers, who looked at the screen from a comfortable distance, mainly 70 cm. The results of observations have no statistical claim or significance: they are only generical directions for the theory and the next experimentation.

As to the description of the stimulus situations employed in the observations, let us start from figure 5, and let us conceptualize the variable conditions making use of figure 8.
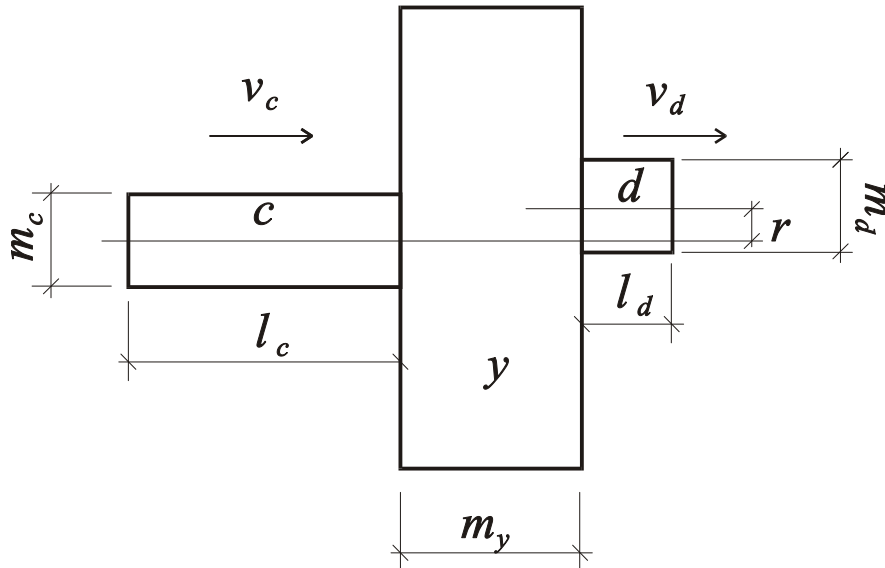

*F*igure *8*: Dimensions of the stimulus situation examined (see the text).

y is the standing rectangle, with a fixed heigh of 53 mm, and a variable width m_y; *c* is the surface decreasing or increasing (as to its area) on the left of the

standing rectangle y: its height is m_c, its length is l_c; d is the surface increasing or decreasing (as to its area) on the right of the rectangle: its heigth is m_d, its length is l_d; v_c is the speed of decrement/increment of c; v_d is the speed of increment/decrement of d; r is the deviation from coaxiality of c and d (for $r = 0$, the axis of c and d is the same).

We will now report the results of our observations regarding the following points:

[1] influence of the speed of decrement/increment of c and d (phenomenally, the speed of each visible part of the moving rectangle);

[2] influence of the width of the standing rectangle (phenomenally, the width of the screen behind which the horizontal rectangle is moving);

[3] influence of the deviation from coaxiality r of the surfaces c and d on either side of the screen;

[4] influence of the height of either surfaces c and d; for instance, a narrow rectangle on the left and a wide rectangle on the right;

[5] influence of the relation between decrement or increment on one side and the increment or decrement on the other side (in the previous conditions left side shrinks, and right side grows, but we can have even a rectangle which parts are simultaneously shrinking or growing).

However, there are some missing points, that is stimulus conditions that we for the moment did not attend to. To mention the most important ones:

[6] influence of the starting frame: any animation can begin with the sole appearence of the left rectangle, with no cue for another rectangle on the opposite side; otherwise, at the beginning a little portion of the opposite triangle is in place;

[7] influence of the last frame: any animation can end with the sole presence of the rectangle on the right, being the rectangle on the left quite disappeared behind the screen; otherwise, at the end of animation a little portion of the left rectangle is still in place;

[8] for all the conditions, the influence of asyncronies in appearing or disappearing of either rectangle on the opposite side: for instance, the left rectangle goes behind the screen, but it appears on the right too soon or too late.

5. Experimental observations

[1] Influence of speed

The width of the rectangle m_y was 18 mm; the width of both c and d was 7 mm. There were 7 degrees of speed for the decrement of c and the increment of d: 6, 7, 9, 12. 15, 17 and 35 mm/sec. The ratios of decrement to increment were made by the combinations appearing in table 1.

