THE EFFECTS OF KINETIC OCCLUSION AND CATEGORIZATION ON AMODAL COMPLETION

A comment on Gerbino and Salmaso (1987)

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The experimental study of Gerbino and Salmaso (1987) focused on the process of amodal completion, i.e. the process that leads to the impression of a total pattern in the absence of information about all parts of the pattern. One of the questions that they have attempted to answer with respect to this process is whether or not it depends on the categorization of the modal part (i.e. the part about which visual information is present) as a modification of a complete prototype. The major conclusion of their experiments is that amodal completion does not depend upon categorization. Furthermore, they interpret their results as indicating that neither the truncated form of the occluded part nor the unification/segregation of contour segments are phenomenally real.

We designed some variants of the tunnel effect to demonstrate (1) that the explicit categorization of some parts of the input can have an influence on amodal completion and (2) that the truncated form of a pattern can be phenomenally real. Our results corroborate these hypotheses and can, therefore, be interpreted as refuting two rather central claims of Gerbino and Salmaso (1987). The conclusion of our experiment must be that amodal completion is not as primary as they have supposed but can be influenced by kinetic occlusion and categorization stored in visual memory.

The experimental study of Gerbino and Salmaso (1987) focused on the problem of amodal completion, i.e. the impression of a total pattern

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in the absence of information about all parts of the pattern. They are right to stress the importance of this phenomenon, because occlusion of fragments in a visual scene is indeed more the rule than the exception. It is therefore necessary to try to give an adequate account of how human perceivers deal with occlusion and amodal completion.

One of the questions that has to be answered with respect to the process of amodal completion is whether it depends on categorization or not. Is amodal completion dependent on the categorization of the modal part (i.e. the part about which visual information is present) as a modification of a complete prototype or does it depend upon a transformation within the visual code? Gerbino and Salmaso (1987) have attempted to answer this question, which can be reformulated as cognitive vs. perceptual integration (see Kanizsa 1985), by a matching paradigm with the 'same' latencies as the crucial dependent variable.

The major result of their experiments is that amodal completion does not depend upon categorizing the modal part as a modification of a complete prototype. Hence, amodal completion is perceptual instead of cognitive. Furthermore, they find that neither the truncated form of the occluded part nor the unification/segregation of contour segments are phenomenally real (see fig. 1). Truncation and segregation do not play a role in the process of amodal completion according to Gerbino and Salmaso (1987).

We have conducted an experiment in which both of these claims are refuted. Some variants of the tunnel effect are designed to demonstrate (1) that the explicit categorization of some parts of the input can play a role in the perception of displays that could lead to amodal completion, and (2) that the truncated form of a pattern can be phenomenally real.

The tunnel effect is in fact a dynamic variant of amodal completion, first demonstrated by Wertheimer (1912) and further studied in our laboratory by Michotte and his coworkers (e.g. Burke 1952; Glynn 1954; Michotte 1950; Michotte et al. 1964). The name *tunnel effect* stems from a verbal report from one of Wertheimer's subjects who was looking at a stroboscopic movement the path of which was hidden by a screen and who described it 'as if (he or she) saw the movement going through a tunnel' (Wertheimer 1912: 224, our translation). More precisely and omitting the constraints of stroboscopic movement, the tunnel effect can be defined as the phenomenal permanence of an object that is moving behind a screen and that suddenly reappears at the other end of it. People describe it as if they 'see' the object moving

Fig. 1. (a) An occluded figure of Gerbino and Salmaso (1987) and several alternative interpretations: (b) unification/segregation, (c) amodal completion, and (d) truncation.

behind the screen, although there is no physical information about it. So, it is a form of amodal completion in which the amodal part is not static but specified by a transformation of progressive kinetic occlusion.

