Time perception of near-threshold visual events

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INTRODUCTION

The literature suggests that processing of sensory events, perception of time and action are related to one another in a number of ways. Estimation of time is bounded by significant sensory (or cognitive) events, but the exact nature of these events remains unknown. Also, time estimation and motor behavior appear to share a number of cortical areas1,2 so that they are believed to process incoming information in similar ways. Finally, common sense makes believe that action is necessarily triggered by a conscious sensory event. Recent studies however suggest that action and perception can be dissociated3-5.

Here we present a psychophysical attempt to assess some aspects of these putative relationships within the same experimental framework. In particular we ask and answer the following three questions:

1. Can a motor response be equally triggered by a “conscious” and by an “unconscious” sensory event?
2. Is the “conscious/unconscious” status of a sensory event relevant to the estimation of its duration?
3. Do motor response times to and time perception of sensory events follow similar functions of the salience of these sensory events (whatever the “conscious/unconscious” status of the latter)?

Within the context of the present experimental paradigm, the notions of conscious and unconscious sensory events are referred to their evoked internal responses being above and below the perceptual decision criterion, respectively.

EXPERIMENTAL PARADIGM AND METHODS

The experimental design was elaborated within the framework of Signal Detection Theory (SDT). Observers were presented with two successive, spatially overlapping Gabor patches, the first, S1, set at one out of three sensitivity levels (close to d’-s of 1, 2 & 3, obtained by varying the contrast, C, of S1) and occurring in 50% of the trials and the second, S2, highly supraliminar and always displayed (Fig. 1). Observers performed three tasks: (1) a Yes/No detection of S1, (2) a speeded manual response to the onset of any of the S1 and S2 stimuli, and (3) an estimation of the overall duration of S1+S2 (or of S2 alone when S1 was absent) relative to the variable duration of a third, highly supraliminar stimulus, S3. Tasks (1)-(2) and (1)-(3) were paired in independent blocks (Fig 1b & 1c, respectively). Response Time and Perceived Duration were assessed as a function of S1 visibility (d’) and according to the perceptive state of the observer relative to the presence/absence of S1 (i.e. Hits, False Alarms, Misses and Correct Rejections). Observers were four right-handed students (2 women, 2 men – including the author) 23 to 24 years old.

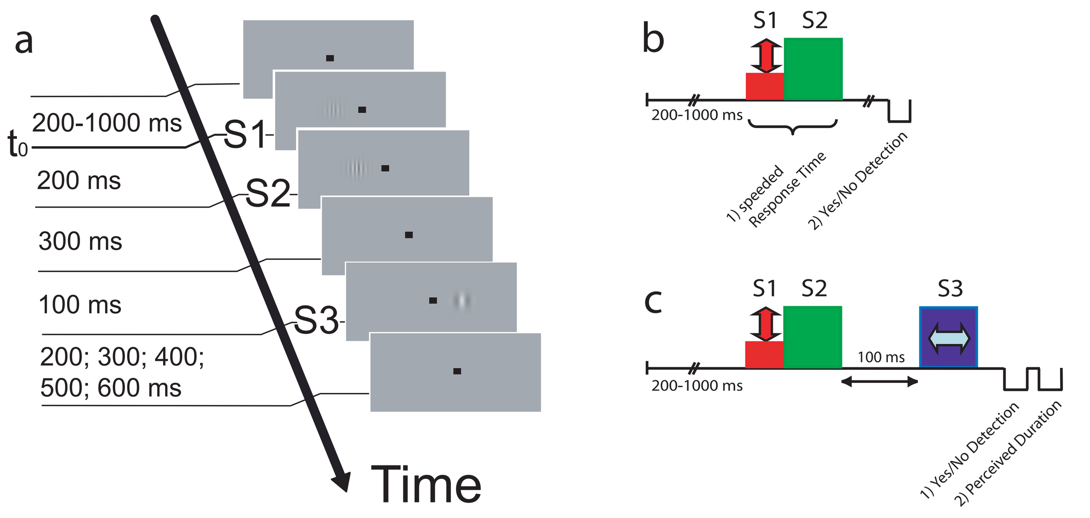


Figure 1. Spatial and temporal configuration of one trial.