Table 1: The ratios of speeds (decrement to increment) of the evolution of surfaces c and d (with the absolute speeds) in observed situations. Boldfaced numbers refer to those ratios for which there is integration of the two movements into one.

		speed of increment of d (mm/sec)						
		6	7	9	12	15	17	35
	6			**1:1.5**	**1:2**		1:3	1:6
	7					**1:2**	**1:2.5**	1:5
speed of	9	**1.5:1**					**1:2**	1:4
Decrement of	12	**2:1**					**1:1.5**	1:3
c (mm/sec)	15		**2:1**					**1:2.5**
	17	3:1	**2.5:1**	**2:1**	**1.5:1**			**1:2**
	35	6:1	5:1	4:1	3:1	**2.5:1**	**2:1**	

In short, there were 26 situations to be observed, with 7 ratios in which c decreased with higher speed than b increased, and with other 7 ratios im which d increased more rapidly than c decreased. Of course, some ratios have been observed at various absolute levels. Not all the combinations of speeds have been observed, as one can infer from the empty cells of table 1. The ratio 1:1 has been not analyzed, since it brought no problems about the unicity of the moving rectangle.

The reports of the observers can be summarized as follows. In general, if the ratio of decrement to increment was less than 1:2.5 or 2.5:1, one single moving object was perceived: C and D were seen as parts of the same object. The perception of one single object became ambiguous with increasing the ratio. When the ratio was greater than 1:3 or 3:1, one single object was not perceived any more: C and D were seen as two distinct objects, that is, C went behind the screen and another object D emerged from it. The effect of absolute speed went to be not so clear.

Interestingly enough, some observers reported that for a given ratio it was easier to see one single object when D was faster; on the contrary, it was easier to see two distinct objects when C was faster. Considering the moving direction of the perceived object, D is its head and C is its tail. When the speed of the head is greater than the speed of the tail, one easily sees an unique elastically stretched object; when the speed of the tail is greater than the speed of the head, it is rather hard to see one single object which rear part is pressed down a head that resists to move. (On this point, see also VICARIO 1997.) This seems to be the reason why it is easier to see two distinct objects when the tail is faster than the head; in other words, the perception of a stretchable object becomes easier than the perception of a squeezed one.

[2] Influence of the width of the standing rectangle

Coming to another variable, namely the width of the standing rectangle y, we tried to investigate its influence by observing its effects on the threshold between single-object and two-objects impressions. In other words, that threshold became our dependent variable. We made use of 4 levels of width: .35. 3.5. 18 and 71 mm. The width of c and d was ever 7 mm. The ratios of v_c and v_d examined were the same indicated in table 1. 104 combinations have been investigated.

The results of observations are as follows. Although the effects of relative speed were similar to those of prior experiment — that is, one single object for small ratios, and two distinct objects for great ratios — different widths of the standing rectangle y (the screen) entailed different thresholds between one- and two-object impressions. When the width of the standing rectangle y is 71 mm, the perception of two moving objects is coercive: some observers reported it even for the ratios 1:1.5 and 1.5:1 (that in the prior experiment, where the width of the screen was 18 mm, obtained the 100% of one-object impression). When the width of the standing rectangle is 18 mm, we have the outcomes already reported in the preceding paragraph; in order to obtain the two-objects impression, we have to reach at least the 1:3 or 3:1 ratio. Finally, it seems that there is no difference between the 3.5 and .35 mm widths of the standing rectangle: in fact, a rectangle just 3.5 mm wide is seen as a thick line, and the rectangle .35 mm wide is seen as a thin line. Anyway, the threshold between one-object and two-objects shifts some more toward greater ratios.