Before reporting the details of the experiment, let us describe our variants of the tunnel effect. In the first one (named *control*, see fig. 2a), the following can be viewed on the monitor. First, nothing is seen at all, except for a pink background; then, suddenly, a purple polygon appears, which will further be called 'occluder'; next, a small dark-brown square appears at the bottom of the purple occluder at location $p0$ and starts moving to the right (the colors were not considered an important factor, but were chosen for purposes of contrast, so that the

Fig. 2. The variants of the tunnel effect used in the experiment: (a) control, (b) occlusion 1, and (c) occlusion 2; p indicates the locations where the movement of the squares sometimes stop.

background, the occluder, and the moving objects would be clearly distinguishable); when it reaches $p1$, it is accompanied by a little square at the upper side of the occluder; from that moment on, both move at the same speed to the right side; when location $p3$ is reached, the lower square disappears behind the occluder (which is why it is called 'occluder') and the upper one keeps moving to $p4$, where it suddenly disappears. The movement from $p0$ to $p4$, which covers a distance of 14 cm, takes about 10 seconds.

In the second and third variant (*occlusion 1* and *occlusion 2* resp.), the displays look very similar (see figs. 2b and c), but the starting point is somewhat before the occluder and the movement continues to $p5$, so that the subject clearly sees either one large rectangle (fig. 2b for occlusion 1) or two little squares (fig. 2c for occlusion 2).

Fig. 3. The memory variant of the tunnel effect with its several subsequent stages; p indicates the locations where the movement of the squares sometimes stop. Starting from stage (d) this memory variant is the same as the control variant shown as (a) in fig. 2.

The fourth variant (*memory*) is rather different though (see fig. 3). First, nothing but a pink background; then, a purple polygon appears (the shape of which resembles half of the occluder in the other two conditions, so it is called 'half occluder') in the upper half of the monitor screen; next, a small brown square appears from behind the half occluder and moves to the right until it reaches p_4 , where it suddenly disappears (fig. 3a). This sequence is seen three times. Afterwards, the brown squares do not reappear, and the half occluder stands alone until another purple polygon appears in the lower half of the monitor screen. Next, a dark square appears at p_0 of this lower half occluder and moves rightwards until it disappears behind the half

occluder (fig. 3b). This phase is also shown three times. For four seconds, both purple half occluders are immobile and nothing happens. Then, a crucial event occurs: the two half occluders (with identical shapes, differing by a 180 deg rotation) start to move slowly towards each other. In the middle of the screen, they fuse to form the same kind of occluder as was used in the other variants (fig. 3c). After the fusion, which takes about 10 seconds, the subject is shown the control variant (fig. 3d).

In all variants the movement stops randomly at locations *p1*, *p2*, or *p3* and the subject has to decide as fast as possible whether he or she saw one or two objects moving. Both answers and reaction times are recorded. It must be stressed that, at *p1*, *p2*, and *p3*, the stimulus information is exactly the same in all variants, but it can be expected that the answers will differ according to what preceded.

In the *control* variant, the subject receives some ambiguous information: the moving brown thing(s) can be viewed either as one large rectangle or as two small squares. The principle of amodal completion as well as the Gestalt law of the common fate (Wertheimer 1923) can be used as the theoretical basis to predict a tendency towards the seeing of one object in this condition. Nevertheless, we claim that the bias towards a 'one' response will be relatively faint when compared with our other variants manipulating factors that have a predicted effect on amodal completion.

In the occlusion variants, the subject receives clear, disambiguating information: they see either one large rectangle partly occluded by the purple polygon or two small brown squares moving in parallel. The *occlusion 1* variant will yield a much stronger tendency to see one single object than the control variant, because information that is present over time specifies the presence of a rectangle. We predict that the phenomenon of amodal completion, which is primary and independent of categorization according to Gerbino and Salmaso (1987), can be influenced by other factors such as the kinetic occlusion of a pattern or the explicit categorization of the moving pattern as one single form (i.e. a rectangle, see fig. 4c).

