Experiments on the Fehrer-Raab effect and the ‚Weather station‘ model of visual masking[1]

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[1] A preliminary short version of this report was presented at the 3 rd Osnabrück Symposion Psychology, and has been published in the proceedings of the symposion (Wolff & Tücke, 1980).

Rough translation – please do not quote

Abstract

The Fehrer-Raab effect (simple reaction time is unaffected by metacontrast masking of the test stimulus) seems to indicate that a stimulus may trigger a voluntary reaction without (or at least before) reaching conscious representation. However, this conclusion can be avoided by assuming that a) it is the mask that triggers the reaction, and b) that the masked test stimulus causes a focussing of attention from which the subsequent mask profits, thus reaching conscious representation earlier than without a preceding test stimulus (This is predicted by the ‚Wetterwart‘ (metereological observer) model of visual masking.). To test this explanation three experiments were performed. In Experiment 1 the perceived temporal position of the mask was determined psychophysically using temporal order judgments. The results showed that the masked test stimulus caused an apparent temporal shift of the mask in the predicted direction. In Experiment 2 the Fehrer-Raab effect was replicated with 2 exposure times of the mask (5 and 15 msec). Reaction time was shorter with the 15 msec mask than with the 5 msec mask, although the former's masking effectiveness (as determined in a separate experiment) was much higher. This proves that the reaction was not triggered by a conscious representation of the test stimulus, and it indicates that the mask took part in evoking the reaction. In Experiment 3 the perceived temporal position of the mask was determined under conditions identical to those in Experiment 2 using the method of constant stimuli. There was an apparent temporal shift of the mask as in Experiment 1. However, comparison with the data from Experiment 2 showed that with the exception of the shortest SOA the amount of the temporal shift was only about half that of the Fehrer-Raab effect. The shapes of the psychometric functions indicated that the observers used at least two different cues for their temporal order judgments. These results make it doubtful that judged temporal order yields a direct estimate of the time of conscious perception. The time of representation and the representation of time are logically distinct, and it may be impossible to determine the former by simply measuring the latter. Some alternative methodological possibilities are briefly discussed.

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The experiments reported herein are concerned with a well-known problem. Ninety years ago, Hugo Münsterberg has phrased it as the question, "... whether the psychological final results caused by voluntary imagined movements could be achieved without a conscious voluntary act of volition (Willensthätigkeit) (and) also whether these higher intellectual functions can under certain conditions be reached without conscious perception. " (Münsterberg, 1889, p. 67).

The question aims at the relation between the kind of representation of cognitive contents – conscious or not – and the kind of functional effectiveness, that they can have. How can a cognitive content become psychologically effective without being consciously represented, and which of his functional consequences are connected to the prerequisite of having reached the stage of conscious representation?

Münsterberg's answer, as stated in the above cited work – the first issue of his 'Beiträge zur experimentellen Psychologie' (Reports on Experimental Psychology) - was radically in contrast to the general view then and now. On the basis of reaction time experiments he concludes, that a stimulus cannot only trigger associative processing before reaching the stage of consciousness, but also a motor reaction: "When perceiving the stimulus, we usually have already started to react on it; our motor apparatus does not wait for our consciousness, but fulfils its duty restlessly, and our consciousness is looking at it and is not allowed to dispose of it." (Münsterberg, 1889, p. 173).

The experiments of Münsterberg were rather sophisticated verbal reaction-time experiments, in which the kind of association task as well as the instruction of the subject was varied. Accordingly subtle was the argument, because of that he came to his conclusion. There is a much more simpler, modern experimental method that seems to confirm Münsterberg's conviction in an astonishing way.

The Fehrer-Raab effect

As is well known, masking comes into play, when two visual stimuli are presented successively at the same or nearby position at short latency. One of the most interesting types of backward-masking – namely masking of the first stimulus by the second one – is metacontrast (see, for example, Alpern, 1953; Breitmeyer & Ganz, 1976; Lefton, 1973; Neumann, 1978; Weisstein, 1972). Metacontrast can be observed, if the masking stimulus is laterally connected to the test stimulus, if, for example, a circle disk is followed by a surrounding ring. Under optimum conditions – typically at an SOA1[2] between 40 – 80 msec – the test stimulus can be completely masked; in the disk-ring-condition, for example, only the empty ring can be seen. Although the disk can be perceived inside the ring at shorter or longer SOAs, it seems to be reduced in brightness – if bright stimuli on dark backgrounds are used.

Thus it is well known that simple reaction time (reaction time a) for visual stimuli increases with decreasing luminous density (see, for example, Teichner & Krebs, 1972). Accordingly it should be expected, that a reduction in brightness up to complete phenomenal disappearance lengthens the reaction time of metacontrast. Fehrer and Raab (1962) investigated this question; and came to a surprising result: in none of the masking conditions reaction time was delayed. With short SOAs the mask even seemed to cause a shorter latency! The fact that the mask has no negative effect on reaction time, although it makes the test stimulus phenomenologically nearly invisible, was confirmed by Fehrer and Biederman (1962), and Schiller and Smith (1966). The data for these three experiments together with findings from a later critical replication (Bernstein, Amundson, & Schurman, 1973) are depicted in Figure 1.

The problem

Findings that are paradox in the sense of wording like this effect – thus are against one's views - often, as a first reaction, give rise to the question, whether

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[2] SOA (Stimulus Onset Asynchrony): Difference in time between onset of the test stimulus and onset of the masking stimulus.

they are reliable at all. Couldn't it be possible that the Fehrer-Raab effect can be turned out to be an artifact? It cannot be denied that reaction time is virtually kept unaffected by masking. But is the test stimulus in those experiments, where this can be seen, actually completely masked? Fortunately, this question, which can easily lead to an unfertile discussion about how to ensure that a stimulus is 'subliminal' (see e.g. Henrich, 1977; Koeppler, 1972), is of no relevance to our topic. The fact seems to be on the one hand, that an uninformed participant shows the Fehrer-Raab effect, although he/she only seems to react on the mask stimulus, and has not the slightest idea about the presentation of the test stimulus (Fehrer & Biederman, 1962); but on the other hand, the discrimination performance of a skilled observer is still considerable for the signal-detection method under the same conditions (Adler, 1979; Bernstein, Amundson, & Schurman, 1973). Thus, the masked stimulus is still detect<u>able</u> to a great extent; but the Fehrer-Raab-effect does not depend on actually <u>being detected</u> by the participant. Whether or not this can be termed 'subliminal', is a question of terminology.

<u>Insert Figure 1 about here</u>

We need not think about this topic, because, as already mentioned, in case of the Fehrer-Raab effect it is not essential, whether the participant is able to detect still utilizable traces of the test stimulus, or, whether it is totally masked. In any case it is reduced in its visibility at the utmost, as can be seen from the entire literature on metacontrast. If reaction time is still unaffected by masking, one has to conclude that motor reaction is not caused by this at most rudimentary existing conscious representation of the test stimulus, but by another sequence of presentation that is not affected by masking.

The problem is, how we have to imagine this effect and whether it, in the sense of Münsterberg, necessarily leads to the conclusion, that the stimulus triggers a voluntary movement without being consciously represented.

<u>An explanatory approach</u>

There is a logical possibility of explaining the Fehrer-Raab effect without going back to Münsterberg's hypothesis. It is based on the fact, that there is a good visible, and in its visual nature essentially unaffected stimulus: The <u>mask</u> deviates in case of metacontrast only slightly from the appearance of the corresponding stimulus in single presentation. The obvious hypothesis, namely that in case of the Fehrer-Raab effect, the reaction is upon the mask and not upon the test stimulus, thus seems to be opposed by quantitative relations: except for the shortest SOAs, reaction time for the sequence test stimulus – mask is clearly shorter as for the mask alone (Fig. 1).

As a result the hypothesis that the participant reacts on the (consciously represented) mask and not on the (nearly invisible) test stimulus would have been refuted only under the condition that the distance between presentation of the mask and its conscious perception is independent of a preceding test stimulus. It would be conceivable, that the faster reaction for a preceding test stimulus is because that in this case the mask can be consciously perceived faster and can therefore be answered faster by the motor system, too.

At first, this seems to be an ad-hoc hypothesis. But that is not true. By contrast, the possibility of an accelerated processing of the mask to such an extent resulted from experiments that had nothing to do with the Fehrer-Raab effect. It was only much later realized, that this might also be a possible interpretation of the Fehrer-Raab effect. The original experiments are described in more detail in other publications (Neumann, 1978; 1979) and shall be depicted here briefly.

Insert Figure 2 about here

With these experiments we intended to analyze the components of the u-shaped curve of the metacontrast-masking function. Thereby it turned out that the dissolution over time plays a critical part: The increasing masking, expanding at first with increasing SOA, is connected to the conscious simultaneity of test stimulus and mask; whereas the following decrease of the masking with yet extended SOA is connected to a dissolution over time. In trying to functionally isolate these two components, we studied among other things, how an additional ('distractor') stimulus in the visual field could affect these two components. The masking condition consisted of a disk and a surrounding ring; as an additional stimulus another disk was presented, which showed up at the same distance from the fixation point in the other half of the visual field.

As can be seen from Figure 2, the result was clear: The additional stimulus increases the masking effect; but that is only true for that part of the increasing flank, where masking starts to decrease. As mentioned above, there is already a dissolution over time; and further analyzes showed indeed, that the effect of the additional stimulus consisted exclusively in augmenting the threshold for the temporal dissolution, whereas it leaves the perceived brightness of the test stimulus completely unaffected (see Figures 3 and 4).

Insert Figures 3 and 4 about here

To explain this effect, we then came to a conception of a model that includes - beside other things – the relevant assumption for the following consideration, namely that a masked stimulus accelerates the processing of the connected mask. The basic idea was the following: In order to be able perceiving a stimulus consciously, the participant has to focus his/her attention to the corresponding position in the visual field. We have called this procedure the 'focussing' of the stimulus; which corresponds roughly to that, what the literature of the sixties called 'Auslesen aus dem VIS' (selecting from VIS [Visual information storage]). (Some of the later works following this tradition of research are, for example, those of Eriksen and coworkers (e.g., Eriksen & Eriksen, 1974; Eriksen & Hoffman, 1973; Eriksen & Schulz, 1979). In partial-report experiments this focussing procedure had been triggered by a specific indicator stimulus in the shape of, e.g., an arrow. But what happens, if a single stimulus is presented? It seems that it has to trigger the process, by which it is focussed, by itself. That sounds a little bit like Münchhausen's ability, to tear oneself out of the swamp with one's own plait; but at a closer look, it is a less remarkable trick.

When we are talking about 'the stimulus', it is, of course, a shortened way of talking, and especially then when we are talking about its physiological representation. As can be seen from relevant literature of the past two decades (see e.g., Breitmeyer & Ganz, 1976; Cornsweet, 1970; Legge, 1978), the presentation of a visual stimulus triggers activity in different neuronal 'channels', which, among other things, are specialized with respect to their spatial and temporal dissolution capacity, i.e., which are different in their sensitivity for special temporal and spatial frequencies. Now there is much support for the existence of so-called phasic ('transient') channels, specialized in the transition of temporal shifts, which transfer only low local frequencies in the spatial region. A characteristic of these channels that fits this functional specialization consists in its velocity; their activity reaches the cortical level at about 50-100 msec faster than that of the 'tonic' ('sustained') channels, specialized in high local frequencies. Concerning their function, phasic channels should have the task of reporting raw information via a shift in the visual field ('blob detectors'), and thereby triggering an attentional shift to the corresponding position. During this focussing process the activity of the slower high-frequency specific channels might come to an end, as is described, for example, by Breitmeyer and Ganz (1976), so that the focussing procedure is supplied with a – so to speak - finished picture of the stimulus.