[3] Influence of the deviation from coaxiality

The deviation from coaxiality (r, see figure 8) was investigated, supposing that it might have influence on the threshold between that ratios that allow the perception of one moving object and that ratios that give rise to the perception of two moving objects. Both c and d were 7 mm in width. We made use of 8 degrees of deviation: 0, .7, 1.4, 2.5, 3.5, 5.3, 7 and 10.6 mm. Deviation 0 means that there was no difference between the horizontal position of c and that of d; deviations are all positive, in the sense that d is ever above c (like in figure 8); when $r = 7$ mm, the lower side

of d is collinear with the upper side of c; when $r > 7$ mm, c and d are completely separated. We chose three values for v_c and v_d: 6, 12 and 35 mm/sec, in so obtaining 72 stimulus situations (3 speeds for c, x 3 speeds for d x 8 values for r). The width of the standing rectangle y was ever 17 mm.

Let us consider first the three cases of ratio 1:1 between the speeds. When the speed is the same on either side of the screen, it is difficult to distinguish between perfect coaxiality ($r = 0$) and the smallest deviation ($r = .7$ mm). When $r = 1.4$ mm, one sees the *décalage*, but this does not impair the perception of a single object moving behind the screen; rather, one sees the rectangle to writhe during the passage under the screen. (A similar effect is reported by Burke 1962, p. 401, for fast tunnel effect.) An experiment is needed to fix the threshold between the vision of a single or of two objects in function of r; we can just say that at least one observer reported the perception of a single object (even if twisted) in the case of $r = 3.5$ mm (one half of the width of the rectangle).

Now we consider the ratios different from 1:1. When the speed of c's decrements and d's increments are unequal, two distinct moving objects are perceived in almost every case, and an effect of perceptual causality is often reported. When c decreases faster than d increases and the deviation is modest, left rectangle seems to push out the right one. When c decreases slower than d increases, and the deviation r is lesser than 5.3 mm, right rectangle seems to drag out the left one out of the screen. In general, the impression of dragging is a bit clearer than that of pushing. Dragging or pulling is easier observable with the ratio 1:6; pushing is easier observable when the ratio is 3:1; causal connections disappear when the deviation from coaxiality r is more than 3.5 mm. (These cases of perceived causality between movements that are simultaneous, instead of being successive, are briefly discussed in VICARIO, 1998b.)

It is worth to mention some illusions of misalignment between the two rectangles, when they appear as independent objects. For $m_c = m_d = 7$ mm, and $r = 5.3$ mm, there is a sort of overlap of 1.8 mm between the two rectangles; despite this overlap, the upper side of the left rectangle is seen as collinear with the lower side of the right one. For $m_c = m_d = 7$ mm, and $r = 7$ mm, the upper side of the left rectangle and the lower side of the right rectangle are actually collinear, but this time one can observe a sort of gap between their trajectories.

[4] Influence of the height of the evolving surfaces

The influence of m_c and m_d has been investigated, once again in connection with the threshold between the perception of a unique object and the perception of two objects.

There are 6 levels of height for both c and d: 3.5, 7, 10.6, 14.1, 17.7 and 21 mm; from 36 combinations, 22 cases are chosen (see Table 2). Seven ratios of speeds of decrement to increment are made from four absolute speeds: 1:1 (6 mm/sec), 1:2 (6 and 12 mm/sec), 1:3 (6 and 18 mm/sec), 1:6 (6 and 36 mm/sec), 2:1 (12 and 6

mm/sec), 3:1 (18 and 6 mm/sec), and 6:1 (36 and 6 mm/sec). The heights and speeds are combined so that the narrower part increases or decreases with higher speed. Thus, the total number of observed situations is 88. The width of the standing rectangle y is held constant at 17 mm.

Table 2: The width ratios between c and d (with their absolute widths): see the text.

		width of d (mm)					
		3.5	7	10.6	14.1	17.7	21
Width of c (mm)	3.5		1:2	1:3	1:4	1:5	1:6
	7	2:1		1:1.5	1:2	1:2.5	1:3
	10.6	3:1	1.5:1				1:2
	14.1	4:1	2:1				1:1.5
	17.7	5:1	2.5:1				
	21	6:1	3:1	2:1	1.5:1		

Let us now consider the perceptual outcomes for the cases involving the 1:1 ratio. When the speed of c's decrement is equal to that of d's increment, the observers tended to see one single object even if the difference of size of the two parts is rather great: they said that the object seemed to have undergone a transformation behind the screen. Here the last frame exibhits its strength: since it is easy to see in the final "frozen" frame (where a small part of the left surface is still visible) a unique object behind the screen (for instance, like a bottle which neck is on one side, and bottom on the other side), this last perceptual content casts its form to the preceding event.

