

# Transient-Based Image Segmentation: Top-Down Surround Suppression in Human V1

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## ABSTRACT

Previously we studied the effect of spatiotemporal pattern of transients on perceptual organization. Transient synchrony/asynchrony was critical in novel illusions of contextual motion (Likova & Tyler, 2001, 2002a,b, 2003a,b, 2004). We found that strong image segmentation can be generated from transient asynchronies in fields of homogeneous visual noise, a phenomenon that we term ‘Structure-from-Transients’ (SfT). We used fMRI to reveal cortical mechanisms involved in SfT. The stimuli were random dot fields of  $30 \times 40^\circ$ , replaced by uncorrelated dots every 500 ms. Asynchronous updates in subregions of the random-dot fields results in SfT. Exp.1: Figure/ground organization was generated in the *test* stimuli by transient-*asynchrony* between a figure area (a horizontal noise strip  $8 \times 40^\circ$ ) and its surround. The transient changes in the *null stimuli* however were *synchronized*, generating no SfT. Thus the global percepts switched from figure/ground (test) to a homogenous field (null) every 9 s, in 36 blocks per scan. Exp.2: Figure/ground organization was eliminated by segmentation of the field into equal horizontal SfT stripes.

We found dramatic reorganization of the cortical activation pattern with manipulation of the perceptual SfT organization. Exp. 1 revealed excitation of hMT+ and figure/ground-specific top-down suppression of the background region in V1. Both were abolished by eliminating the figure/ground organization with multiple SfT stripes, which instead activated the higher dorsal and ventral tier retinotopic areas. The results support a view of a recurrent architecture with functional feedback loops, exhibiting complex spatiotemporal behavior in the case of a *figure/ground* organization extracted from its specific ‘generator’.

Our study reveals that on a global level the brain makes an important use of *asynchrony* as a relation structuring the spatiotemporal visual input.

**Key words:** Surround suppression, Visual cortex, area V1, Top-down feedback, Perceptual organization, Figure-ground, Asynchrony, Transients, Structure-from-transients, Image compression

## INTRODUCTION

It seems intuitively obvious that the brain should be well suited for extracting different *regularities*, *structures*, and *ordering* in the dynamic three-dimensional world that we inhabit. The alignment of elementary components in space and time is a key signature of their object relationships in the world. This is one reason that *synchrony* has typically attracted more attention than *asynchrony* (Palmer, 1999, Engel & Singer, 2001). Asynchrony is usually thought as a destructive ‘agent’, rather than a structure-generating ‘agent’. One definition of asynchrony is that “asynchrony is the *relation* that exists when things occur at *unrelated* times”. Our study focuses, therefore, on the roles of asynchrony in visual organization and reveals that, on a global level, the brain makes important use of *asynchrony* relations to structure the spatiotemporal visual input.

These considerations lead to the question: What are the ‘*quanta*’ of visual dynamics, which may come in synchrony or in asynchrony relative to each other? *Transient changes* may be considered to be the elemental ‘*event*’ structuring the dynamics of visual scenes. Previously we studied the effect of spatiotemporal pattern of transients on perceptual organization. Synchrony/asynchrony of transients was critical in novel illusions of contextual motion (Likova & Tyler, 2003a,b; 2004a). We now find that strong image segmentation occurs on the basis of *transientfield asynchronies* between regions of otherwise featureless field of noise transients. Regions of the field that undergo synchronous noise replacement are perceptually integrated into unified zones (despite the fact that the noise is spatially uncorrelated from frame to frame), while the boundaries defined by asynchrony are seen as sharp segmentations between the regions. We term this novel phenomenon ‘*Structure -from-Transients*’ (SfT). When the regions meet the criteria for figure (smaller, surrounded) versus ground (larger, surrounding), the SfT is capable of supporting strong figure-ground percepts although, interestingly, it negates the tendency to generate a depthordering with the figure in front, which is common for other figure/ground cues.

We view the processing our brains are performing as inherently 4-dimensional, incorporating time as well as the three spatial dimensions. Thus, in order to understand and to correctly perceive dynamic visual scenes we need spatiotemporal (i.e., 4D) structure, not simply isolated spatial-only, or temporal-only structures. To explore this concept, we compared two basic categories of spatiotemporal organization in SfT: *figure/ground* organization and *segmented structure of multiple equivalent parts*. These stimuli were contrasted *against homogeneous* dynamicnoise stimuli with no SfT.