With this kind of model the effect of the additional stimulus was well explained. The assumption was that two stimuli, appearing simultaneously at different positions in the visual field, trigger two phasic reactions, and, in doing so, also two competing signals for the allocation of attention, whereby the focussing is delayed. But unless it has consciously been attended, the test stimulus is immune to masking by the following mask. If its attention is delayed by the additional stimulus, then the temporal region in which it can be masked, is extended by the same period of time. From this the finding accounted for, that the additional stimulus causes a shift of the increasing flank of the masking function by a constant amount.

So far as to the theoretical and experimental background at that time. This model accounts for the Fehrer-Raab effect because it also implicates an hypothesis about the time of perception for the mask. In case the mask is presented alone, the process of focussing towards the mask is triggered by the activity of the phasic channels that causes its own appearance. But, if it is preceded by a test stimulus, then the focussing starts at <u>its</u> appearance; hence, it starts earlier at about the difference in time between test stimulus and mask (i.e., the SOA). If, during this procedure, the mask is in the position of the test, then it should have already been consciously represented earlier as at that point in time, at which the allocation of attention is triggered by the phasic activity caused by itself (the mask). The acceleration of its processing would be exactly equal to the SOA between test stimulus and the mask, because the focussing would have been triggered earlier at about this amount.

Perhaps the model can be made clearer by the following analogy: Lets imagine there is a meteorological observer, who surveys his instruments at a lonely station. He cannot turn his attention simultaneously to all instruments, what is not necessary, since an instrument shows a new value only from time to time. For our meteorological observer does not miss this (change), the instruments are adjusted so, that each time an acoustic signal sounds, if a notified value is changing. This signal corresponds to the phasic reaction. A certain time is passing until the observer has turned his head and moves his glasses into the right position for reading the new value. This would be the procedure of focusing. But now it can happen that an instrument changes his display twice, shortly one after the other. This would be analog to masking. The first change triggers the sound signal and starts the shift to the corresponding instrument; but before the new value could have been read, it has already been replaced by another one. The first changed value is hidden for the observer; it was 'masked'.

Suppose furthermore, that, immediately after reading, the observer gives a short message into the telex; that shall be our analogy for the motor reaction. Usually, about 1 minute is passing between the change of the display and the point in time at which the telex is set in motion. This duration might be 30 seconds, which the observer needs to go to the corresponding instrument in response to the signal, plus 30 seconds for the reading and the other actions necessary for setting the telex in motion. Let us now suppose that two changes of the display are following each other at a distance of 10 seconds. The tone triggered by the first change (= the phasic reaction) causes the meteorological observer to look 30 seconds later to the display, but which, at that point, already shows the again changed value for 20 seconds. The observer reacts to this value (that, in his view, is 'consciously represented'!) by setting the telex in motion; and from this point in time on, his 'reaction time' does not amount to one minute, as usual, but only to 50 seconds. Thus, for the observer from outside it seems as if the meteorological observer reacted to the first change of the display by activating the telex; but, he himself feels to have reacted to the second change. That corresponds to the Fehrer-Raab effect.

We have tried to test this hypothesis with a small experiment.

Experiment 1

To test the hypothesis, that a masked and invisible stimulus delays the point in time at which the masked stimulus is consciously registered, the same procedure can be used, with which optical illusions in psychophysics are measured: an identical comparable stimulus is used, that is not affected by the illusion, and the point of subjective equality is determined. In this way we proceeded in this experiment; the psychological method was the constancy procedure.

Method

The masking was produced by the disk-ring-design. The mask was a ring, appearing just about 1 deg. to the right of the fixation point; the test stimulus was a preceding disk, the square of which corresponded to the inner square of the ring. The disk appeared with less luminance density (about 1,8 cd/m^2) on dark background; exposure time for the mask was 10 ms, for the test stimulus 2 ms, and the SOA was 80 ms. The other conditions of presentation were the same as those described in Neumann (1978). Under these conditions the masking was practically total, i.e., also under careful observation no brightening could be detected in the inner of the ring, that should have indicated the test stimulus. (Nevertheless, it shall not be excluded, that a skilled observer in a signal discrimination task has any further cues for discrimination at his/her disposal; but it is, as mentioned above, not essential.) On the left of the fixation point the comparable stimulus appeared at the same distance of just 1 deg.; a ring, identical with the mask, yet without a preceding test stimulus. The experimental variable was the SOA between the mask and the comparable stimulus; it was varied in steps of 20 ms in the area from –80 ms to +80 ms. In one half of the presentations, the mask was preceded by the test stimulus, in the other half as the control condition, only the ring was presented also on the right side. In the experimental as well as in the control condition each of the 9 SOAs was presented 80 (participant W.S) respectively 32 (participant O.N.) times. The task of the observer was to indicate which of the two rings appeared first.

Results and discussion

The result is shown in Figure 5. As can be seen, the proposed effect was qualitatively clearly effective. There seems to be a temporal shift of the mask, if it is preceded by a masked stimulus. Yet quantitatively, the finding is not as satisfying: The supposition was that the mask seems to flash up at exactly that point in time, at which the test stimulus was presented in reality. That is not the case; for none of the two observers, the extent of illusion does reach to this amount. Instead of 80 ms, for W.S. it amounts to about 45, for O.N. to about 40 ms. There is a variety of possible explications for this. The most obvious is, perhaps, that it was due to the time parameters used: To reach a clearly measurable effect, we had used very large SOAs of 80 ms between test and mask stimulus. But in this case a very short exposure of the test stimulus had to be chosen (2 msec) to avoid temporal dissolution. Thus it amounted only to a fifth of the exposure of the mask; and it could be possible that the temporal difference between the two exposures was partly compensated by slower processing of the test stimulus. A further possible reason for the measured amount of the temporal shift being smaller than expected could have been caused by the choice of the comparable stimuli. To avoid the introduction of a bias in favor of our hypothesis, the SOAs of –80 msec to +80 msec were symmetrically placed around the point of objective simultaneity. For a temporal shift in the order of 80 msec SOAs of the test stimulus – mask stimulus this had meant that the participant had to judge under the experimental condition nearly always ‘right’ , which is in contrast to the well-known tendency of equal distribution of judgments.

Insert Figure 5 about here

The intention of the following two experiments to be reported was - besides other things – to reach further explication of this issue. But primarily it was intended to establish a connection to the Fehrer-Raab effect by way of measuring this effect and the temporal shift effect under most similar conditions.

Experiment 2

In this experiment, which was developed by Barbara Rosengärtner in the course of her Diploma (Rosengärtner, 1980), the Fehrer-Raab effect should have been measured. Beside the disposability of comparable data, the experiment was based on the following experimental approach:

If it is correct that the participant reacts upon the conscious representation of the mask also then, when reaction time seemingly ‘starts to run’ from the onset of the test stimulus, then the features of the mask should be reflected in the reaction time. More precisely: It is well-known that for simple reaction times in the order of up to about 10 - 20 msec Bloch’s law is effective; i.e., a prolongation of presentation time leads to the same shortening in reaction time as an energetically corresponding increase in luminance density (Hildreth, 1973). Thus a prolongation of exposure time of the mask should reduce reaction time in this temporal range also then, if the participant seems to react to the test stimulus. On the other hand, the effect of the masking is obviously enhanced by this. So, in case the reaction were triggered by a somehow conscious representation of the test stimulus, then the reverse prediction should hold; the reaction should be slower when the mask is exposed for a longer time.

Pre-test

The intention of the pre-test was to compare the effect of different masks. As in Experiment 1, the test stimulus was a small cyclic disk on the right of the fixation point. In contrast to the first experiment the disk was not masked by a ring, but by a larger cyclic disk with the same diameter as the outer contour of the ring in Experiment 1 (Fig. 6). Except that, the design of the stimulus and the other test conditions were the same as in Experiment 1. Luminance density of all stimuli was about 4 cd/m^2 . The test stimulus was exposed for 5 msec. The exposure of the mask could amount to 5, 10, or 15 msec. There were eight SOAs of 5, 15, 25, 35, 45, 65, 85, and 105 msec.

The effect of masking was determined according to a verbal judgment method. As already reported, it is essential for the masking effect in case of metacontrast, whether a succession of test stimulus and mask is perceivable. This dimension was judged by the observer: “1”, in case of only one temporally integrated stimulus being perceivable, “2”, in case of test stimulus and mask being perceived successively. The second essential cue for the presence of the test stimulus is the number of perceived contours: In the area of strongest masking with medium SOAs, only the outer contour of the mask can be seen; in case of less masking, in the inner of the mask a more or less clear second contour can be seen, the one of the test stimulus – so that the whole looks like a fried egg. In an earlier, still unpublished experiment, we found that these two cues ‘succession’ and ‘contour’ are good indicators for detection performance in these kinds of masking. At least one of them must be perceivable, so that the observer can detect the test stimulus. Besides the judgment “1” or “2”, the observer made a binary judgment in relation to this dimension (“yes” presence, “no” absence of the inner contour) after each exposition. Each of the 24 combinations of the 8 SOAs and the 3 exposure times were judged by each of the two observers for 12 times.

Insert Figure 6 about here

As the data of both observers were rather similar, they were combined in Figure 7. In correspondence with earlier findings (Neumann, 1978), the exposure time of the mask has only a small impact on the temporal dissolution, but massively influences the degree of masking in case of temporal integration of test- and mask stimulus. At 5 msec the observers were still able to detect in this range and at all SOAs indicators of a contour of the test stimulus. At 10 msec the part of the ‘yes’ judgments is a little bit reduced; at 15 msec it is only just between 50 (SOA 5 msec) and 25 percent (SOA 45 msec).

Method

According to these data the conditions for the main test could be chosen. In doing so, we took the following points into account: First, the participant should always perceive only one single, temporally integrated stimulus – this was above all essential with regard to the test with the temporal shift (Experiment 3). On the basis of the findings of the pre-test (and in accordance to earlier data, see Neumann, 1978), this is reliably the case up to an SOA of 45 msec. For the main test the three SOAs of 5, 25, and 45 msec were chosen. The exposure time of the test stimulus was as in the pre-test 5 msec, respectively; thus the ISIs were 0, 20, and 40 msec. Second, according to the above reported rationale of the experiment two exposure times of the mask should be compared, from which the longer one (a) triggers a faster a-reaction according to Bloch's law, and (b) has a stronger masking effect than the shorter one. In the range of temporal integration, the data of the pre-test show a distinct difference in the masking effect between the exposure times of the mask of 5 and 15 msec. These times of exposure meet according to the data of Hildreth (1973) also condition a. They were used in the main test.

Insert Figure 7 about here

The experimental design thus consisted of 3 (SOAs) x 2 (exposure times) masking conditions. Additionally, there were three control conditions: Presentation of the test stimulus alone and the mask alone with the two exposure times. Thus, in total there were 9 experimental conditions.

The course of test was the following: A trial started with an acoustical warning signal. After 700 or 850 msec the presentation of either the test stimulus-mask succession or one of these two stimuli alone started according to the respective test condition. (The two foreperiods had a random succession; each half of the experimental conditions was combined with the shorter and with the longer foreperiod, respectively. The duration of the foreperiod was always the interval 'onset warning signal – onset test stimulus'. In both conditions, in which the mask was presented alone, the SOA was 5 msec in the experimental control, but the exposure of the test stimulus was inhibited by interrupting the connection to the tachistoscope. Thus, in this case the actual foreperiod was 5 msec longer as in the other conditions).

The participants were two skilled observers (B.R., female; H.C., male), who conducted the experiments in the course of their diploma. Each participant made 15 test trials, in which each of the combinations of 9 experimental conditions and 2 foreperiods were randomly presented 4 times, respectively. The participant reacted by pressing a morse button. Reaction time was measured exactly to one millisecond.