In the cases by which the ratio between the speeds departs from 1, observers report the presence of two distinct moving objects linked by somewhat causal connection. For instance, when at left we have a wide surface that diminishes slowly, where at right we have a narrow surface that increases rapidly, one begins to see the narrow object pulling or dragging the wider that is resucked on the left. Otherwise, when at left we have a narrow surface that diminishes rapidly, where at right we have a wide surface that increases slowly, one sees a narrow object that pushes out of the screen a bigger one. In general, the impression of pulling or dragging is more frequently reported than that of pushing.

Considering the differences in width between the two surfaces, we can only say that the greater the difference is, the easier is the rising of causal impressions. When there are the conditions for these causal connections, it is the narrower part that assumes the role of "cause". This is probably due to the fact that the narrower part

moves faster: even in MICHOTTE's (1963) launching effect the "active" role is played by the object that moves faster. It is apparent that differences in width and in speed of the two surfaces mutually influence themselves, but this point deserves further investigation.

In comparing the previously reported effects of deviation from coaxiality (deviation that brings for the most part to the perception of two objects), with the effects of differences in width (that bring for the most part the perception of a single object), one should conclude that coaxiality is a factor of integration more sensitive than the sameness in width.

[5] Influence of the relation of increment and decrement at the two ends

Up to now we considered stimulus situations where to a given type of evolution on one side corrisponded an evolution of opposite sign on the other side: typically, to a decrement on the left corrisponded an increment to the right. Now we will examine the case of an evolution of the same sign on either side of the screen.

There are two forms: (5a) decrement on both sides, and (5b) increment on both sides. Like for the preceding points, we will test the influence of the variable by means of variations in the speed of evolution of both the surfaces.

The speeds of increment and decrement at the two ends are: 6, 12 and 35 mm/sec. From combination of these absolute speeds, we obtain seven ratios: 1:1; 1:2; 1:3, 1:6; 2:1; 3:1; 6:1. The total number of observed situations is 18 (3 speeds for c x 3 speeds for d x 2 types of relation). The width of both c and d is 7 mm, and the standing rectangle y is ever 17 mm in width.

The results of the cases involving the 1:1 ratio can be summarized as follows. When both c and d evolve at the max speed of 35 mm/sec, either in decrement or in decrement, two independent moving objects are perceived. No stereokinetic effects (see METZGER, 1975, chapter XV) take place. In reducing the speed, leaving the 1:1 ratio unchanged, perceptual impressions become ambiguous. For instance, at first glance two distinct objects are seen, but in the course of presentation they integrate themselves in one object. For the speeds of 12 and 6 mm/sec, and for the sole form of decrement, a strong stereokinetic effect takes place: the object lessening behind the screen keeps its phenomenal size, and therefore it is seen moving away in the third dimension; otherwise, a V-shaped rigid object takes place, rotating on its Y-axis behind the screen, and having its wings behind its vertex. Stereokinesis is of course the sign of the realized integration of the two surfaces in one object (and of the two movements in one event).

When the speeds of evolution at the two ends are different, especially when they are chosen at high ratios, two distinct moving objects are easily perceived. The type of evolution (decrement on both sides, increment on both sides) does not matter. In other words, difference in speed of evolution is crucial to the forming of one or of two objects.

There is another interesting outcome, for the situations by which *c* and *d* evolve with different speeds. Phenomenal asynchronies take place, regarding the beginning and the end of evolution of either part. (Remember that both surfaces begin and end their evolution at the same times, coming out from the screen in the variant 5a, or disappearing into it for the variant 5b, at the same moment.) For instance, if *C* moves to the left more slowly than *D* moves to the right, *C* seems to come out from the screen after *D*'s emergence. To the contrary, if *C* goes under the screen at a speed lesser than *D*, *C* seems to disappear after *D* disappears. We seemingly face a case of temporal displacement (VICARIO, 1963), probably due to a sort of FRÖLICH (1929, p. 22.) effect.