We employed functional Magnetic Resonance Imaging (fMRI) to reveal and differentiate cortical mechanisms involved. Our study is the first fMRI report on structure-from-transients, transient-asynchrony image segmentation and figure-ground based on transient-field asynchrony/synchrony. We found that the spatiotemporal pattern of transient asynchronization crucially affects both the perceptual SfT organization, and the corresponding neural substrate.

## METHODS

### Scanning procedure

The fMRI responses were collected with 2D spiral acquisition from a custom occipital surface coil in a GE Signa 3T scanner. There were 23 coronal slices at 3 s TR, with TE of 30 ms and flip angle 70°, providing 2.5 x 2.5 x 3 mm voxels throughout the occipital cortex. The stimuli were rear-projected onto a translucent screen inside the bore of the scanner by means of an LCD projector controlled by a Macintosh computer. The observer's head was stabilized by chin and forehead tape, with the eyes viewing the front of the projection screen via a 45° mirror to. The observer's task was to maintain fixation on a red 4 x 4 pixel fixation point at the center of the stimulus. No motor task was imposed, in order to limit the differential brain response to sensory processing signals and avoid confounding the perceptual responses with motor or decision processing.

### Data analysis and visualization

A high-resolution anatomical (T1-weighted) 3D MRI volume scan of the entire brain was also obtained for each observer (voxel size = 0.94 x 0.94 x 1.2 mm). Gray (cortex) and white (nerve fiber) matter were segmented for each observer using publicly available software.S1. The cortex was specified as a manifold extending 3 mm above the segmented gray/white matter boundary, which was flattened from a locus centered on the occipital, to a radius of 70-80 mm (depending on the size of the occipital lobe) to form a flatmap for full visualization of the relevant fMRI activity.

The differential fMRI activity profile within the cortical voxels was then mapped directly onto the cortical flatmap, to allow visualization of the response properties over complete cortical areas with the gyri are coded in lighter gray than the sulci. The horizontal axis in the circular flat maps shown in Fig.2A is oriented from medial (on the V1 side) toward lateral (on the **hMT+** side); the top of the flat maps is dorsal, the bottom – ventral relative to the **hMT+** ROI. The boundaries of the retinotopic projection areas **V1**, **V2d**, **V2v**, **V3d**, **V3v**, and **V4** were established as described in Engel et al. (1997). Retinotopic projection areas **V3A**, **V3B** and **V7** were specified in accordance with Press et al. (2003). The **hMT+** motion complex was identified using an expanding and contracting motion vector field of white dots on a black background, alternating with static dots.

The fMRI (BOLD) response to the differential test/null stimulation was analyzed by extracting the Fourier fundamental of the time series at every voxel at the stimulus alternation rate of 1/18 Hz. The initial response transient to stimulus onset was excluded by beginning dummy visual stimulation 9 s before the experimental stimulus sequence was initiated. A statistical correction for multiple occurrences was applied to the criterion for

significant response, in terms of the amplitude of the Fourier fundamental. A coherence level of 0.47 provided a significance level of  $p < 0.00005$  in each voxel, or a corrected level of  $p < 0.05$  per 1000 voxels to specify the presence of a significant response. Once a seed location had been established adjacent voxels were included in the ROI down to a coherence level of 0.3 ( $p < 0.01$  in each voxel) for the ROIs defined.

### Stimuli

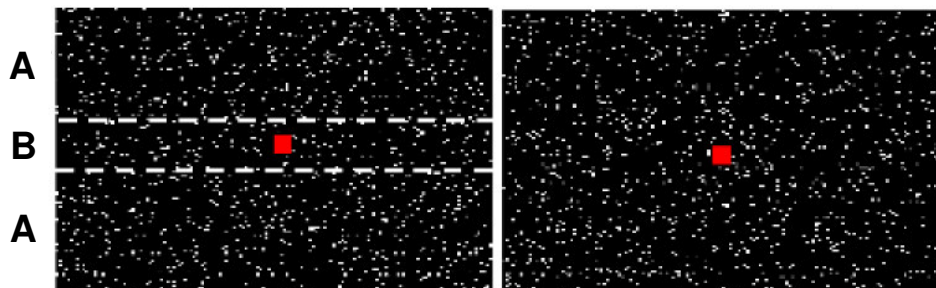
Classically, the dynamic visual noise (DVN) stimuli are obtained by *synchronously* updating the noise at every point in the stimulus field at a constant rate over time. The main occipital responses to DVN are found in V1, while V3A and especially hMT/V5+ respond less to DVN than to motion.