RESULTS & CONCLUSIONS

Yes/No Detection paired with speeded Response Time (RT)

Fig. 2 presents median RTs (averaged over the 4 observers) as a function of S1 C (and the corresponding d’; bottom and top abscissas), for each SDT response category. RT decreases with C (or d’) for Hits only (red circles) and is C (or d’) independent for the remaining categories. While these data replicate those of Waszak & Gorea6, we present here a slightly different account from theirs.

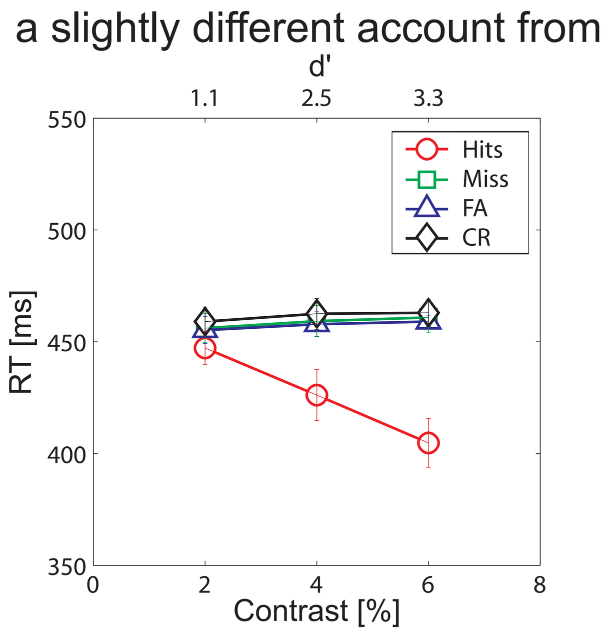


Figure 2. Response Times as a function of Contrast and d' for the four SDT categories.

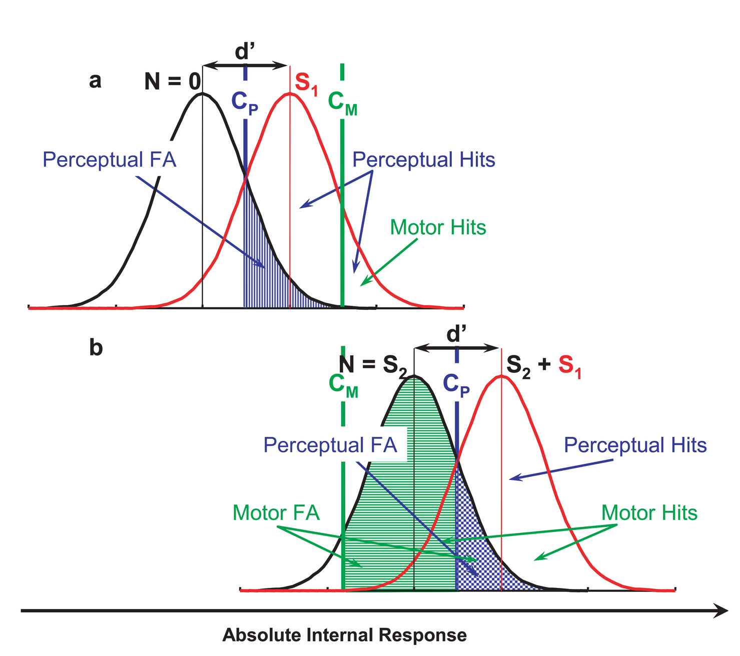
Given that control experiments show that under the present experimental conditions (Fig. 1), S2 does not mask S1, the effective perceptual comparison carried out by observers in order to reach a Yes/No response is in-between internal states evoked by the absence of S1 and of S2 (Noise), on the one hand, and by S1 alone (Signal), on the other hand, while ignoring S2 altogether. Accordingly, the perceptually critical internal states are of relatively low absolute magnitudes so that only those associated with the perceptual Hits (or a proportion of those) exceed the motor threshold (see Fig. 3a). The fact that RTs for perceptual Misses do not depend on d’ implies that the associated internal states never exceed the motor threshold so that the latter must be equal to or higher than the highest perceptual criterion presently assessed (i.e. for the higher d’). Such a high motor threshold also accounts for the independence of RT from d’ for CR and FA trials. In particular, the RT independence from d’ for the FA trials implies that the motor threshold is definitely higher than the highest assessed perceptual criterion. Within this interpretative framework…