These factors of kinetic occlusion and categorization play a similar but even stronger role in the *occlusion 2* variant: the information about the progressive occlusion of two little squares will cause the effect of amodal completion to disappear. The two brown parts will not be seen as an amodally complete rectangle but as two distinct forms that are

Fig. 4. (a) Our occluded figure and several alternative interpretations (in analogy with Gerbino and Salmaso 1987): (b) unification/segregation, (c) amodal completion, and (d) truncation. The occluder is omitted to avoid redundancy.

fully or modally present. Furthermore, this variant of the tunnel effect will demonstrate that truncated forms can be seen as such, which would raise some doubts about the claim of Gerbino and Salmaso (1987) that truncation does not play a role in amodal completion (see fig. 4d).

The *memory* variant is designed to distinguish between the two factors that are present in the occlusion variants: kinetic occlusion and categorization. Gibson and his coworkers (Gibson et al. 1969; Kaplan 1969; Reynolds 1968) have studied the tunnel effect in order to demonstrate that there is enough information to specify the existence of an object behind a screen and that there is, in consequence, no need to rely on memory, inference, or some other kind of mediating processing in order to explain it. The perception of the object behind the screen is, according to this direct or ecological approach, based on the direct pickup of the optical information about deletion and accretion of parts of the visual input provided by a transformation of progressive and reversible occlusion. This explanation stands in sharp contrast with the one given by some indirect or cognitive perceptionists. For example, Rock and his colleagues (Rock and Gilchrist 1975; Rock and Sigman 1973) rely on inference and 'problem solving'.

We do not claim to be able to solve the controversy between direct and indirect theories of perception by a single experimental study

(contrary to e.g. Calis et al. 1984), but we do think that our memory variant can enhance the plausibility of the influence of information present in visual memory by demonstrating that the categorization of the input as either one or two forms can precede the perception of amodally completed or modally truncated patterns by several seconds or minutes. It is predicted that people will make use of the supplementary information provided by the fusion display that precedes the control display. They will recall the disambiguating information from their visual memory and they will implicitly or explicitly 'reason' as follows: first, there was one small brown object moving across the purple half occluder; next, there was another one, and finally, both half occluders fused, so one and one makes two. A tendency to see two objects in the memory condition will not only corroborate the validity of an indirect account of the tunnel effect (for an elaboration on this validity see Wagemans and d'Ydewalle 1988). It will also refute the thesis of Gerbino and Salmaso (1987) that amodal completion is independent of categorization. The fusion display will cause the subjects to categorize the input as two truncated squares so that amodal completion does not occur. In short, we predict that the phenomenon of amodal completion can be blocked by an explicit categorization stored in visual memory.

Method

Forty-eight subjects, all undergraduates at the University of Leuven, participated in the experiment. Only students from faculties other than psychology were asked in order to be sure that they were not familiar with the original studies of Michotte. Subjects volunteered and were not paid for their efforts.

The subjects individually viewed the displays on the monitor (18 × 24 cm) of a personal computer standing 40 cm away. The subject was told to observe what was happening on the screen. In the observational phase the variant of the tunnel effect was shown three times with continuous movement. When this phase was finished, instructions were given before the response phase started. The subject was informed that the movement would stop at some places and was instructed to decide whether they were seeing one or two objects moving just prior to the stops. This was to be indicated by pressing '1' or '2' on the keyboard of the same computer as fast as possible. Answers and reaction times are registered directly by the computer. It was stressed that the question was not difficult and that they did not have to think about it. Also it was added that no response was needed at *p*4 (the experimenter pointed at the right place

on the screen). The response phase consisted of nine trials in which the moving brown object(s) stopped randomly at p_1 , p_2 , or p_3 . The movement continued when the subject pressed either the '1' or the '2' button. The randomization process was programmed in such a way that every stop place was used one single time in each group of three trials.

There are four conditions with twelve subjects being randomly assigned to each. In the control condition, the subject received the above described control variant of the tunnel effect three times in the observational phase and nine times in the response phase (this total number of 12 trials is constant over all conditions). There are two occlusion conditions, one in which subjects get the occlusion 1 variant and another with the occlusion 2 variant. The instructions in these conditions are the same as described above. In the fourth condition, however, the instructions are slightly different. In the viewing phase of this memory condition, subjects received the memory variant of the tunnel effect immediately followed by the control variant which was again repeated three times. The subject was then told that the last part of the display would be shown several times more, and the rest of the instructions were given. Everything else was exactly the same as in the control condition. More details about the method can be found in Wagemans and d'Ydewalle (1988).