Insert Figure 8 about here

Results

The data of a session were mediated for each of the 9 experimental conditions. The medians for all sessions are depicted in Figure 8. The two most important findings can be seen directly in the Figure: First the Fehrer-Raab effect was replicated. The pattern of results in case of H.C. corresponds in all details to that of earlier experiments, which was already analyzed in Figure 1. This is also true for B.R. with the restriction, that contrary to the usual finding, the reaction time for the combination of test stimulus and mask in case of the two longer SOAs (25 and 45 msec) is slightly longer (between 1, 2, and 3,9 msec) as compared to the test alone. Thus, the Fehrer-Raab effect did not show up perfectly in this case, but, of course, it did not fail to come, as the measured times are far beyond those, that were to be expected, if the participant reacted but to the mask. The second important result concerns the effect of the exposure duration of the mask: as was expected, the reaction time for the exposure of 15 msec is according to Bloch's law somewhat lower as for the exposure of 5 msec. The remarkable fact is, that this not only holds for the presentation of the mask alone, but also if it is preceded by a test stimulus, and the Fehrer-Raab effect occurs.

For the statistical analysis the reaction times of each participant were mediated over each session, so that the analysis of variance comprised 15 values per cell respectively from each participant.

The first analyses were to assure, that the Fehrer-Raab effect was replicated at all; i.e., the Null-hypothesis was to be tested, that the reaction in all conditions was solely determined by the mask. Therefore the data were calculated as 'Reaction time from (onset of) mask'. The factor 'SOA' consisted of the three SOAs 5, 25, and 45 msec as well as of the basic condition 'mask alone'; the factor 'duration of exposure' comprised the two values 5 and 15 msec. For both participants a highly significant effect of the SOAs could be seen (H.C.: $F(3,42) = 744.23$, $p < .001$; B.R.: $F(3,42) = 429.23$, $p < .001$). For H.C. the duration of exposure of the mask was a significant factor ($F(1,14) = 5.76$, $p < .05$), whereas for B.R. a trend into the same direction did not reach significance ($F(1,14) = 2.11$, $.10 < .20$).

In case of both single analyses there was no sign of an interaction between SOA and exposure time of the mask ($F < 1.0$), what accounts for the impression of a nearly parallel course of the reaction time curves for 5 and 15 msec. (Fig. 8). Although the reaction time 'from onset of mask' is massively shortened by the preceding test stimulus, the impact of the exposure time of the mask is still kept unchanged.

The following analyses were based on the reaction times, calculated from the onset of the test stimulus.

If reaction time would be determined exclusively by the test stimulus, then it would have to be expected that the exposure duration of the mask has no effect on the reaction time in those conditions, in which it is preceded by a test stimulus. According to the pre-analysis this seems to be the case although. Neither the reaction time in this case, measured from onset of the test stimulus might depend on the SOA. We studied this in the following analysis, in which only those conditions were taken into account, in which the test stimulus as well as the mask were presented; here the factor 'SOA' thus had only the three steps 5, 25, and 45 msec. Apart from that, the proceeding was the same as reported above. The separated ANOVAS for both the participants had corresponding results:

The SOA had an very significant impact on reaction time (H.C.: $F(2,28) = 12.95$, $p < .001$; B.R.: $F(2,28) = 6.28$, $p < .01$); exposure duration of the mask does not reach significance any more. (H.C.: $F(1,14) = 1.88$, $.10 < p < .20$; B.R.: $F(1,14) = 1.62$, $.20 < p < .25$).

As it is unimportant, of course, for the presence or absence of an effect of the exposure time of the mask, whether reaction time is measured from the onset of the test stimulus or the mask, and because the preceding analyses resulted with the inclusion of the condition 'mask alone' in an significant effect of the exposure time and not into an interaction with the SOA, the narrow miss of significance in the actual analysis will have no other meaning, that in this case the number of measurements was not sufficient to reach clear reliability.

The more important aspect of the pattern of results is the distinct impact of the SOAs to reaction time. It is obvious that neither the reaction is triggered by the test stimulus alone nor (according to the preceding analysis) exclusively by the mask. Reaction time is with an SOA of 5 msec at the lowest and increases with the two longer SOAs. That proves an impact of the mask. A cue for the kind of impact can be seen from the next analyses, in which for each of the two exposure times of the mask and for each of the two participants separately a one factor ANOVA was calculated, which included the condition ‘test stimulus alone’ as the fourth step of the factor ‘SOA’. Unfortunately, this factor reached here only significance in case of H.C. (duration of exposure 5 msec.: $F(3,42) = 3.66$, $p < .02$; duration of exposure 15 msec.: $F(3,42) = 4.92$, $p < .01$), whereas for participant B.R., the data of whom are more ‘noisy’ in total, no significant difference can be reached with this analysis of the values. For H.C. the following Dunnett-Test with the condition ‘test stimulus alone’ as control condition shows as the only significant difference a decreased reaction time with the SOA 5 msec (exposure duration 5 msec: $t(4,15) = 3.17$, $p < .02$; exposure duration 15 msec: $t(4,15) = 3.80$, $p < .01$, two-sided).

Discussion

First, the experiment should test, whether the Fehrer-Raab effect is replicable under our conditions, and second, it should give an indication of the effect of the exposure duration of the test stimulus. The replication was successful; for the two participants the reaction time on a mask that is preceded by a test stimulus with an SOA of 25 or 45 msec is far beyond the latency on the mask alone. A comparison between the reaction time on the masked and the unmasked test stimulus shows in case of H.C. the typical pattern of results from earlier experiments: with a short SOA the latency on the masked test stimulus is even still lower as on the unmasked test stimulus, and with increasing SOA it comes closer to this one. In case of participant B.R. it seems as if for the two SOAs of 25 and 45 msec the reaction time for the succession test-mask is slightly longer as compared to the test stimulus alone; a tendency, that does not reach significance yet. What has caused this effect, if it should be real, is not clear.

The fact, that the latency for the exposure duration of the mask of 15 msec is generally slightly shorter as compared to the 5 msec latency, clearly proofs that the reaction could not have been triggered by a conscious representation of the test stimulus. As has been shown in the pre-test, in case of an exposure duration of 5 msec and the SOAs used here, nearly always a trace of the test stimulus can still be detected, whereas with 15 msec usually nothing of it can be perceived. If, nevertheless, in the last case the reaction time is shorter, this can only mean, that the motor reaction does not depend on that representation of the test stimulus, which is based on the judgment of the observer on the perceived shape of the stimulus. If the exposure duration of the mask with preceding test stimulus would have no influence at all on reaction time, then this would allow for the hypothesis, as an early advocate of which we have got to know Münsterberg: The test stimulus triggers the reaction before it could still become conscious, and consciousness is thereby only an interested observer – here, due to masking, acting like an observer, whose sight is covered. But without him it even works as well, and with him it does not work better.

But now we find, that over all SOAs the more effective mask does not only not lengthen the reaction time, but even shortens it. For the presentation of the mask alone this was to be expected according to Bloch's law. But how can this effect continue, if a test stimulus precedes and then, as supposed by the Münsterberg hypothesis, the reaction is already triggered by him long ago, when the mask reaches the stage of conscious representation? At first glance, it looks as if we have with this a rather unequivocal confirmation of the hypothesis, which I scheduled as our starting supposition. If the reaction is really on the consciously represented mask under masking conditions, too, and the effect of the test stimulus only results in a forward shift of the point in time of this conscious representation, then it would not be surprising, that also in this case the longer and therefore seemingly brighter mask has still the shorter reaction time.

But if we think about it in more detail, it becomes clear, that the finding corresponds nicely to our considerations, but gives no special impressive proof for their correctness. It proves that some kind of representation of the mask which underlies here the varied area of the summation of brightness, has an supporting impact on reaction time. But that does not proof, that this is its conscious representation. If the test stimulus can trigger a reaction, <u>without becoming conscious at all</u>, then the mask could support this procedure thus, <u>still before</u> it has become conscious. Thus, the actual test of our hypothesis cannot be supplied with this finding; and this was not intended with Experiment 2. This should have been tried with Experiment 3, which in terms of its experimental design is a replication of Experiment 1, i.e., a psychophysical determination of the perceived temporal position of the mask, yet under conditions, which are exactly corresponding to Experiment 2, so that the direct comparison of the reaction time data is possible.

Experiment 3

This experiment was conducted by Hans Cazin in the course of his Diploma (Cazin, 1981). The plan had been to take over all conditions of Exp. 2 to Exp. 3. But the pretests indicated a less clear pattern of results as expected. Therefore, we decided to reduce the number of possible combinations of conditions, and to augment the number of observations in each combination of conditions instead, as well as to conduct the experiment additionally with a third, unskilled participant (M.M., male).

Method

The reduction of combinations of conditions was reached by using only one exposure duration of the mask, namely 5 msec. The question of the experiment, whether the perceived temporal position of the mask will be shifted by the preceding test stimulus to the same amount to which the reaction time is shortened, can be answered without varying the exposure duration of the mask. Furthermore, the condition ‘test stimulus alone’ could be omitted, as the necessary control value was delivered by the condition ‘mask alone’. So there were the following masking conditions: Mask alone, SOA 5 msec, 25 msec, and 45 msec with exposure of test stimulus and mask for 5 msec, respectively. Figural features, position, and luminance density of the stimuli were the same as in Exp. 2. Additionally, the comparable stimulus appeared, which was identical to the mask except being located – at same distance – on the left instead of on the right side of the fixation point. As another experimental variable the SOA between the mask and this comparable stimulus was introduced. Variation was made in steps of 20 msec between –80 msec (comparable stimulus precedes) and +80 msec (mask precedes), thus at 9 stages. (To avoid misunderstandings in the following, the SOA between test stimulus and mask will be called SOA(M) (masking SOA), and the SOA between mask and comparable stimulus SOA(C) (comparable stimulus-SOA).

All 36 combinations of the 4 SOAs (M) and 9 SOAs (C) were presented 8 times in random succession in each test trial of 288 presentations. There were 10 test trials for each of the 3 participants, so that the evaluation is based on 8640 single judgments in total. The participant indicated by the judgment ‘left’ or ‘right’ which of the two stimuli – the mask or the comparable stimulus – was seen first. As the area of the SOAs(M) stayed beyond the threshold of temporal dissolution (see pretest of Exp. 2, p xxx), this instruction was clear. Also in case of a perceivable trace of the test stimulus, it appeared simultaneously with the mask. The judgment 'simultaneously' was not allowed; in case of doubts, the participant had to guess. As in Exp. 2, each presentation was preceded by an acoustical warning signal at a distance of 700 msec, calculated from the onset of the test stimulus. (For condition 'mask alone' the control was the same as reported for Exp. 2).

Results

The results are depicted in Figure 9., which illustrates the relative frequency of judgment 'right' (i.e., mask is seen/perceived first) in relation to SOA (C) - abscissa – and to SOA(M) – parameter of curves – of the three participants and mediated over them.

A statistical analysis is not very fruitful in case of an psychophysical experiment like this in which measures are taken. For the sake of completion an analysis of variance was calculated for each participant. For each of the 36 cells of the experimental design (4 SOA(M) conditions including 'mask alone'; 9 SOA (C) conditions) the relative frequency of the judgment 'right' from each of the 10 experimental sessions was determined.

Insert Figure 9 about here

These values were taken into the ANOVAs after arc-sin transformation. Both factors showed a highly significant effect for all 3 participants (always $p < .001$). Also the interaction for H.C. and M.M. was highly significant ($p < .001$), whereas for B.R. it just missed significance on the 5 % level. As can be seen from Fig. 9, this interaction is easy to explain; it is the expression for having chosen a slightly too large area of the SOAs (V), namely from –80 msec up to +80msec, so that the extreme SOAs were outside the threshold functions, i.e., resulted in 100% respectively 0% 'right'-judgments in all conditions. That the judgment changed according to the SOA (V), is, of course, also trivial. The only essential fact for the experimental question is the significant effect of the factor SOA(M) (H.C.: $F(3,27) = 30.70$, $p < .001$; B.R.: $F(3,27) = 7.70$, $p < .001$; M.M.: $F(3,27) = 34.38$, $p < .001$).