*The SFT Paradigm:* Our paradigm differs from the standard approach by introducing *asynchrony* in the noise updates in specified zones of a large field of DVN to achieve spatiotemporal segmentation in that field. The asynchrony produces virtual borders between the zones which appear as sharp and vivid as motion or luminance borders. The elements were 'featureless' pixel-size dots with uncorrelated positions from frame to frame. A block design was applied: the stimuli consisted of a *test* and a *null* phase, with *SFT* during the *test* phase and *uniform noise* updates during the *null* phase. The fMRI signal during the null was subtracted from the signal during the test. Both were DVN fields of  $30 \times 40$  deg, with the dots in each field replaced by uncorrelated dots every 500ms (1 Hz): because the noise updates were uncorrelated, no coherent apparent motion should be perceived in the transient fields. The test and the null were alternated in 18 s cycle (9 s test, alternating with 9 s null presentations), in a total of 36 cycles per experimental condition. Each condition was repeated 4 times in the same session.

## EXPERIMENT 1:

### STRUCTURE-FROM-TRANSIENTS WITH FIGURE/GROUND ORGANIZATION.

The test and the null were equivalent in all aspects (the same white dots randomly distributed on a black background, the same dot density and luminance, the same update rate of 1 Hz, and the same global size of the DVN field). The only difference was that the whole RDN field was updated simultaneously, i.e., in-synchrony during the null, while during the test a horizontal central region (marked as 'B' in Fig.1) of  $8 \times 40$ deg was updated with a *delay* of half the update frequency (i.e., ISI = 250ms) relative to the surrounding regions above and below it.



*Fig. 1.* Stimulus configuration for Exp.1. The dots in each field were replaced by uncorrelated dots every 500ms: thus transients but no organized apparent motion should be perceived. On the *right* is shown the *null* stimulus – homogeneous DVN field  $30 \times 40$ deg, updated every 500 ms. On the *left* is shown the *test* stimulus with the same update rate but with 250 ms *asynchrony* of the central (B) region relative to the surrounding top and bottom regions (A), thus constituting a Structure-from-Transients (SFT) condition in the *test* period. There were no luminance borders – the dashed lines only mark the illusory borders perceived between the asynchronous regions. Subjects were to steadily fixate at a small square in the center throughout the scans.

## EXP. 1: RESULTS

The results of Experiment 1 reveal that the only region of the entire occipital cortex that is strongly activated by the transient-field segmentation into a central bar and its surround region is, in fact, hMT+ (Fig. 2A). Most of the surrounding cortex is silent with respect to fMRI activation, although there is also inconsistent activation in the dorsal areas V3A/B, which are also a known component of the motion pathway. This pattern of activation is verified in the averaged activation for the four relevant regions of interest in six hemispheres of three observers (Fig. 2B), showing positive activation in hMT+ and (with higher variability) V3A. It should be emphasized that this activation of the dorsal pathway is specific to the segmentation structure of the stimulus field, since the local transients were present throughout in both test and null epochs and could not have given rise to a differential fMRI signal. The positive activation therefore implies the discovery of a *unique SFT* segmentation mechanism that differs from any other kind of *dynamic* segmentation mechanism known up to now, with hMT+ playing a crucial role in defining the figure/ground organization.