…the inference of a motor threshold higher than the perceptual response criterion along the sensory continuum necessarily yields the conclusion that only conscious perceptual events trigger a motor response.

While current experiments in our lab suggest that the motor threshold is invariant, it may well be exceeded by the perceptual criterion on an absolute internal response scale (Fig. 3b). This should be the case in experiments where S2 effectively masks S14,6 so that the critical perceptual comparison is in-between S2 and S2+S1. As S2 is highly suprathreshold (and always triggers a motor response), this comparison is carried out at high internal response regimes with the perceptual criterion well above the motor threshold (on an absolute internal response scale). Under such conditions RT should depend on d’ for all four internal states (H, FA, etc.). This should however not be the case if S2 follows S1, as is the case in all backward masking paradigms. This is so because the internal responses associated with CR and FA – by definition evoked by the Noise stimulus (S2) – are delayed in time relatively to the onset of S1 and cannot thus contribute to a shortening of the associated RT.

Overall, the present interpretative framework accounts for a number of recent studies3-6.

Fig. 3. Theoretical approaches proposed for inferring the motor response criterion. The Gauss black and red functions show probabilities of a given perceptual internal response given that the stimulus is absent (Noise, N = 0 or S2) and present (Signal, S1 or S2+S1; the subscript specifies the stimuli in Fig. 1). Perceptual, CP, and motor, CM, criteria are shown as heavy vertical blue and red lines, respectively. While CP (as well as perceptual sensitivity, d’) can be directly derived from observers’ yes/no responses, CM can only be inferred. The presence of the suprathreshold stimulus S2 is critical inasmuch as it will always triggers a motor response whether or not S1 is present and detected. (a) CM >> CP; (b) CM << CP (see text for more).



Yes/No Detection paired with Perceived Duration (PD)

Fig. 4 presents mean PD (assessed as Points of Subjective Equality) as a function of S1 contrast (and the corresponding d’; bottom and top abscissas) for each SDT response category. Dotted lines represent the physical durations of S2 (300 ms) and S1+S2 (500 ms).

PDCR is about equal to 300 ms, the physical duration of S2, and is independent of S1 contrast. PDHits is larger than PDCR but far less than the 500 ms duration of S1+S2. Thus the near threshold stimulus S1 is perceived as much shorter than its physical duration. Furthermore, PDHits does not vary with S1 contrast. PDMisses and PDCR are approximately equal, indicating that an unseen/unconscious sensory event (evoked by S1) doesn’t contribute to PD. PDFA exceeds the physical duration of the corresponding S2 stimulation. Thus a conscious event, even though fictitious, modifies PD. Finally, PDFA is also superior to PDHits. This is not surprising as Hit internal responses are time locked to the onset of S1 whereas FA internal responses may occur at anytime between the beginning of the trial and the onset of S2.

In short, PD does not vary with sensitivity within the tested range and is significantly longer for Hit and FA than for CR and Miss trials. The latter observation points to the fact that...

...only conscious perceptual events trigger time counting.