Thus, there is no doubt that the test stimulus preceding the mask has shifted the perceived temporal position of the latter. So the finding from Experiment 1 was replicated. But the main topic in this experiment was about the amount of the shift: Is it in the scale, that would be necessary to lead back to the Fehrer-Raab effect measured in Exp. 2 to this temporal-shift effect?

Originally, it was planned to determine the amount of the temporal shift by an exact calculation of the threshold, i.e., to find out by calculation the point of subjective simultaneity. Prerequisite would have been, of course, that we can rely upon a normal psychometrical function, that the data thus follow a Normalogive or can be transmitted into it. As is shown in Figure 9, this is surprisingly not the case. A flattening in the middle segment of the threshold function can be seen differently clearly for the three participants, which makes it impossible to determine exactly the point of subjective equality. Therefore we have restricted ourselves to the graphical determination of an approximate value for the amount of the temporal shift. The curves from the three experimental conditions (test stimulus → mask) were shifted horizontally against the curve in the comparable condition (mask alone) until the best coincidence was reached and the amount of the shift was read exactly up to one millisecond. This has been done for each of the three curves for each participant for 10 times. The standard deviation of the 10 determinations was between 0.82 and 1.29 msec. A later examination by a second evaluator resulted in similar values (median difference between the two evaluators: 1.9 msec). These estimates for the temporal shift are depicted in Figure 10 together with the values for the Fehrer-Raab effect.

Insert Figure 10 about here

Discussion

Although the proposed effect did show up in principle, the data are at first sight not very satisfying, and this for three reasons: First, as can be seen in Figure 10, the temporal shift did in no case reach the amount, which should be expected, if our hypothesis were right, because of the reaction time data, with the exception of SOA(M) of 5 msec. Second, the psychometrical function shows an atypical course, namely more or less marked for all participants and under all conditions. And third, there are clear differences between the three participants regarding the amount of the temporal shift as well as concerning the deviation of the curves from the form of the normalogive.

The following considerations might offer the opportunity to understand this pattern of results. For the time being they are speculative and need testing by further experiments. At first, we inquire how it could have come to the deviation of the psychometric function from the normalogive and to the differences between the observers, and then return to the Fehrer-Raab effect.

The observer's task of judging which of two successively presented stimuli was the first is formally comparable to the task of judging, which one of two stimulus objects presented in a three dimensional field is the spatially closer one. In case of this latter situation the participant will use cues, and, in doing so, depending on the respective circumstances, which of these (e.g., the binocular like cross-disparation, convergence, and accommodation, or the monocular like overlap and linear perspective) and with which weight will determine the final judgment. We have nothing else to expect, if we give an observer the task of judging the temporal succession of two stimuli.

The temporal succession is as much and as less 'immediately given' as the spatial order: Under usual conditions it is so in the sense, that it is not the result of a conscious construct, but rather is phenomenologically simply 'there'; but it is in no way in the sense, that the perceiver, so to speak, would immediately know about it, without the need of cognitive processing that mediates this knowledge. That the temporal succession is perhaps not as clear with the temporal arrangement as with the spatial one is thus based on the complicated double character of the dimension 'time': It is, like among others the surrounding space, one of the cognitive arrangement dimensions; but it is at the same time also the dimension, in which the cognitive processes take place, measurable for the observer outside. Therefore it easily comes to a confusion between the time of perception and the perception of time (or, for example, also in the variant of Efrons (1970), a confusion between the perception of the duration and the duration of perception: The perceived duration, say, of a flash light is something different than the duration of perception, the content of which is this perceived duration. As well as – despite Chomsky – the idea of the green is no green idea.).

Which are the cues for the temporal succession of two stimuli? On looking through the experimental literature it can be seen at first that the cues itselves can be of a non-temporal kind in various ways. The most obvious – and in the literature on time discrimination often neglected (but see Sternberg & Knoll, 1973) – example is the phenomenological localisation in the acoustic space, which still allows for the discrimination of smallest temporal successions of tones. In case of visual and auditory stimuli, a further non-temporal cue is the perceived clarity or intensity, above all with close spatial vicinity between the two stimuli. It allows for the discrimination of the succession still with SOAs of only some milliseconds (Efron, 1973; Yund & Efron, 1974).

In these cases a temporal feature of the stimulation is represented, but not as a temporal aspect of the phenomenal representation, but in the shape of its spatial or qualitative aspects.

But also, if the discrimination of the feature dimension 'time' is mediated by the temporal aspect of the phenomenal representation, too, the question arises, which cues allow the participant to discriminate between simultaneity and succession. Time is thus not perceived as such, but rather it is the dimension, in which perceived processes take place. So it has to be clarified, which kinds of

processes at the perceived representation of the stimulus succession allow the participant to judge right, which one of the two stimuli was the first and which one was the second.

A process that is possible primarily with visual stimuli appearing at neighbouring positions, is apparent motion (Thor, 1968; Robinson, 1968). Here the temporal succession is spatially represented as the direction of movement; hence it is clear, that the discrimination is not simply based on the perception of 'time', but rather the perception of a process 'in the course of time' (here spatially directed). This is, in my view, in principle also the point with the following cases to be reported on, in which no apparent motion can be perceived.

Which processes can be perceived depends, of course, on the spatio-temporal structure of the stimulus succession. The perhaps simplest case is that, in which the two to be discriminated occurrences are the appearance and disappearance of one and the same percept . If they are perceived as in succession, then the impression of 'duration' arises; if they temporally coincide in the phenomenal representation of the stimulus, then a 'flash' is visible – the stimulus object disappears – one can say - at the same instant at which it appears.

This qualitative difference in the representation of a short visual stimulus was already mentioned by Piéron (1923) in his outstanding essay on the problems of temporal perception. In a practice experiment (Braukmann, Heinze & Richter, 1975), we found that the threshold for this transition can be determined quite reliably; it is about 60 msec. In the meantime the work of Servière, Miceli, and Galifret (1977) has been published, which confirms this value.

If the two transients, marking the temporal onset and end of the appearance of a perceptible object, are closer than about 60 msec, they are hence not perceived as being separate occurrences. How is it in case of two transients that both mark the onset of a perceptible object each at the same position? We already know the result: This is the situation in which the second stimulus masks the first one; and as we have seen (Fig. 7) here the threshold for temporal dissolution is at the same position, hence at about 60 msec. Beyond this threshold the 'flash' is perceived again, whereby the figural as well as the brightness and colour features of the perceived stimulus object are the result of an integration of test stimulus and mask (see above). In case of going above this threshold the perceived process indicating the temporal succession is not still duration, but change – e.g., in case of the metacontrast-disk-ring arrangement the change of the inner of the ring from bright to dark.

At this point we can return to our problem, the peculiar form of the psychometric function in our experiment and the differences between the participants. Which course of the psychometrical function would have to be expected, if the participant would only use the cue 'change' to answer the question which of two stimuli was the first one at the same position. The judgment would have to rely thus on the direction of the change, e.g., from bright to dark or from dark to bright. But that requires, of course, that the change can be perceived at all; and as we have seen, the threshold for the perception of this process is about 60 msec. The threshold function starts of course already to increase, but, as our data as well as those of Servière et al. (1977) show, the probability of perceiving a change or duration, respectively, is beyond an SOA of 20-30 msec practically null. If the participant could exceptionally use this cue, then he/she has to guess at a shorter SOA, which of the two stimuli was the first one. This holds for no matter which stimulus x or y is the first. The psychometric function should therefore have a flat course in the range of –20 to 30 msec to +20 to 30 msec, as is illustrated in Fig. 11a. But that is – much stronger marked - exactly the contour of the curve, which we have found in our experiment!

Insert Figure 11 about here

Therefore, the problem turns round: necessary of being explained is actually no longer the deviation of our psychometrical functions from the normalogive, but the small amount of this deviation. Apparently, there must be another cue available in our experimental design than those discussed so far.

Hence, our design differs – as most experiments on temporal discrimination – from the cases reported so far in that the two stimuli, the succession of which is to be judged, are in different positions in the visual field. It seems likely to suppose that this is the reason for the difference. But what does the additional cue consist of? Apparent motion must be ruled out, because it cannot be made responsible for the discrimination performance beyond 20-30 msec. Is there another form of representation of 'change' that can be used at such a low SOA, namely just in case of spatial separation of the two stimuli? I cannot completely exclude this possibility, but it is implausible. If the SOA is as short that two stimuli at the same position are represented as a single process of flashing, it cannot be seen, how in case of separated location a process can be perceived, which they are parts of. In this case, additionally, the necessity of a spatial shift of attention must be taken into account.

This conclusion seems to refute our starting assumption, that the participant disposes of temporal information only to the amount to which this information is cognitively represented in a perceived process. The contradiction disappears, if we drop the silently made assumption, that in the process containing the succession information necessarily both succeeding stimuli must be cognitively integrated, as in case of 'duration', 'change', and 'motion'. But that is not necessary at all for the participant's ability of solving the task. That one of the two stimuli is the first one can also be represented as a feature of its own appearance as such. In other words: to make a correct judgment, it is sufficient for the participant to be informed that one of the two stimuli – say, the right one – is the first one. The cognitively represented process can be this ‘right – first – appearance’; it must not include the second stimulus at all.

The basis of functioning in case of this procedure of the ‘first to appear’ could hence be due to a process which I have tried to illustrate in the beginning with the example of the weather station man: the shift of attention to that position, where – indicated by the activity of ‘transient’ neuronal channels – a change took place. We hypothesised that the weather station man will be informed about this change by an acoustic signal and then needs a certain amount of time until he has gazed at the measuring instrument in question. If the display changes again when he is turning to the instrument, then this remains hidden and the result of the first change is ‘masked’. Similarly, we suppose that an acoustic signal of another instrument keeps undetected in this space of time. (Although it might be registered later, because the warning signal still continues – this would be a symbolisation of an aspect of ‘visual persistency’). If we now ask the weather station man, which of the two instruments – that one which he turned to, or the other one – has changed its display first, then he will answer this question just as good correctly. He will say: It must very well have been that one, which I have turned to; because if it had been the other one, then I had turned to that one.

The discrimination of temporal succession according to this model should result in a psychometrical function in the shape of a normalogive (Fig. 11b). If there were no noise at all during the processing of the two stimuli, then it should be a stage function at the SOA null, i.e., the participant should always give the correct answer. Indeed the processing durations for the two stimuli will form two distributions which overlap each other depending on their temporal distance, so that the same conditions are given as in that case, when the threshold function shows the normal form of the Ogive.

Due to these considerations, we can understand the forms of the psychometrical function in our experiment as an overlap of the both ideally typical forms of curves in Fig. 11. If the succession judgment would be based exceptionally on a cognitive represented process of the kind of a ‘change’ integrating the two stimuli spatio-temporally with each other, then the course as depicted in Fig. 11a should be found. If the participant would be able, on the other hand, to rely exceptionally on the fact, which of the two stimuli calls for attention as the first one, than the course should be the one as can be seen in Fig. 11b. Apparently both kinds of cues are essential, namely, in fact with a differing weight from participant to participant as is illustrated in the form of the psychometrical function (Fig. 9).

General Discussion

The judgment of the observer about which of the two visual stimuli being 'the first', hence does not reflect, as we had presupposed perhaps a little bit naive, the temporal distance between the conscious representations of both stimuli directly.