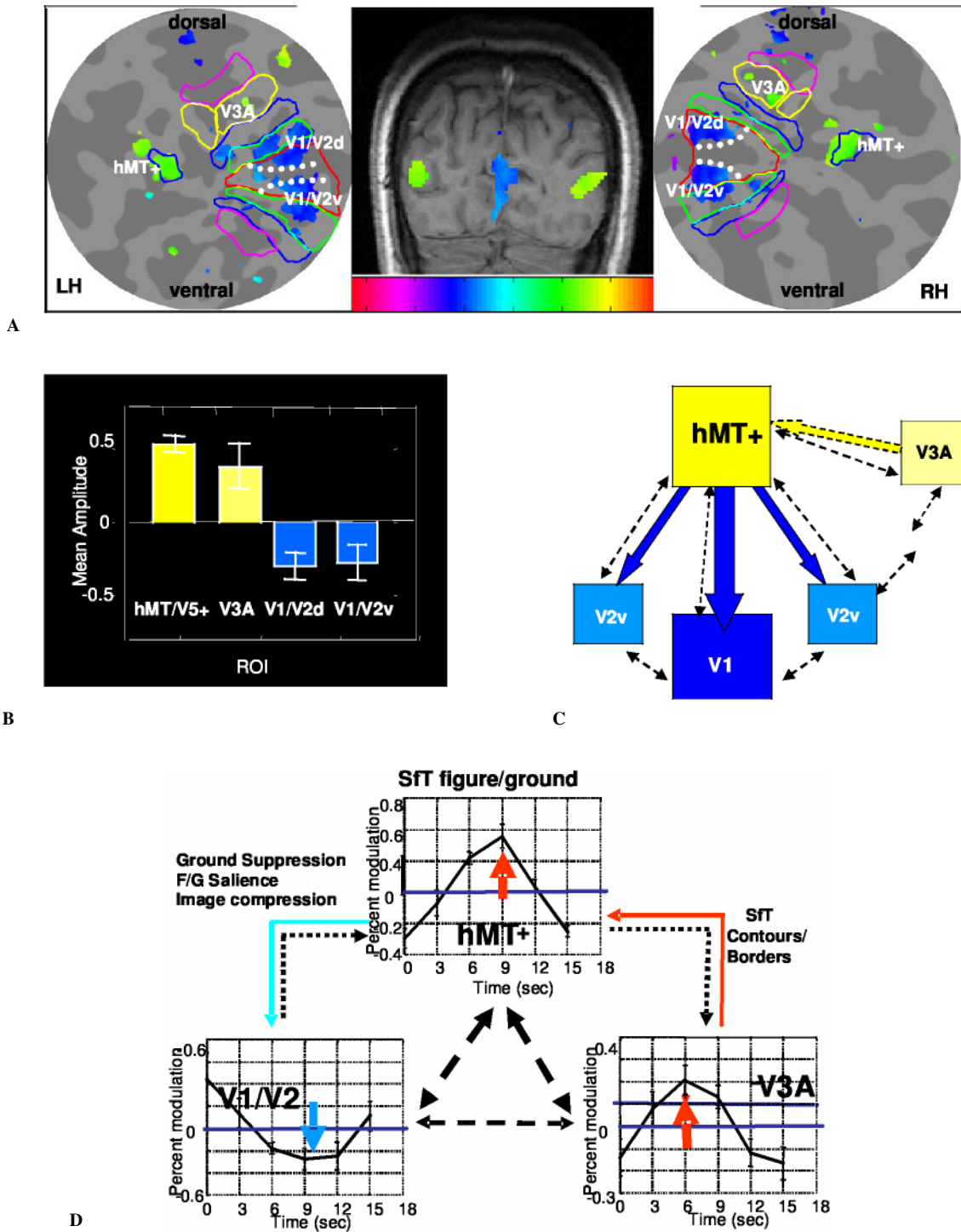


Fig. 2A. Cortical slice (center) and left and right hemisphere flatmaps showing activation (greenish coloration) and suppression (bluish coloration) in response to a transient-field asynchrony defining a single-bar figure on a same DNV background. B. Average responses over six hemispheres ( $\pm$  s.e.m.) for four cortical regions defined on the flatmaps. C. Proposed model of interactions among hMT+, V1/V2 and V3A cortical areas. hMT+ is proposed to be the main site involved sending a suppressive feedback signals toward V1/V2 (blue) and presumably 'exchanging' segmentation related information with V3A (yellow). D. The time course of the hemodynamic response in hMT+, V1/V2 background projection, V3A illustrates the proposed flow of information during an iterative process of segregating a figure from its background in a structure-from-transients. The basic functions performed in each area are listed. Activation signals are designated by red arrows, inhibitory effects by blue arrows.