6. Further observations

Slow-motion tunnel effect is literally a mine of perceptual phenomena, in part referable to well known facts or concepts (especially in the frame of MICHOTTE's theories), in part to be yet explored. We will point out at least two aspects of the effect that seem worth of attention.

As for the first aspect, we repeatedly obtained from experimental observers reports of subjective uncertainty, in the sense that the discrimination [one moving object]/[two moving objects] underwent several undesired fluctuations. This is not surprising, since so poor kinetic structures are often open to "interpretations" or to connections with richer already experienced perceptions in everyday life (as students of causal effects well know). However, it seems to us that this sort of uncertainties is not primarily due to the objective difficulty of the task (like in an usual threshold determination, when standard and comparison stimuli are too near in value), but to the fact that the object of discrimination is an event, moreover lasting several seconds. This means that at the beginning of the event one undergoes the impression, for instance, of unicity (or duplicity), since the emerging parts of the sliding rectangle are in a certain proportion, but after a while the proportion is changed, and the observer is sure to be in front of a case of duplicity (or unicity); just a little later the moving parts of the sliding rectangle find themselves in another arrangement, and the observer returns to the impression of unicity (or duplicity). At the end of the presentation the observer does not know whether he has to mention the impression gained at the beginning or in the middle of presentation, so reporting in an erratic or biased way. In the classical (fast) tunnel effect things go otherwise: the act of perception regards only what happens in the 100-500 msec separating the first from the third phase, allowing threshold uncertainties, but no changes of mind.

What emerges from the facts is that we are methodologically unprepared for managing the psychophysical evaluation of complex, non-stationary events, the perceptual outcome of which is changing over time (on this problem, see VICARIO, 1993b). As to the slow-motion tunnel effect, one could imagine that the aspect of the last phase will prevail against the aspects of the preceding phases (recency effect), but this is far to be proved: some experiments on length estimation of evol-

ving lines (VICARIO, VIDOTTO and TOMAT, 1994; VIDOTTO, VICARIO and TOMAT, 1996) surprinsingly show the absence of both primacy and recency effects.

The second observation to be reported refers (a) to the perception of causation and (b) to perception of succession.

(a) The coercive impression that the left rectangle is pushing out the right rectangle, or that the right rectangle is dragging out the left rectangle is undoubtedly a perception of causation, since it is quite clear which movement or object is"active" and which is on the contrary "passive". However, it is rather easy to point out that this perception of causation is not grounded on the distinction before/after, since the events on the left and on the right of the rectangle are strictly simultaneous. (Nothing new: in squeezing a toothpaste tube, we are perfectly aware that the movement of the thumb is strictly simultaneous with the movement of the coming out paste, but we clearly distinguish the movement that is "cause" from the movement that appears as an "effect". On this point, see also VICARIO, 1998b) This means that MICHOTTE's theory of perceptual causality should be reconsidered, since we have perception of causality in absence of temporal succession of physical movements.

(b) The observer of the mentioned situations is perfectly aware that the movements he sees are simultaneous. Nevertheless he feels that the movement he perceives as "active" is occurring *before* the movement he perceives as "passive": the pushing action of the right rectangle seems to precede the emerging of the right rectangle; the pulling action of the right rectangle seems to precede the swallowing up of the left rectangle). In this way not only the cause/effect relation, but even the concurrent *before/after* relation seem weakly bounded to the objective state of affairs.

7. Concluding remarks

The perceptual phenomena here described seem to take place in the frame of tunnel effect. There are of course at least two main differences between the original paradigm (BURKE, 1952) and the present setting: (1) fast versus slow motion of the object; (2) absence versus presence of the object in the "middle" phase. As to the second point, let us remember that during its sliding behind the screen, the slow moving rectangle shows both its head and its tail, and therefore the "middle" phase is only spatial, and not a temporal one. Since in fast motion tunnel effect the phases succeed each other, BURKE's setting is very suitable for illustrating the *horizontal* aggregation or segregation of events; on the other hand, since in slow-motion tunnel effect the phases are simultaneously present, the setting comes down to illustrate *vertical* aggregation or segregation of events.