This temporal distance is – anyway in connection to our topic in question which is dealing with the explanation of the difference between reaction times – defined in the (physical) reference system of the external observer. The difference in time about which a psychophysical measurement can give some information, yet belongs to the reference system of the psychological time, where the - for the observer cognitively represented - processes took place.

Furthermore: In the psychophysical experiment, the observer does in principal not at all tell something about the temporal or other features of his cognitive representations, but about features of the content represented by them. The temporal distance between two representations, which was of interest to us in the context of our question, hence cannot at all be object of his/her judgment. Rather, his judgment itself relies on a cognitive representation, namely on that of a process, which can be different and that can lead to different psychometrical functions.

Following these conclusions, a psychophysical measurement that we made in Experiment 3 cannot afford such an immediate testing of the weather station model as an explanation of the Fehrer-Raab effect as we had hoped for. On the other hand, some expectations can be derived from the results:

According to the weather-station model, the participant reacts on the consciously represented mask in Experiment 2, which was however advanced in time by the preceding test stimulus, namely by the amount of the SOA (M) (the SOA between test stimulus and mask). Their judgment in Experiment 3 depended according to our expectation on two cues, namely the perception of a succession between mask and comparable stimulus in the one or another direction; and the noticed direction (to the mask or to the comparable stimulus), in which the attention was directed first by the onset of exposition.

Under the supposition of the weather station model, the second cue would be determined by the SOA between the comparable stimulus and the test stimulus alone, because the latter seems to trigger the shift of attention to that position, at which in the following the mask is focussed. In using this cue it hence would lead to a shift of the psychometrical function to the complete amount of the SOA between test stimulus and mask. That this was not the case could be explained by the fact that this cue was not sufficiently used. An indication therefore could be that the participant M.M., which showed the smallest flatten out in the middle of the psychometrical function, also showed a clearly stronger shift in time as compared to the other two observers.

It then has to be explained why the shift is smaller, when the participant more often uses the cue “perceived succession” for his/her judgment. Basically it is true in this case, as mentioned above, that a change in time of the representation (like supposed by the weather station model) must not necessarily lead to an exactly corresponding change in the representation of time (as can be seen from perceived succession). These general facts could be taken as an explanation of our data in form of a radical and a less radical variant.

The less radical variant supposes, that the perceived succession is determined in its temporal relation to the comparison stimulus not only by the onset, but also by the end of the representation of the mask. According to the weather station-model the beginning of the conscious representation of the mask is advanced in time by the test stimulus, its end, however, not. The mask had then to appear extended (which also corresponds to the introspection of the author). If the observer would take both points in time into consideration for this judgment by using the temporal midpoint between onset and end of the representation of the mask as reference value, then the effect of the temporal shift had to divide itself into two halves as compared to the Fehrer-Raab effect, which would nearly correspond to the conditions in Fig. 10.

The more radical supposition is, that the perception of succession is generally independent from the matters of attention, as is dealt with in the weather station-model. It is obvious that neither change in the time of representation caused by changes of attention can affect the representation of time; otherwise one would see, e.g., in viewing a still scene, the elements of it successively appear and disappear, according to the moving of attention.

Perhaps then the information represented temporally as perceived succession is mediated by transformation channels, which are completely or in any case to a large extend insensitive to effects of attention. That the proposed effect qualitatively appeared at all in Experiment 3 would then be due to the fact, that all participants also used the second cue, which is independent of perceived succession. Whether one of these two explanations is right, has to be clarified in experiments, in which these supposed cues are specified as judgment criteria.

Independent of the result from those experiments there are considerable logical doubts, that our basic question can be answered at all in comparing reaction-time data and data from a psychophysical threshold experiment. The working hypothesis 'time of perception' cannot precisely be explained by procedures, in which the perception of time is examined. Maybe it is not precisely explainable at all by psychological methods; but perhaps there are possibilities to avoid the difficulties that are involved in our procedure. Therefore, it would be necessary to find criteria for the point in time of the conscious representation, which are not fixed at a temporal judgment of the participant. Is it possible to assume, e.g., that a choice reaction can be triggered not until the stimulus is consciously represented? Experiments conducted by Peter Wolff and co-workers in Osnabrück (e.g., Brüggen, 1981) show promising points of departure for such a methodological approach.

Another aspect, that may not be neglected in discussing the question asked in the beginning, is the neuro-psychological one. Here are very clear indications that visual stimuli can be responded to motorically, although they do not reach conscious representation due to neurological failures (phenomenon of 'blind-sight'; see e.g. Perenin & Jeannerod, 1978; Weiskrantz, Cowey, & Passingham, 1977; Weiskrantz, Warrington, Sanders, & Marshall, 1974).

During the last years there was a kind of rethinking in cognitive psychology concerning the plausibility of unconsciously represented cognitive processes. Whereas during the 1950s and 60s the research on subliminal perception failed because of the persistent demand to doubtlessly proof the existence of its subject-matter at all (see, e.g., Eriksen, 1956, and the utmost sceptical judgment of even

Neisser, 1967), in the meantime the hypothesis of unconscious cognitive processes has become almost self-evident. In many models of information flow conscious representation is banished in a small box at the utmost right, that can be reached not until the processing has already reached its end.

Why shouldn't it be possible to trigger a motor reaction without the assistance of consciousness? This possibility still seems to meet with similar reservations like those, the hypothesis of subliminal perception had to face two decades ago. The reason might be – like then – a phenomenologically based prejudice: One sees oneself as the master of one's voluntary action and derives thereof that this must also get into going by a consciously represented 'Fiat!'. I had this conviction, too (Neumann, 1980), and oversaw thereby, that the possibility of consciously preventing a reaction does not necessarily imply its consciously mediated triggering. An a-reaction is without doubt not 'automatic' in the sense that it could be triggered independently from the person's consciously represented action plan merely by the appearance of the stimulus. But not everything which occurs during the realisation of an action plan must be consciously controlled.

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Figures

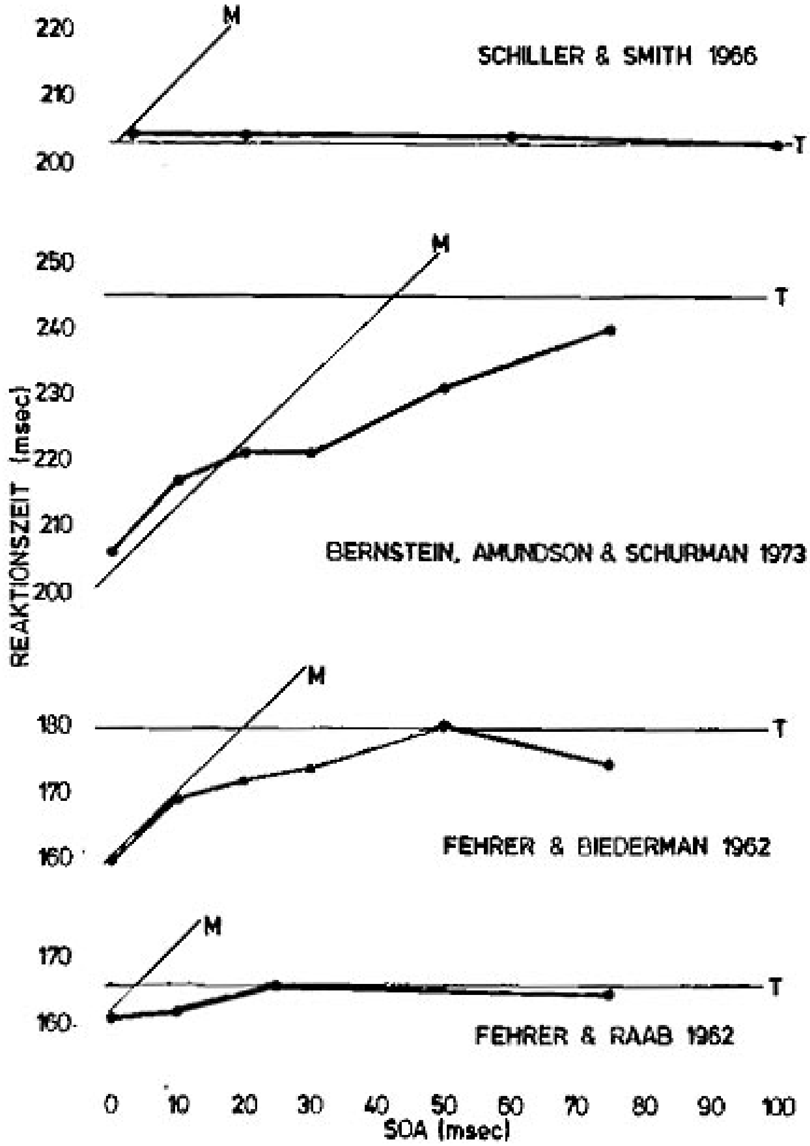

Figure 1

Data from Fehrer-Raab experiments and later replications. The bold curves show the reaction time for the sequence S1 (test stimulus) – S2 (mask stimulus) measured from the onset of the test stimulus. The thin line 'T' shows the reaction time only for the test stimulus, the thin line 'M' shows the time, that would have been measured, if the participant had reacted but to the mask stimulus. As the reaction time is scaled at the ordinate from (?) testing time on, the value 'M' increases to the amount of the SOA. – In the experiment of Schiller and Smith (1966), reaction time for the test stimulus alone was not measured under the same conditions as the other times. Here, the value of the SOA for 'T' was 100 msec, so that it was practically impossible that the masking stimulus could have affected the reaction.

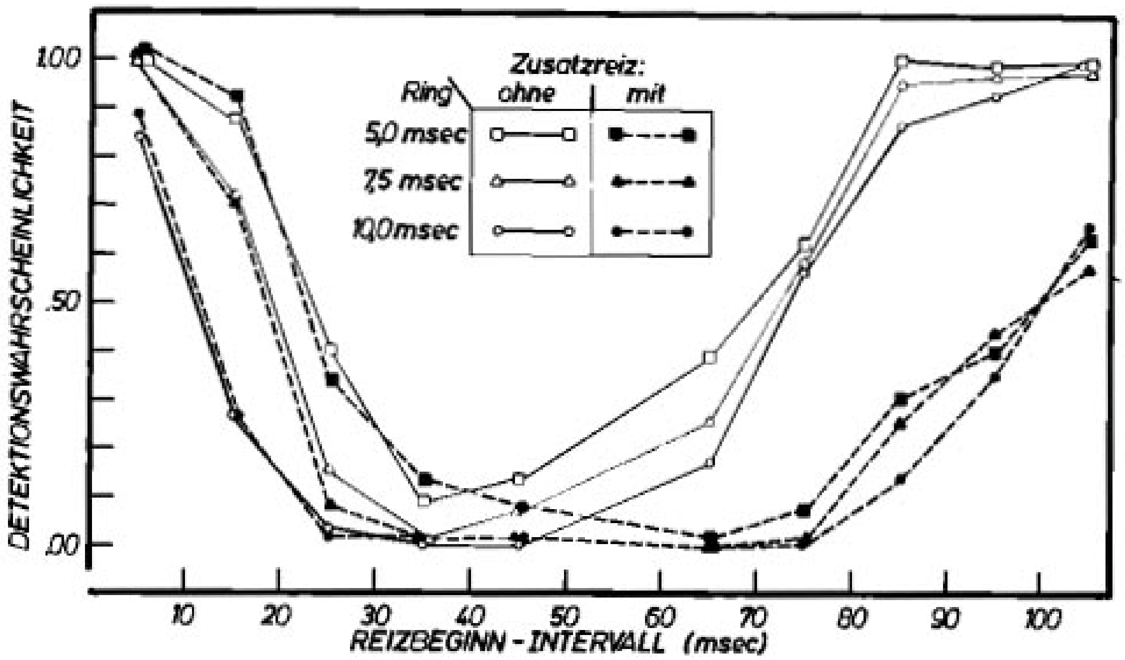

Figure 2

Possibility of test stimulus detection (answer 'yes') in relation to stimulus-onset interval, duration of exposure of the mask, and presentation of an additional stimulus (a disk, identical with the test stimulus, which is presented simultaneously on the other side of the fixation point; exposure time for test stimulus and additional stimulus: 5 msec). The essential finding in this context is the shifting of the increasing flank of the masking function caused by the additional stimulus, whereas it has no effect on the left decreasing flank. – Data mediated over 3 observers; 60 judgments per data point (from Neumann, 1978).