While the strongest activation found during the transient-field asynchrony segmentation was in hMT+, the retinotopic areas V1 and V2 showed strong *negative* signal (in blue), implying a suppression relative to the baseline activation of the DVN field alone. This negative response is consistent in all six hemispheres studied (Fig. 2B). Inspection of the negative signals on the flatmap reveals that the suppression pattern is well structured – it is located in the areas of retinotopic representation of the surrounding top and bottom region, regions ‘A’ in Fig. 1. The white dashed lines within the V1 areas indicate the projected shape of the horizontal borders – wider apart in the foveal representation and narrowing toward the peripheral representation as the cortical magnification function takes effect. Since the asynchrony border between the two regions is the only defined feature in the field, the most obvious expectation would be that any signal (activation or suppression) would be found along this border. Instead, the suppression starts from the borders and expands throughout the projection of the periphery – the suppression is coincident with the “background” regions of the figure/ground segmentation.

## EXP. 1: DISCUSSION

First, it was quite surprising to find no fMRI activation in V1 or V2, as those areas are most often considered to be involved in scene segmentation and contour or border integration (von der Heydt & Peterehans, 1989, Reppas et al., 1997). Second, in contrast to previous motion-borders studies, hMT+ should not be activated by the transient-field alternations. Reppas et al. (1996) for example, conclude that responses for motion boundaries are largely absent from the motion-selective area MT/V5 and far extrastriate visual areas and demonstrate that information for segmenting scenes by relative motion is represented as early as V1. Similarly, van Oostende et al. (1997) find that segmentation based on coherent motion differentially activates area KO rather than hMT+.

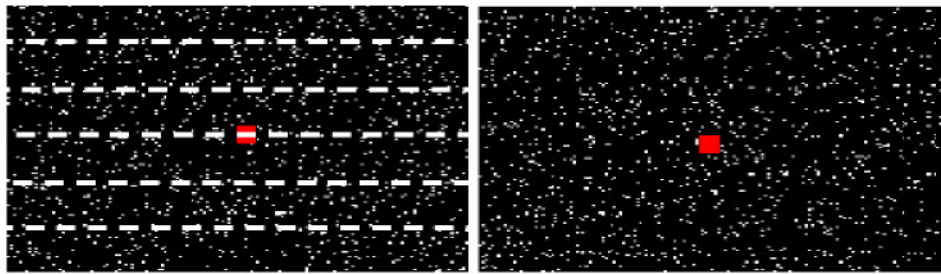
In order to unravel the cortical circuitry giving rise to these opposing activations and suppressions, we focus on the regions of suppression throughout the projection of the surround regions of the stimulus in areas V1-2. What puts them in a special position? What stimulus property is different about the stimulation of these areas? Locally, there is no difference from the stimulation in the null region, but, from the view point of perceptual organization, they are the *background* relative to the central “figure” region. The neurons in primary visual cortex V1 are well known to have small receptive fields (RFs), thus being restricted to very small regions of the visual field and perform lowlevel features such as orientation, spatial frequency, etc. The classical RFs of these neurons are unlikely to be able to perform the segmentation operation required to recognize the figural organization (especially when defined by the abstract property of transient-field asynchrony rather than luminance, motion or stereoscopic borders). Lamme (1993), Lee et al. (1998, 2002) and Lamme, Super & Spekreijse (2002) have found that V1 neurons exhibit a delayed modulation of stimulus-driven responses that derive from the larger perceptual context of these features such as the percept of figure-ground segregation (16, 18). The neurophysiological evidence of figure/ground processing in MT/MST (Allman, Miezin & McGuiness, 1985; Duffy & Wurtz, 1991, Grunewald, Bradley & Anderson, 2002) indicates that this is one cortical locus that could be generating the delayed large-scale responses in V1 neurons.