As a matter of fact, slow-motion tunnel effect exhibits a lot of interesting phenomena in addition to the ones mentioned in the preceding list. Some of them are

barely perceptual: for instance, during its motion out of the screen, the rectangle grows thinner as it becomes longer, in so verifying the interdependence of visible heigth and width (LIPPS' illusion, 1897, fig. 39); vernier acuity for the misalignment of the head in respect of the tail of the rectangle is severely impaired by the presence of the interposed screen. On the contrary, some other phenomena are at the same time perceptual and expressive: for instance, when there is vertical segregation, that is when the rectangle that goes to disappear on the left is *not* the same rectangle that comes out on the right, the first is perceived *pushing* the second (when the first is long and the second is still short), or the second is perceived *pulling* the first (when the second is long and the first is already short). This last effects are clearly of the same species as the well known effects revealed by MICHOTTE (1963) in his inquiries on the perception of causation (launching, entraining, trigger, tool, *etc*.).

Apart from the many side phenomena, here reported in some detail, it seems to us that slow-motion tunnel effect is suitable for showing that there are some problems in the assumption of a rather rigid correspondence between physical happenings and perceptual events (constancy hypothesis, see VICARIO 1991). Phases of perceptual events belong each other in a way that is not the same of the phases of related distal or proximal stimuli, or of hypothesized neural processes. In our example, the building up of a unique rectangle, sliding behind a screen, is due to several factors not yet identified that certainly do not match to the ones that we can obtain from the description of physical or neural facts. We face the same problems WERTHEIMER (1923) brought to solution for the building up of perceptual objects (that is, for *stationary* events; on this topic, see VICARIO 1989, 1998a), when it was to overcome the hypothesis of a rigid correspondence of the geography of the retina with what one actually sees. Our inquiry on the slow-motion tunnel effect should be regarded as a step in this direction. We think that the research on the formation of perceptual events in our temporal field had to begin at least with the discovering of the reasons of aggregation and segregation of momentary phases, leaving to further experimentation the testing of the so-called Gestalt principles of organization (proximity, similarity, closure, passing-by curve and so on).

Summary

The well-known tunnel effect (WERTHEIMER, 1912; BURKE, 1962) is described. Since it deals with three successive movements (the first and the third modal, the second one amodal) that are integrated in one kinetic structure, it becomes suitable to illustrate the problem of *horizontal organization* of perceptual events (integration or segregation of successive events). A new kind of tunnel effect is described (a long rectangle sliding behind a standing screen, where the speed of translation of the emerging parts of the rectangle is far slower: 1 cm/sec instead of 40 cm/sec; see figure 5). This slow-motion tunnel effect deals with movements that are simultaneous (on either side of the standing screen), and then it becomes suitable to illustrate the *vertical organization* of events (integration or segregation of simultaneous events). A phenomenological investigation follows, in order to ascertain the conditions that favour either the perception of the emerging surfaces as parts of a unique object, or the perception of two distinct simultaneously evolving objects, the one disappearing under the screen and the other emerging from it. Some conditions (amount of surfaces involved, speed of their change, coaxiality of the moving objects, and so on) have been systematically treated; the effects of some other conditions (direction of the movements, asyncronies of the movements, arrangement of the surfaces in the starting and in the final frame of the animation, and so on) have been indicated. Some remarks on the perception of succession and of causation, as well on the suitableness of translating the Gestalt principles of organization (WERTHEIMER, 1923) from the perception of objects to the perception of events, are set forth.