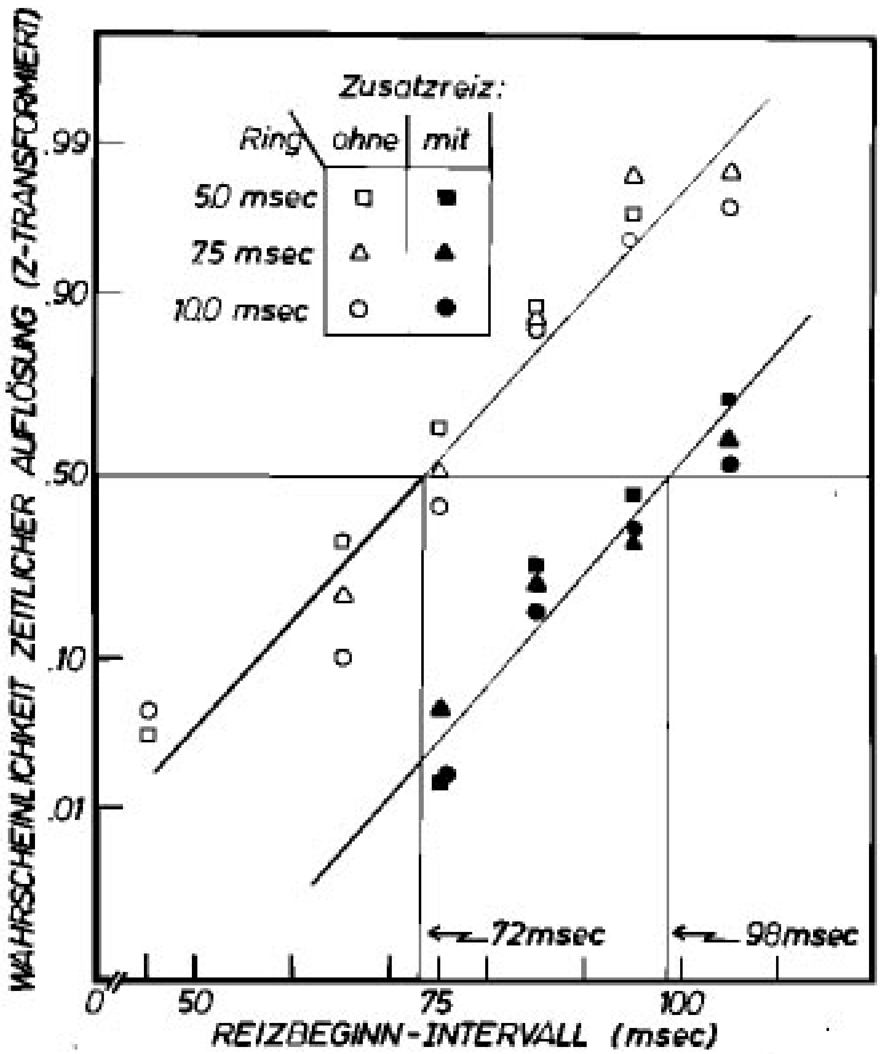

Figure 3

Effect of an additional stimulus on dissolution over time. The conditions of presentation were the same as those explained in the legend of Figure 2; yet, the observer had to judge the dissolution over time after each exposure (‘one’ = test stimulus and mask are integrated over time; ‘two’ = the test stimulus precedes the mask in time). Then the observer scaled the brightness (see legend of Figure 4). – Data mediated over 3 observers; 60 judgments per data point (from Neumann, 1978).

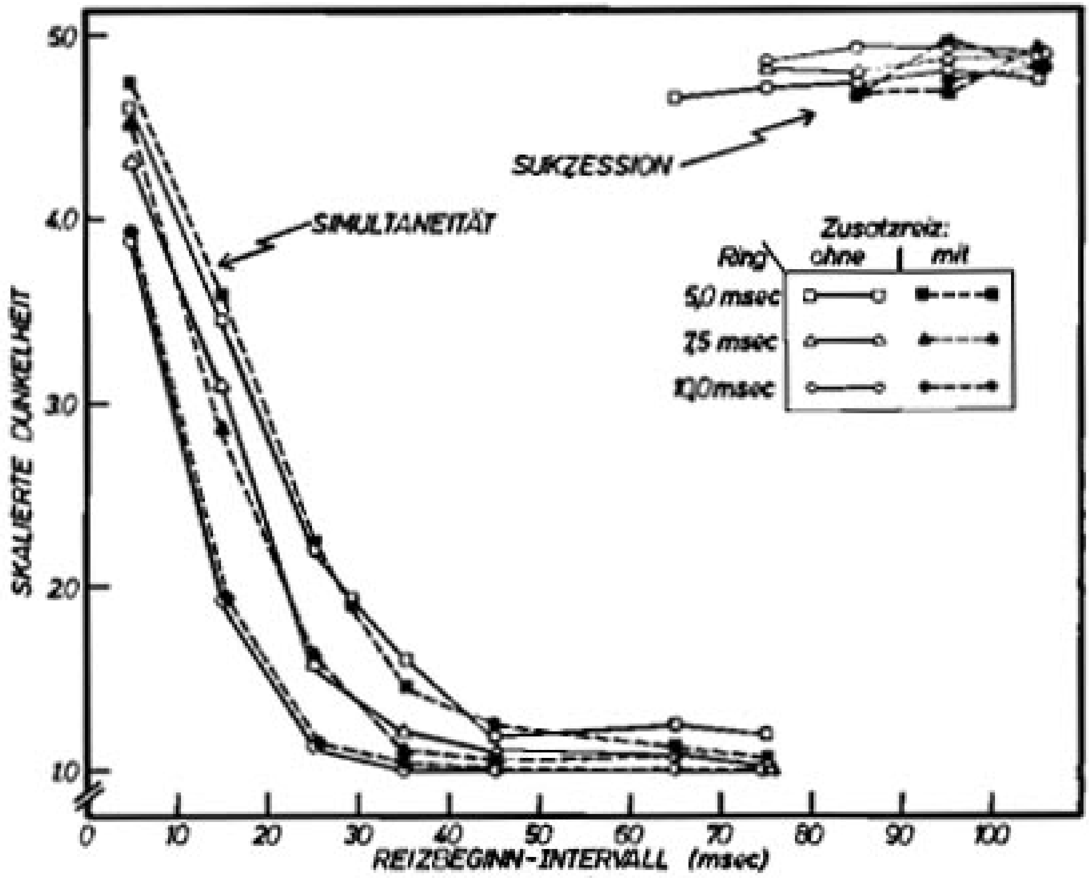

Figure 4

Mean scaled darkness of the inner ring. The first stimulus was decisive for dissolution over time. (5-point-category scale, with 1 = white, and 5 = black). See also Figure legend 3 (from Neumann, 1978).

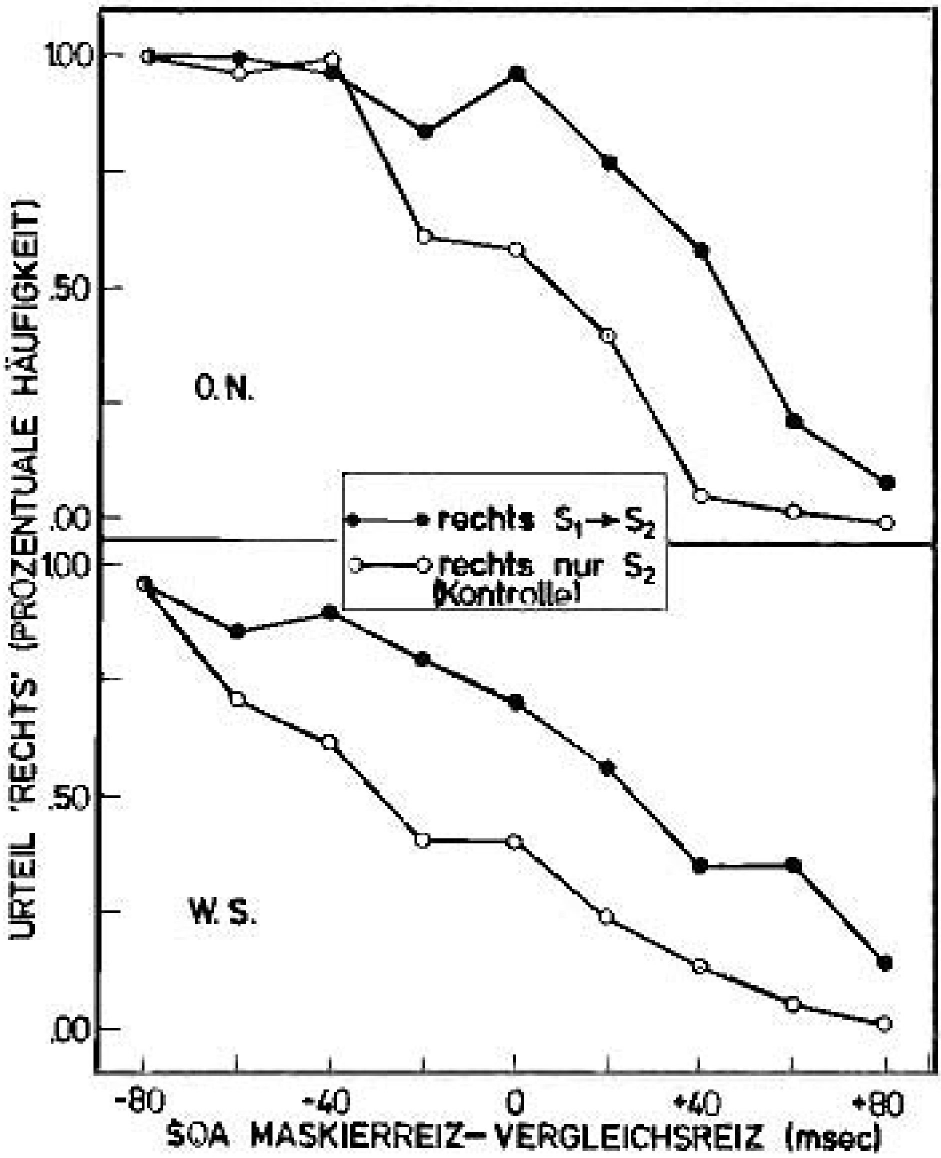

Figure 5

Judgment of the succession of two rings in dependence of a masked disk preceding the right ring. In the control condition only the two rings were presented (open symbols). In the experimental condition (filled symbols) the right ring with an SOA of 80 msec was preceded by a disk exposed for 2 msec which was invisible. Negative SOAs = right ring is exposed by left ring. The participant indicated which ring he/she saw first. The judgment ‘simultaneously’ was not allowed.