Results

Two methodological remarks about the data analysis should be made, before going into the details of the results. The first concerns the use of reaction times as a dependent variable. In Wagemans and d'Ydewalle (1988), the same data are used together with some other results in an attempt to oppose direct and indirect theories of the tunnel effect. In that context, the reaction times had a significant theoretical importance. In the present paper, this measure is not as important as the answer itself ('1' or '2'), and the response times are therefore excluded from the discussion.

The second remark concerns the ANOVA that is used. The reports of one vs. two objects should be treated as categorical data, because averages falling between one and two have no sensible interpretation. Nevertheless, the categorical data were recoded in order to use an ANOVA. For the reader, the data are displayed as categorical, namely as percentages of 'two' answers. Again, not all analyses that are performed are discussed here. For example, the effects of stops and trials, which are relevant in the other context mentioned above, are not taken into consideration. The rejection rate is set at $p < 0.05$.

There is a significant main effect of tunnel effect variant ($F(3, 44) = 21.35$; $MSe = 0.63$). The percentages of 'two' answers are 41%, 12%, 85%, and 84% for control, occlusion 1, occlusion 2, and memory resp. The paired comparisons reveal all differences that could be predicted. All the experimental conditions (occlusion 1 and 2 and memory) differ significantly from the control condition ($F(1, 44) = 7.01, 16.81$, and 15.44 resp.; $MSe = 0.63$). Furthermore, occlusion 1 differs from occlusion 2 ($F(1, 44) = 45.54$; $MSe = 0.63$).

Discussion

There is a tendency to see one object in the control condition, although it is only faint: 59% of all trials is seen to be the movement of one larger rectangle instead of two smaller squares. Formulated in terms of individual subjects' preferences, four subjects perceive the display as one moving object all of the time, four others see it as one object in the majority of the trials, and only one subject perceives two objects in all trials. Thus, the control variant of the tunnel effect is a dynamic case of amodal completion: the two moving parts are amodally connected and seen as one object in the majority of the trials. Nevertheless, the phenomenon of amodal completion is not as primary as suggested by Gerbino and Salmaso (1987). The results in the occlusion variants demonstrate that amodal completion can be enhanced or inhibited by information specified over time. In occlusion 1, the effect of amodal completion is much stronger than in the control variant (88% 'one' answers compared with 59%). In occlusion 2, there is almost no amodal completion (only 15% of the trials). On the contrary, in most of the trials (85%), the little squares are perceived as two complete and separately moving objects and thus, in a sense, as mosaic (as Buffart et al. would call it) or truncated. This demonstrates that truncation can play a role in phenomena like the tunnel effect, contrary to the claim of Gerbino and Salmaso (1987).

Although there is no information about deletion and accretion of two visual structures specifying progressive and reversible occlusion of two patterns, the memory variant is most frequently seen as the movement of two little squares instead of one large rectangle (84%). This result is an indication that an explanation in terms of transformations in the optic array cannot be the full story. Furthermore, it is seen as clearcut evidence for the role of categorization denied by Gerbino and Salmaso (1987). We have demonstrated that an explicit categorization of the modal parts of the pattern as constituting two separate (i.e. truncated) objects, can have a very important negative effect on amodal completion. In the memory condition, there simply are almost no trials seen as instances of amodal completion (16% 'one' answers).

In sum, our results can be interpreted as refuting two rather central claims of Gerbino and Salmaso (1987): (1) categorization can have an influence on amodal completion and (2) truncation can be phenomenally real. The conclusion must therefore be that amodal completion is

not as primary as supposed by Gerbino and Salmaso (1987) but can be influenced by kinetic occlusion and categorization stored in visual memory.