Zusammenfassung

Beschrieben wird zunächst der bekannte Tunneleffekt (WERTHEIMER, 1912; BURKE, 1962). Da dieser mit drei aufeinanderfolgenden Bewegungen zu tun hat (die erste und dritte modal, die zweite amodal), die zu einer einzigen kinetischen Struktur vereinigt werden, erscheint er gut geeignet, das Problem der *horizontalen* Organisation visueller Ereignisse zu analysieren (nämlich die Vereinigung bzw. Trennung von aufeinanderfolgenden Ereignissen). Beschrieben wird dann eine neue Art von Tunneleffekt: ein langes Rechteck bewegt sich dabei gleitend hinter einem festen „Schirm" mit einer vergleichsweise geringen Geschwindigkeit von 1cm/sec (statt üblicherweise 40 cm/sec - vgl. Abb. 5). Dieser Zeitlupen-Tunneleffekt hat es mit mehreren gleichzeitig ablaufenden Bewegungen zu tun (nämlich auf beiden Seiten des Schirmes) und eignet sich zur Demonstration der *vertikalen* Organisation von Ereignissen ((nämlich die Vereinigung bzw. Trennung von gleichzeitigen Ereignissen). Eine Analyse auf phänomenologischer Ebene soll die Bedingungen klären, unter denen die auftauchenden Rechteck-Flächen als Teile eines einzigen Objekts oder als zwei Objekte - eines hinter dem Schirm verschwindend, das andere auftauchend - wahrgenommen werden. Einige Faktoren (Größe der Fläche(n), Geschwindigkeit, vertikale Verschiebung etc.) wurden systematisch untersucht, für die Effekte durch Faktoren (u.a. Bewegungsrichtung, Synchronizität der Bewegungen, Anordnung der Flächen zu Beginn und am Ende) gab es klare Hinweise. Es folgt abschließend eine Diskussion über die Wahrnehmung von Abfolge und Verursachung sowie über die Angemessenheit, die Gestalt-Prinzipien der Organisation (WERTHEIMER, 1923) von der Objekt-Wahrnehmung auf die Ereignis-Wahrnehmung zu übertragen.

References

BOZZI, P. (1969). *Unità, identità, causalità* [Unity, identity, causality]. Cappelli, Bologna.

BURKE, L. (1952). On the tunnel effect. *The Quarterly Journal of Experimental Psychology, 4*, 121-138.

BUTTERWORTH, G. (1991). Phenomenal permanence. In G. THINÈS, A. COSTALL, G. BUTTERWORTH (eds.), *Michotte's experimental phenomenology of perception (*pp. 117-122). Hillsdale N.J.: Lawrence Erlbaum Associate.

FRÖLICH, F. W. (1929). *Die Empfindungszeit*. Jena: Fischer.

KANIZSA, G. (1975). Amodal completion and phenomenal shrinkage of visual surfaces. *Italian Journal of Psychology, 2*, 187-195.

KANIZSA, G. (1991). *Vedere e pensare* [Seeing and thinking]. Il Mulino, Bologna.

KOFFKA, K. (1962). *Principles of Gestalt Psychology*. Routledge & Kegan, London.

LIPPS, T. (1897). *Raumästhetik und geometrisch-optische Täuschungen*. Leipzig: Barth.

METZGER, W. (1934). Beobachtungen über phänomenale Identität. *Psychologische Forschung, 19*, 1-60.

METZGER, W. (1975). *Gesetze des Sehens*. Kramer, Frankfurt am Main.

MICHOTTE, A. (1962). À propos de la permanence phénoménale: faits et théories. In A. MICHOTTE et COLLABORATEURS (eds.), *Causalité, permanence et réalité phénoménales* (pp. 347-371). Louvain: Publications Universitaires.

MICHOTTE, A. (1963). *The perception of causality*. Methuen, London.

MICHOTTE, A. & BURKE, L. (1951). Une nouvelle énigme de la psychologie de la perception: le "donnée amodal" dans l'experience sensorielle. *Actes du XIII Congrés Internationale de Psychologie*, Stockholm, Proceedings and papers, pp. 179-180.

MÜLLER, K. (1963). Der Aufbau figural-optischer Phänomene bei sukzessiver Reizung. *Psychologische Arbeiten, 8*.

PETTER, G. (1957). Osservazioni sperimentali sulla natura dell'effetto tunnel [Experimental observations on the nature of tunnel effect]. *Rivista di Psicologia, 51*, 1-15.

THINÈS, G. (1977). *Phenomenology and the science of behaviour*. Allen & Unwin, London.

THINÈS, G. (1991). The experimental phenomenology of Albert Michotte. In G. Thinès, A. Costall & G. Butterworth (eds.), *Michotte's experimental phenomenology of perception (*pp. 13-21). Hillsdale, N. J.: Lawrence Erlbaum Associates.