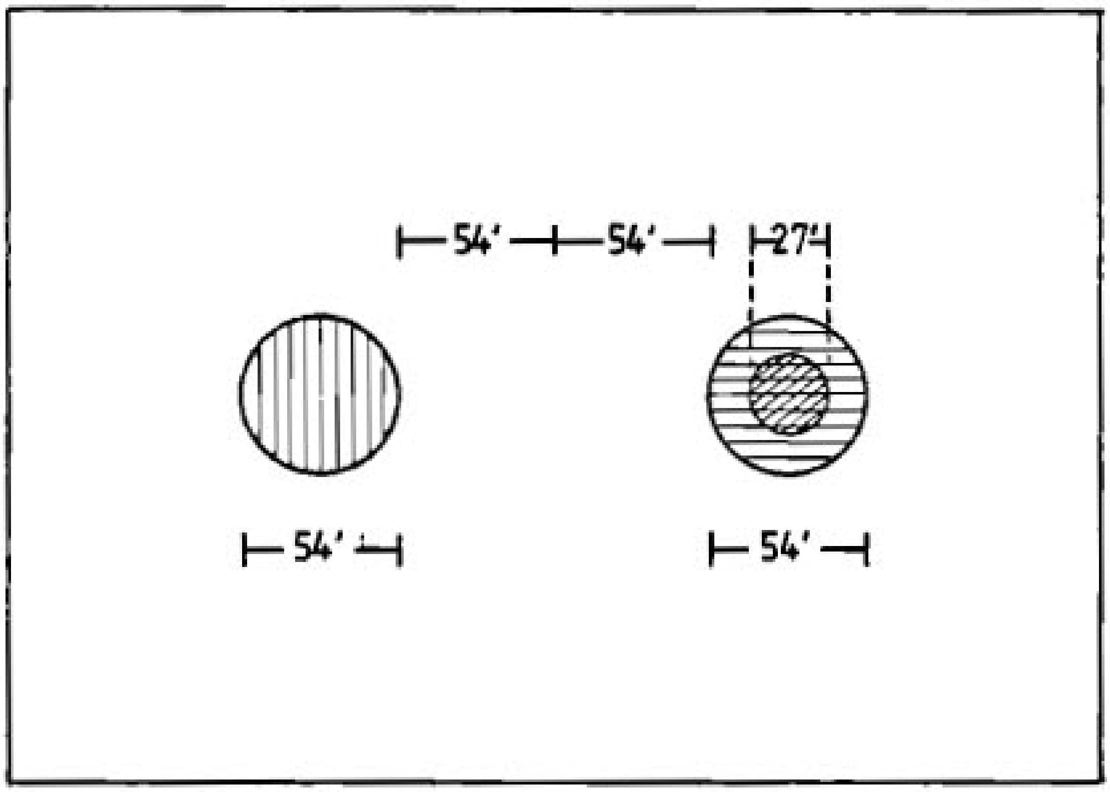

Figure 6

Arrangement of stimuli in Experiments 2 and 3. The stimuli showed up light on a black background. Horizontally hatched: mask; vertically hatched: comparable stimulus (only Exp. 3); diagonally hatched: test stimulus. In the control conditions, the mask (Exp. 2 and 3) as well as the test stimulus (only Exp. 2) were presented alone. The SOA (M) between test stimulus and mask amounted to 5, 25, or 45 msec; the SOA (V) between mask and comparable stimulus varied in 9 steps between –80 and +80 msec.

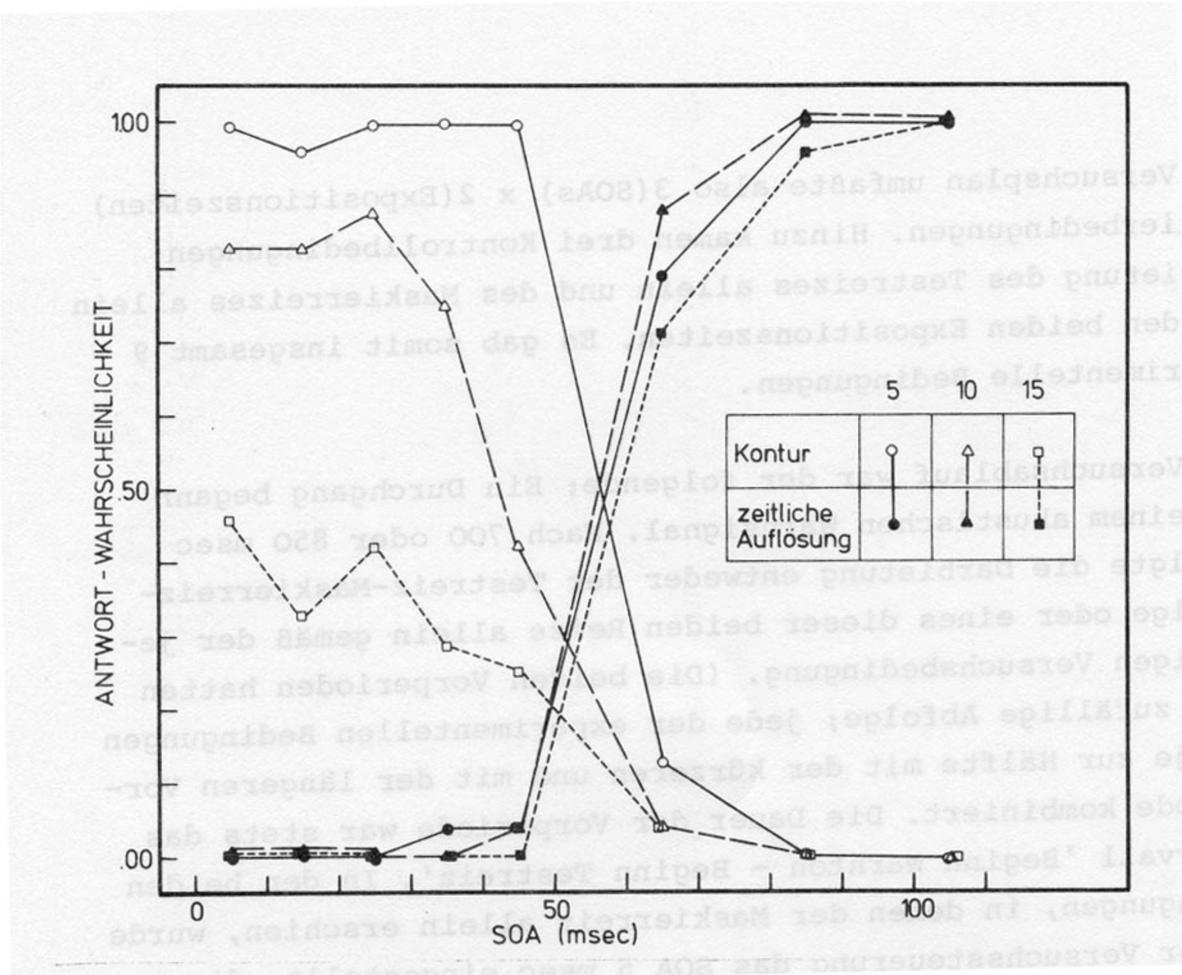

Figure 7

Pre-test data from Experiment 2. Arrangement of stimuli see Fig. 6; duration of exposure of the test stimulus was 5 msec. As in the earlier test (see Figure caption 3) the observer judged twice; first about the temporal dissolution (‘one’ or ‘two’), then about the existence of a contour of the test stimulus in the inner of the mask (‘fried egg’ yes or no).

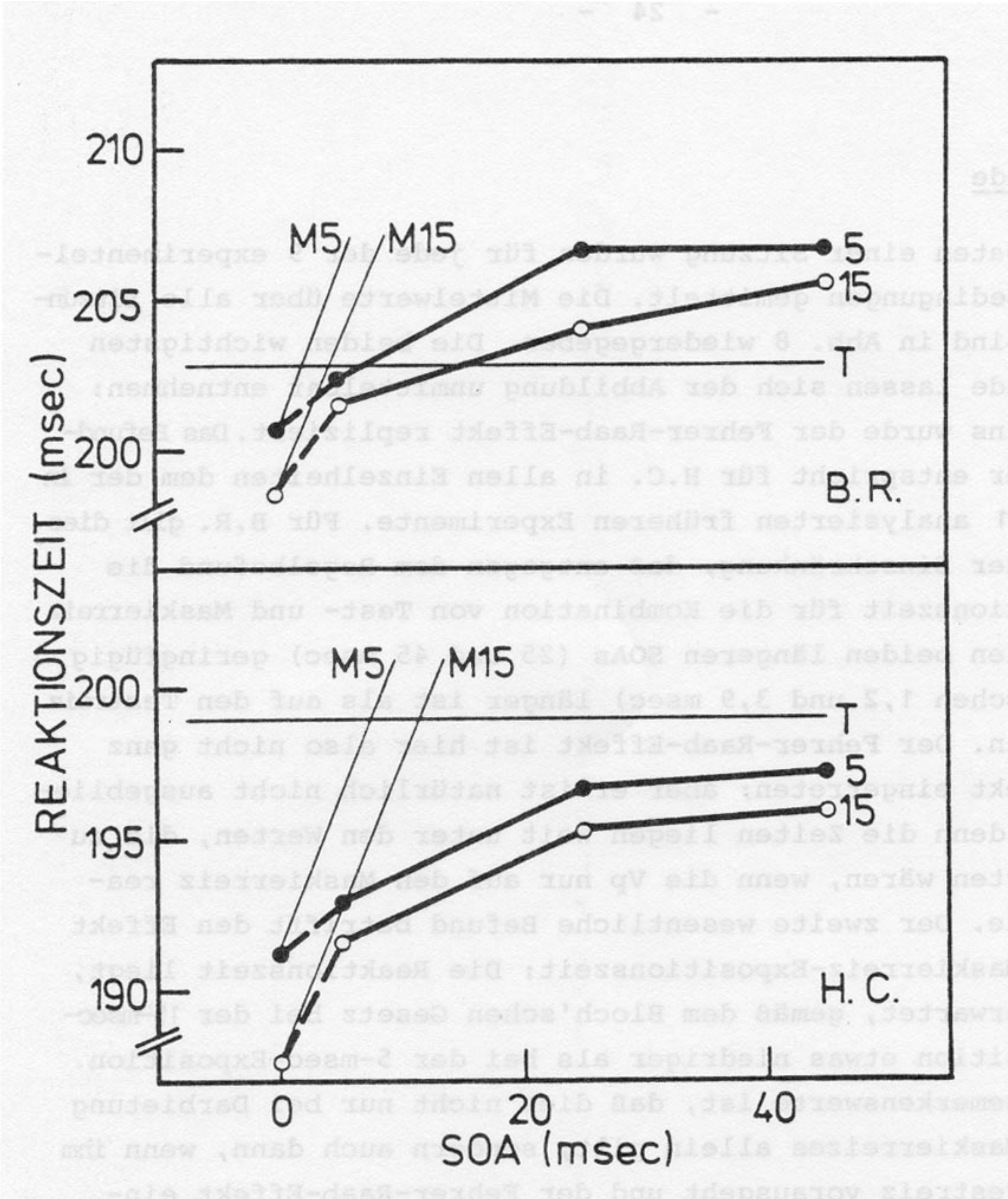

Figure 8

Reaction times of both participants in Exp. 2, presented like Fig. 1. The values 5 and 15 are the exposure durations of the mask.