Similarly for the present data, the background suppression in V1/V2 must be generated from a figure/ground organization elsewhere in the cortex. The only reasonable suggestion is that this area is hMT+, the sole strongly activated occipital area under the fMRI paradigm. It is logical for hMT+ to be involved in ‘structuring’ our perception of dynamic images since it is equipped for processing transient-based signals and, as the homolog of the MT/MST complex, has a plenitude of large-scale receptive fields available for the purpose. Our data therefore, suggest that hMT+ is performing the figure/ground segmentation/classification and generating a negative, suppressive feedback to V1 (Fig. 2C). The only other retinotopic area significantly activated at the same criterion as

hMT+ was part of V3A and, inconsistently, the adjacent area V3B. The complementary nature of segregation and integration and the hypothesis of a recurrent architecture with feedbacks constituting functional loops and thus exhibiting more complex temporal behavior/dynamics could underlie the negative and delayed response in V1/V2.

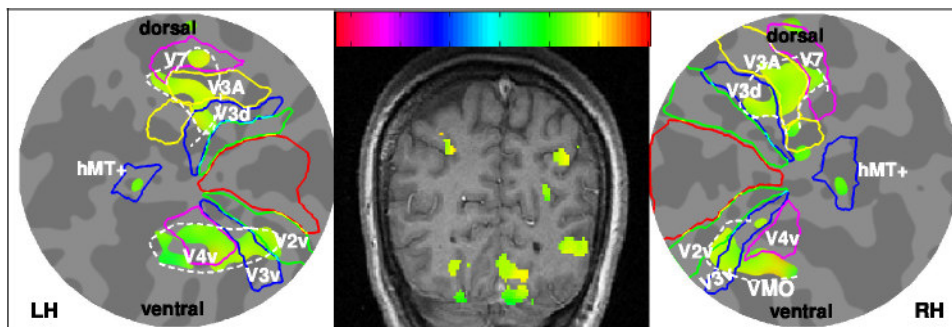
## EXPERIMENT 2: MULTIPLE ASYNCHRONY-STRIPE SEGMENTATION ELIMINATING FIGURE/GROUND STRUCTURE.

The only retinotopic area activated in Experiment 1, although partially, was the V3A/B complex, predominantly V3A. What is the function of V3A? Our suggestion is that contribution of V3A is restricted and focused on contour/border integration (Likova & Tyler, 2004), presumably with a feedback to hMT+. One logical way to further test the proposed model was to segment the same image into many equivalent horizontal stripes. First, this will “break” the figure/ground organization by segmenting the same image in multiple regions, no one of which would be more salient, i.e., will pop-out as a figure. Second, it will increase the number of contours. Based on the model of Fig. 2C, the following *predictions* can be made: (1) V3A activation will increase, because the number of borders is increased; (2) in contrast, both hMT+ activation and V1/2 suppression will go away because there is no figure/ground organization.



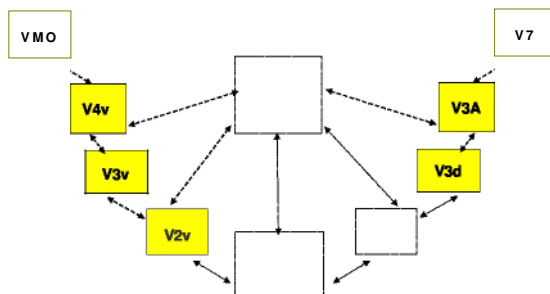
**Fig. 4.** Stimulus configuration for Exp.2. The null stimulus (*right panel*) was the same as in Exp.1 - homogeneous DVN field 30 x 40deg, updated every 500 ms. The test stimulus (*left panel*) differs from the test in Exp.1 only in the spatial pattern of asynchrony regions: there were many virtual same-width regions created by *asynchronous* dot updates between neighbors, thus transients in all even stripes happened simultaneously, but with a delay relative to the transient changes in the odd stripes. No stripe was perceived as a dominant figure. Steadily fixation was kept on a small square in the center.

## EXP. 2: RESULTS



**Fig.5.** By elimination of the figure/ground organization in the test-SfT, the segmentation on the principle of transient-asynchrony resulted in a radically different pattern of cortical activation. This pattern confirmed the predictions of our model described above: both the activation of hMT+ and the suppression of V1/V2 jointly disappeared, while, in contrast, the V3A signals were enhanced. In addition, there was an activation shift toward the higher dorsal (V3, V3A/B, V7) and higher ventral retinotopic areas (V2v, V3v, V4, VMO) in all observers.