VICARIO, G. (1960). L'effetto tunnel acustico [Auditory tunnel effect]. *Rivista di Psicologia, 54*, 41-52.

VICARIO, G. (1963). La "dislocazione temporale" nella percezione di successioni di stimoli discreti [Temporal displacement in the perception of sequences of discrete stimuli]. *Rivista di Psicologia, 57*, 17-87.

VICARIO, G. (1965). Vicinanza spaziale e vicinanza temporale nella segregazione degli eventi [Spatial proximity and temporal proximity in the segregation of events]. *Rivista di Psicologia, 59*, 843-863.

VICARIO, G. B. (1982). Some observations in the auditory field. In J. Beck, J. (ed), *Organization and Representation in Perception* (pp. 269-283), Lawrence Erlbaum Associates, Hillsdale N. J..

VICARIO, G. B. (1989). Forma ed eventi [Form and events]. In O. Longo, (ed), *Forma, rappresentazione e struttura* (pp. 115-129) [Form, representation and structure]. Napoli: Laboratorio Servizio Tecnologia..

VICARIO, G. B. (1991). L'ipotesi della costanza in psicologia [The constancy hypothesis in psychological research]. *Rivista di Psicologia, 66*, 9-18.

VICARIO, G. B. (1993) On experimental phenomenology. In S. C. Masin (ed), *Foundations of perceptual theory* (pp. 197-219). North-Holland, Amsterdam.

VICARIO, G. B.(1993b). Considerazioni di metodo nello studio della percezione degli eventi [Methodological consideration on the study of perceptual events]. *Ricerche di Psicologia, 17*, 105-120.

VICARIO, G. B. (1995). *La percezione di eventi* [The perception of events]. (Lectures to the students of Psychology of perception, University of Padova, to be published during 1999.)

VICARIO, G. B. (1997). Effetto Benussi in campo cinetico. [The Benussi's effect in the cinetic field.] In: L. Czerwinsky Domenis, (ed). *Obiettivo bambino Pubblicazione in onore di Giorgio Tampieri (*pp. 43-52). Milano: Angeli.

VICARIO, G. B. (1998a). Introduzione [Introduction]. In G. B. VICARIO, G. B. & E. ZAMBIANCHI (eds), *La percezione degli eventi* (pp. 9-28) [Event perception]. Milano: Guerini Studio.

VICARIO, G. B. (1998b). *Time in physics and psychological time*. (Invited lecture to the International Symposium on Psychology of Time, San Marino RSM 1996, in press on Teorie e Modelli.)

VICARIO, G. B., TOMAT, L. (1992). Un caso di completamento amodale in condizioni cinetiche [A case of amodal completion in kinetic conditions]. *Giornale italiano di Psicologia, 29*, 755-768.

VICARIO, G. B., VIDOTTO, G., TOMAT, L. (1994). Valutazione della lunghezza di linee esposte stabilmente o in evoluzione: dati e problemi [Length estimation of stationary and of evolving lines: data and related problems]. *Ricerche di Psicologia, 18*, 81-100.

VIDOTTO, G., VICARIO, G. B., TOMAT, L. (1996). Length estimation of evolving lines. In S. C. MASIN. (ed), *Proceedings of the twelfth annual Meeting of the International Society for Psychophysics* (pp. 411-416). Padua: Department of General Psychology.

WERTHEIMER, M. (1912). Experimentelle Studien über das Sehen von Bewegung. *Zeitschrift für Psychologie, 61*, 161-265.

WERTHEIMER, M. (1923). Untersuchungen zur Lehre von der Gestalt, II. *Psychologische Forschung, 4*, 301-350.

Anschrift der Verfasser:

Giovanni Bruno Vicario
Dipartimento di Psicologia generale
Università di Padova,
via Venezia 8
I-35131 Padova
e-mail: vicario@ux1.unipd.it

Yoshie Kiritani
Dept. of Design & Architecture
Faculty of engineering
Chiba University,
1-33 Yayoicho, Inageku,
Japan - Chiba 263-8522
e-mail: kiritani@design.ti.chiba-u.ac.jp