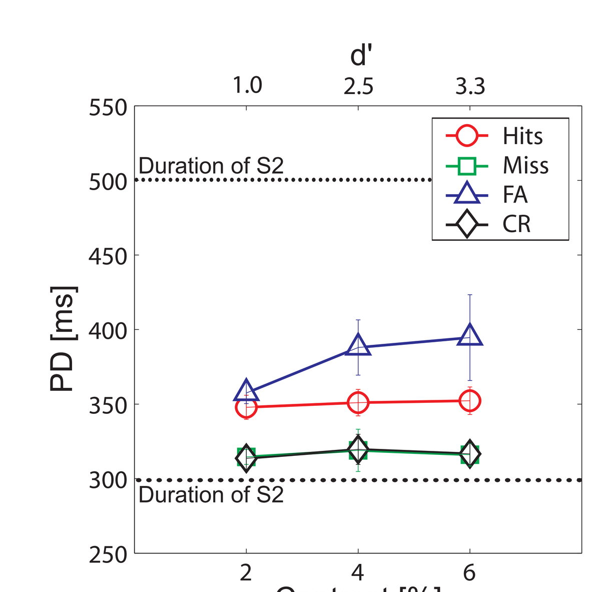


Figure 4. Perceived Duration as a function of Contrast and d' for the four SDT categories.

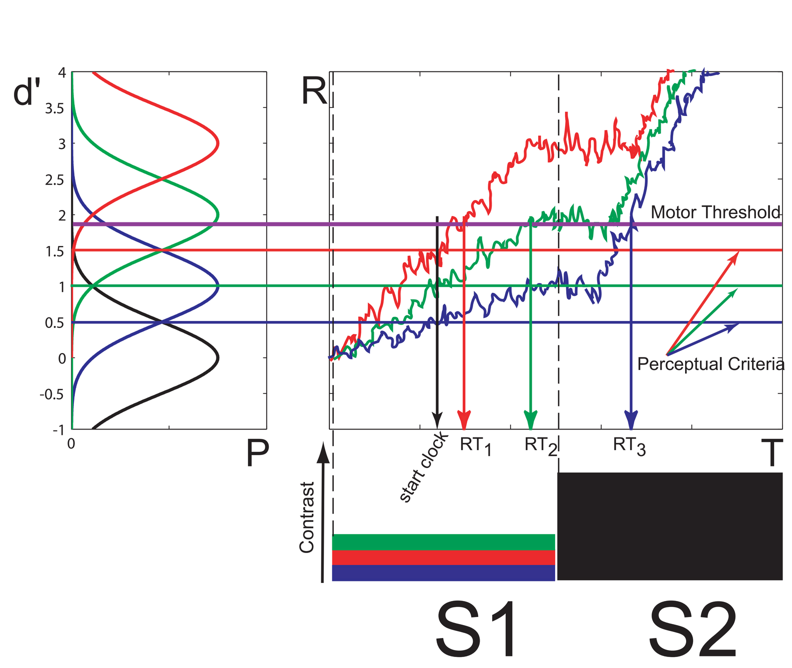


Figure 5. Response Time and Perceived Duration Model described in the text.

Time Perception vs. Motor Response latencies

The pattern of results for RT (Fig. 2) and PD (Fig. 4) differ in many ways: RTHits decreases with contrast (and d’), whereas PDHits doesn’t. RTFA equals RTCR, whereas the equivalent PDs are significantly different. It follows that time perception and motor responses reflect different underlying processes.

Fig 5 illustrates how these processes might operate on the internal evoked responses so as to account for the differences above. The interpretation framework poses that speeded motor responses are triggered once the internal evoked response exceeds a fixed motor threshold, whereas the onset of “time counting” is controlled by a “cognitive” perceptual criterion, proportional to d’. As the slope of the internal response over time increases with the contrast (and d’) of the target, the fixed motor threshold will be exceeded proportionally earlier; instead the PD invariance with contrast (and d’) is accounted for by the strict correlation between this slope and the perceptual criterion. Given our definition of a conscious event (an evoked response exceeding the perceptual criterion) and the present inference of the motor threshold as being superior to the perceptual criterion, the onset of both “time counting” and motor responses must be triggered by conscious internal events. In short

Speeded Response Times are controlled by a fixed motor threshold whereas Perceived Duration is dependent on the perceptual

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