Consistent with our predictions, this seemingly slight manipulation of the spatiotemporal structure of the test stimuli *dramatically reversed the pattern* neuronal activation in the visual cortex (Fig. 4). Both the activation of hMT+ and the suppression of V1/V2 were strongly reduced, while in contrast, the signals in V3A were dramatically enhanced. In addition, there was a dorsal/ventral spread of activation to dorsal retinotopic areas V7, V3d and ventral areas V3v and perhaps V2v, with further activation in more ventral cortex in an adjacent to V4 area (VMO). Note the consistency in the spread of activations in the two hemispheres in Fig. 4, which are essentially independent probes of the neural response pattern. Similar patterns of activation (and nonactivation) were seen in the both hemispheres of all observers.



**Figure 5.** A schematic representation of the retinotopic areas involved in the occipital network which is processing transient-asynchrony based segmentation. Interestingly, it occupies a series of areas in both dorsal and ventral pathways.

## EXP. 2: DISCUSSION

The process of segmentation requires on one hand the borders to be identified, on the other hand integration to be performed inside the regions on either side of the borders. The activation of the second-tier retinotopic areas by the multiple-border SfT stimuli has several implications for the organization of these illusory temporal borders. If the border identification process was instantiated in a particular retinotopic area, that area should show (yellow-green) activation along the lines of border representation. In a case of a non-isolated, but multiple borders, their activation signal may appear spread because of the relatively low spatial resolution of the fMRI technique. It would be interesting to explore in future studies how the signal is affected by varying the border density. The results of Experiment 2 support the segmentation mechanism as a source of differential BOLD signal. It is satisfying to see this border identification for the SfT cue in the second-tier retinotopic areas, providing a nice distinction of their function from that of the first tier areas V1 and V2. (In this regard, it is likely that the small activation seen in V2v in Fig. 4 is due to spread of activation from V3 by partial volume effects rather than direct activation in the V2v cortex itself). The pronounced reduction of activation in hMT+, relative to that in Exp.1 (Fig. 2A), clearly indicates that V3A and hMT+ are involved in different aspects of the SfT processing, since their responses change in opposite directions when the number of borders is increased. The natural interpretation is that both higher dorsal and ventral V3 complex are processing the border structure *per se*, but are not involved in the identification of SfT figure from ground, since their response largely disappears for the strong figure/ground conditions of Exp. 1. Conversely, the hMT+ area seems to be predominantly involved in the SfT figure/ground organization, since its response evaporates when more contours are added to swamp the segmentation process with an overabundance of SfT contours.

## GENERAL DISCUSSION

Visual transients are a prominent feature that underlies fundamental processes as segmentation and binding. Our purpose was to reveal the cortical correlates of *structure-from-transients*. With the fMRI technique we discovered strong involvement of the occipital cortex. A strikingly interesting was the finding that even at the level of such an abstract segregation (based solely on transient-field asynchrony in fields of featureless white visual noise) the pattern of activation was dramatically changed by varying the global segregated configuration in the stimuli, i.e., thus varying the stimuli organization at perceptual level.

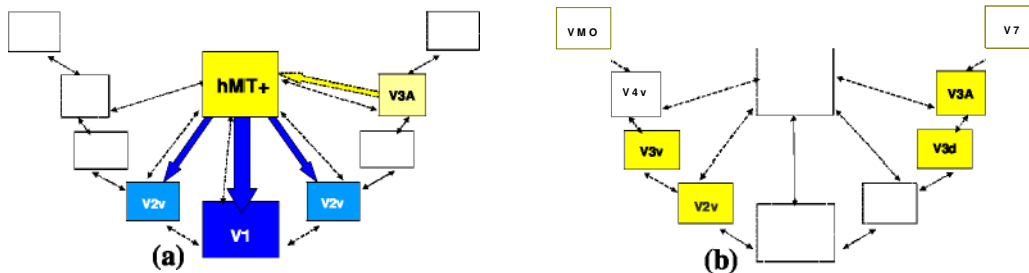
During figure/ground structure (Exp.1) the only fully activated occipital area was the human motion complex hMT+. V3A (in some subjects, V3B also) was weakly and partially activated. Surprisingly, none of the other retinotopic areas was activated. Moreover, V1 and V2 (which are often thought to be contour-processing modules) not only did not show any activation – they were strongly suppressed. Analysis of the pattern of suppression revealed that at least in SfT the human brain applies a strategy very different from any described until now: we found that *instead of facilitating the figure projection in V1/V2, suppression of the background regions is chosen*. Is there any rationale, any advantages in this surprising inverse strategy? To increase the salience of a figure one needs to increase the *relative* figure/ground difference along one or more visual dimensions. This enhancement can be done in two basic ways – by increasing/facilitating the figure signals or by decreasing/suppressing the background signals. The second approach has obvious informational advantages. First, it may be an effective mediator of a mechanism of information *compression* for later processing stages. If the only figure/ground mechanism were figure enhancement, all the processing of the background regions would continue unimpeded. If their signals are suppressed, however, subsequent processing for those regions is inactivated. Second, as a mediator of perceptual *adaptation*; background suppression could constitute an important component of the *attention* guiding mechanisms, as well.