Although we have stressed the contrast with Gerbino and Salmaso (1987) in the foregoing, some comments are now added in order to clarify our position with more nuances and less antithetically. A first note concerns the methodologies in the two studies. Gerbino and Salmaso (1987) used 'same' latencies in a simultaneous matching task as an objective measure of the importance of a phenomenal identity between an amodally completed form and a modally complete one. We used percentages of 'one' responses as a measure of the preference of the observers to see amodal completion. Some questions about the perceptual nature of our task may be asked. Indeed, our results might reflect a postperceptual effect due to cognitive interpretation. Rock (1985: 14) is very explicit about this: 'In some cases, knowledge of the possibility of perceiving something differently can lead to an active attempt to do so, which is often successful'. Our experimental situation might well be a typical instance of such cases.

These problems were present already in the original studies of Michotte and it is not a surprise that he was tackled about this issue as soon as his work became more widely known (Boyle 1972; Joynson 1971). In the more detailed report of our studies with the tunnel effect variants (Wagemans and d'Ydewalle 1988), we have elaborated our solution to this problem more fully. Here, we can stress that the problem of possible postperceptual effects remains a very difficult one even today. Buffart et al. (1981: 272) were clearly confronted with similar problems in their studies with amodal completion: 'It may be asked whether the figural completions observed in these experiments are really perceptions or are determined by more deliberate cognitive processes. This is a particularly delicate issue, since the distinction between perception and belief is not easy to make in a convincing way'.

Hochberg (1982: 196) admits also that 'the question of what a perceptual response entails is not clearly answerable'. Nevertheless, he has used the opposed-set measurement procedure as a tool for investigating the role of subjects' intentions in perceptual organization (Peterson and Hochberg 1983) and he has suggested the occurrence of perceptual couplings as a measurable criterion for saying that some response is perceptual rather than judgmental (Hochberg and Peterson 1987). Despite these efforts, he is well aware of the fact that 'nowhere

in those experiments, some version of a response bias can be ruled out' (Hochberg and Peterson 1987: 372). Therefore, it can be concluded that the issue of perceptual versus postperceptual responses is far from settled.

Furthermore, we are convinced of the possibility of similar cognitive biases in the experiments of Gerbino and Salmaso (1987), no matter how objective they may call their measure. Reaction times of about one second make subjective deliberations not impossible. In fact, the reaction times we found were very similar in absolute terms. Perhaps, it is simply more difficult to learn to say 'yes' when matching a truncated occluder with a complete target, because of factors other than categorization (e.g. unfamiliarity, complexity, etc.). It is probably no accident that accuracy is always worse in their C condition.

A second comment is about the disambiguation effect in our occlusion and memory conditions. As stated previously, the control condition yields rather ambiguous perceptual impressions (59% completions). This ambiguity is clearly reduced in the occlusion 1 condition (88% completions). Although the remaining occlusion 2 and memory conditions have also a disambiguating effect (85% and 84% non-completions resp.), the completion 'solution' is not fully suppressed. This slight asymmetry in disambiguation force can be seen as an indication for a spontaneous tendency to completion and, hence, as an argument in favor of Gerbino and Salmaso's (1987) position about the primacy of it.

However, several questions remain unanswered with respect to this position. First, why is amodal completion so primary and how is it achieved? Gerbino and Salmaso (1987: 27) have introduced the latter question but they have not answered it. They have unraveled the different stages that occur in the matching task involved in their experiments and that is a major achievement indeed. But they have not unraveled the process of amodal completion itself and that is not a minor neglect we think.

A second question is in what sense amodal completion is primary, taking into consideration that it is such a context-sensitive process as we have demonstrated it to be. Our study can be seen as one of the many showing the context-sensitivity of amodal completion (see e.g. Buffart et al. 1981; Leeuwenberg and Buffart 1984). In fact, Gerbino and Salmaso's (1987: 44) own experiment 5 makes use of a static equivalent of our kinetic occlusion conditions and they seem worried to be unable to reject the hypothesis that disambiguation is a context-sen-

sitive process on the basis of their findings. Therefore, our own study is not very spectacular in this respect, but it forces Gerbino and Salmaso to rethink their notion of the primary nature of amodal completion.

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