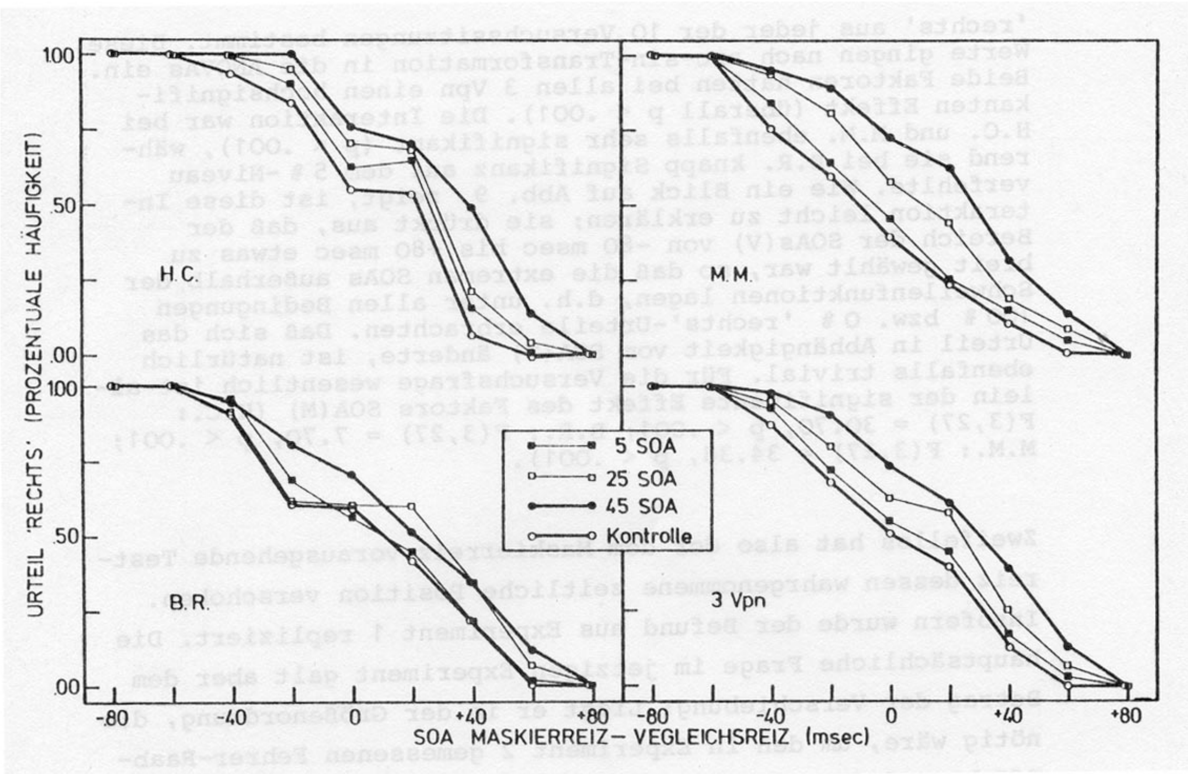

Figure 9

Psychometrical functions from Exp. 3 separated for the three participants and mediated over them (see right below). Exposure duration of test stimulus, masking, and comparable stimulus: 5 msec; spatial arrangement as depicted in Fig. 6. On the abscissa the SOA between masking and comparable stimulus (negative SOAs: masking stimulus precedes), on the ordinate the relative frequency of the judgment 'right' (i.e., masking stimulus precedes comparable stimulus). Parameter is the SOA between test and masking stimulus. In the control condition, the masking stimulus appeared without preceding test stimulus.

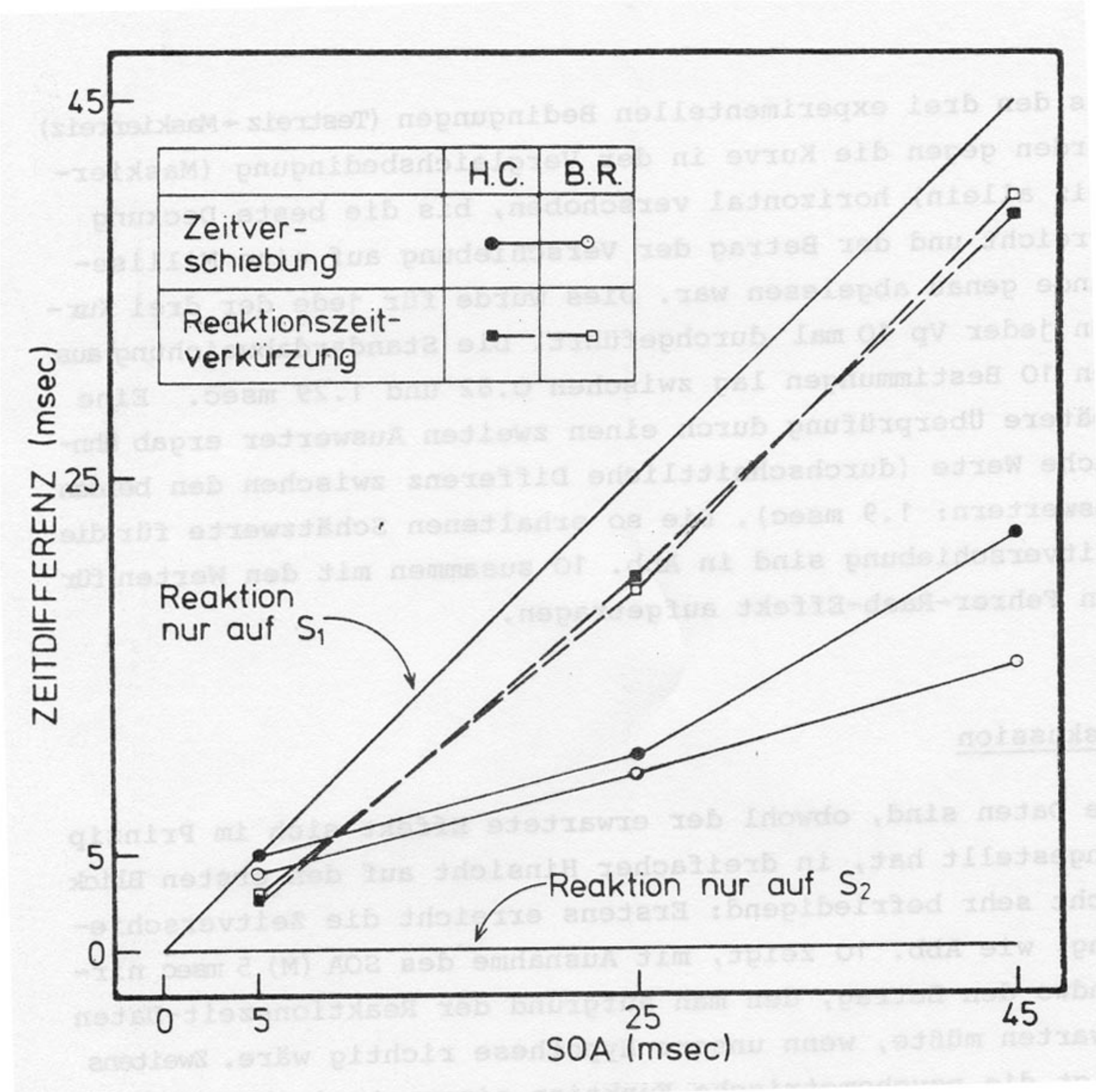

Figure 10

Comparison of the data of Exp. 2 and 3 for the participants H.C. and B.R. On the ordinate the amount is written as ‘difference in time’ from Exp. 2, by which the reaction time for the masked stimulus in contrast to the reaction to the mask alone was reduced (dashed line). Correspondingly, for Exp. 3 there is as ‘difference in time’ the amount by which the psychometric function was shifted by the preceding stimulus in contrast to the curve for the mask alone (continuous line). Due to the difference of the threshold function from the Normalogive this difference could not be exactly calculated. It has been graphically estimated by shifting the curves against each other in such a way that they covered each other at best. The values registered are the medians of each of 10 determinations, which standard deviation was in the order of one millisecond. In case of reaction to the mask only (S2) the difference would be null, in case of reaction to the masked stimulus (S1) it would be identical to the SOA. These curves are drawn for comparison.

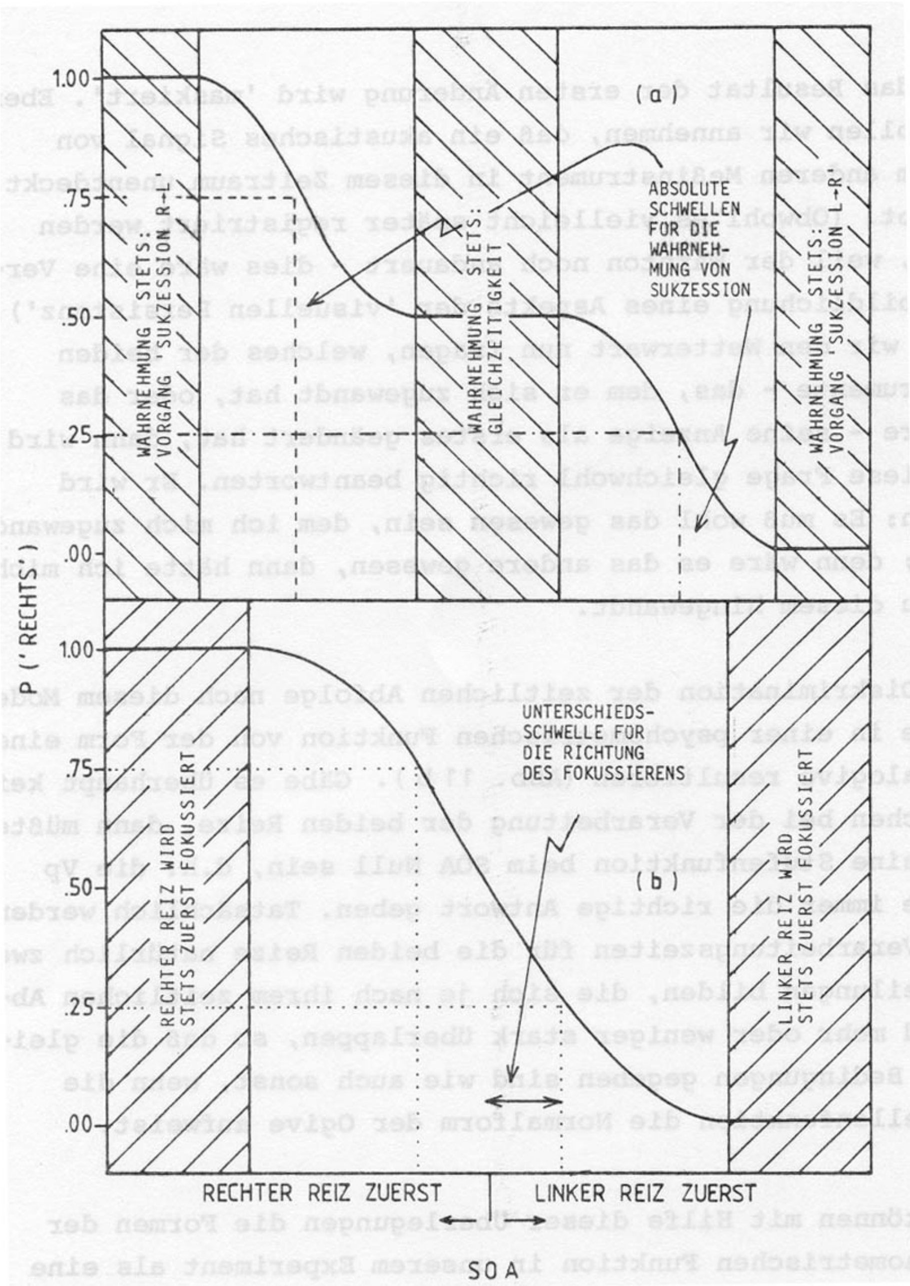

Figure 11

Hypothetical psychometric functions for the temporal succession judgment. In the first case (Fig. 11a, above) it is supposed that the observer bases his judgment on the perception of a process 'succession R→ L' (right → left) or 'succession L→ R' (left → right). For the perception of a process there is an absolute threshold. The threshold function is limited by regions, in which on the one side simultaneity is always perceived, and on the other side always succession in the one or another direction. – In the second case (Fig. 11b, below) it is supposed, that the observer indicates that stimulus as being the first one, in which direction his attention had been drawn first. Here, the threshold function is an ogive limited by those regions, in which always the right or always the left stimulus calls for attention first. The degree of accuracy, at which the direction of focussing noticed by the observer corresponds to the position of the objectively first stimulus, shows up in the difference threshold.