What mechanism underlies this discriminative “behavior” to the figure vs the ground representations in V1, if as we know, V1 has very small RFs performing a low-level local processing? There is, however, evidence for a top-down feedback mechanisms able to modulate the V1 responses in result of conveyed information about the perceptual interpretation of larger parts of the visual scene thus taking into account the global context (Lamme, 1995; Lamme Super & Spekreijj *se.*, 2002).

Our finding that the puzzling suppressive response in V1/V2 goes away jointly with the hMT+ activation when the figure/ground organization was eliminated (under the conditions of the second experiment) implies that hMT+ was the generator of the suppressive signal. These data imply a crucial role of hMT+ in figure/ground segregation for structure-from-transients.

How hMT+ performs this function one can only speculate, but some suggestions could be made. Segregation and integration constitute a dual process and different models focused more on one or on the other of those aspects. It is well known psychophysically that the visual system is able to “capture” very slight regularities like “integrating” a trajectory of a single coherently moving dot in a field of many randomly moving dots (Verghese & McKee, 2002). It is inherent to motion-processing function of hMT+ to extract and look for spatiotemporal correlations. It seems more likely that hMT+ is looking for coherence on a global scale and is well equipped to segment by integration over the regions of similar features, with ‘expertise’ in spatiotemporal integration. Once it organizes the “parts” (in our

case –the central region (figure) on one hand, and the background region) on the other hand, it should be able to compare and analyze the relations between those ‘parts’, including their figure/ground relations. Does hMT+ do all this in isolation? On the basis of V3A activation during Exp.1, and its strong increase in Exp.2 with increase of the number of virtual borders, it may be suggested that the two areas are communicating in a search for a converging structural solution. Thus, the V3A signaling of the presence of the two borders in Exp.1 would support and increase the hMT+ ‘confidence’ in its perceptual decision to segregate the figure from the background.



**Figure 6.** A comparison between the occipital networks engaged in Exp.1 (see *a*) and Exp.2 (see *b*) vividly demonstrates the dramatic reconfigurational effect of spatiotemporal modulations on structure-from-transients mechanisms.

What our results revealed also is that the increase of illusory borders in the absence of figure/ground do not simply increase the activation in V3A, but increase the activation in almost all of the higher-tier retinotopic areas, both dorsal and ventral. In contrast to the figure/ground case, here neither V1 nor V2d were involved at all – either in an inhibitory or a facilitatory manner. Interestingly, V2v was involved again, but in an inverse fashion – it was positively activated, rather than being suppressed. A swath of activation runs through V2v, V3, VMO (and/or V4v in some cases); and dorsally – from V3d, V3B, V3A to V7. No structured activation was found anywhere in the lateral occipital complex.

In summary, (1) strong differential signals found in both experiments suggest that the response properties of the occipital areas to SfT differ fundamentally from the transients *per se* or DVN mechanisms, and (2) the dissociation between the fMRI responses to figure/ground segmentation versus the same kind of asynchronous segmentation when subdivided into equivalent regions (i.e., eliminating figure/ground) suggests further dissociation and implies an recurrent hierarchical architecture with a higher priority to the higher perceptual functions, as figure/ground organization vs simpler kind of segmented structures. In conclusion, we have found strong fMRI responses in the occipital cortex for a novel kind of fundamental spatiotemporal structure, designated as *Structure-from-Transients*.

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