SCIENTIFIC REPORT

ESF EMRC EXPLORATORY WORKSHOP

Attention, Action and Time

Amsterdam, Netherlands, 8 - 9 March 2006

Convened by:
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1. Executive Summary

Schedule:

Arrival	Evening of Tuesday 7 March 2006
Meeting opened:	09:00 on Wednesday 8 March 2006
Meeting closed:	17:00 on Thursday 9 March 2006
Departure	Evening of 9 or morning of 10 March 2006

Meeting Venue:

Filmmuseum
Franse Zaal (French Room)
Vondelpark 3
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Objectives

Attention research has focused on static situations, involving the selection of inert properties such as colour or shape, during a demarcated time period. In contrast, the real world consists of dynamic, continuous scenes putting different requirements on the observer in terms of selection, sustained attention, and action planning. Moreover, attention itself is a dynamic process – or rather a set of dynamic processes – with different components operating at different time courses. Very little is known about the interaction between the dynamics of our environment and the dynamics of attention itself.

The primary aim of the workshop was to discuss the dynamics of attention and action and their interaction with the environment, focusing on the effects time has on attention and vice versa, the problems neuropsychological patients have with temporal aspects of sustained and selective attention, as well as on the underlying brain mechanisms. As a spin off, new methods for exploring these issues would be exposed. For this purpose, participants were asked in advance to try and present their newest work. Moreover, to guarantee a high scientific level, some of the best scientists from their respective fields were invited (and attended)

A second objective was to explore new research avenues and to lay the groundwork for future collaborations on these topics between the various European labs involved. For this purpose, participants were asked in advance to end their talks with (several) open questions, unexplored connections with other work, or unresolved aspects of their data. Furthermore, it was aimed to promote new explorations and cross-fertilisation by the inviting scientists from several different backgrounds (neurology, neurophysiology, neuroscience, neuropsychology, biology, cognitive psychology, computational modelling, and pharmacology), who would bring along their own new methods and insights.

A final objective was to give young talented European researchers the opportunity to interact with top senior researchers with their own field as well as neighbouring fields. To get them involved in future collaborations would make a small but important contribution to keeping good researchers in Europe. For this purpose we asked each senior researcher to bring along young talents from his or her lab, and we also invited some directly. All participants, including these young talents, were given the opportunity to present their work and ideas.

Organisation

The workshop was organized by Chris Olivers and Jan Theeuwes and held in the Film museum, set in the surroundings of the Vondelpark in Amsterdam (Netherlands). The Film museum provided a very apt setting because of the dynamic nature of the medium (as was pointed out by Ulrich Ansorge, who teaches on the psychology of film; apparently there are many correspondences between film theory and attention theory).

The meeting started on Tuesday night (7th March) with informal drinks and food in Vertigo, the restaurant below the Film Museum. About 12 people attended. It quickly resulted in a lively discussion on scientific findings as well as the differences in science between the different European countries.

The workshop officially started at 9am on Wednesday with some introductory information on the ESF by the ESF representative, Dr Bruhn. Two participants arrived at 10am due to obligations elsewhere. The scientific programme consisted of 40 minute talks, each followed by 10 minute discussions, each of which was filled with useful, often lively, and occasionally heated debate. Interactions were informally continued during a common lunch, followed by the afternoon session. The day was ended with a one hour collaborative exercise during which a network of scientific links (i.e. common theoretical stances, common research questions, and/or common methods) was built between the labs that had presented that day. The day ended with an excellent diner at Onder Ons, in the centre of Amsterdam.

The second day continued with scientific sessions, and ended with a collaborative exercise during which the talks of that day were integrated into the network already built the day before. Furthermore, a future plan of action was agreed upon, and the ESF representative (Dr Bruhn) provided the group with tips and suggestions as to how to proceed further with regard to possible European funding (either via the ESF or through other routes). The workshop was then officially closed.

Afterwards, about one third had to leave to catch their flights or trains. The others joined for drinks and tapas and looked back upon a successful workshop.

2. Scientific Content

The meeting was divided in four major sub themes: 1. Short-range dynamics of attention: Bottom-up and top-down control; 2. Short-range dynamics of attention: Models and brains; 3. Attention and dynamic stimuli; 4. Long-range dynamics of attention: Sustained attention and arousal. Each of these sessions contained around four presentations of 40 minutes each, followed by 10 minutes discussion. Each day ended with a collaborative exercise during which findings were further discussed and connections between different studies were made.

● The scientific part of the workshop was opened by **Chris Olivers** (Vrije Universiteit Amsterdam), who presented recent data that put a new perspective on the attentional blink, the unavailability of attention for around 500 ms after processing of a target. The phenomenon has been thought to reflect a cognitive bottleneck that can process only one target at a time, and it takes 500 ms to clear this bottleneck. However, the new data suggests that the attentional blink is caused by a much more dynamic set of excitatory and inhibitory attentional processes that operate on a scale of 100 ms. Even during target processing, attention responds flexibly to the stimulus, but is just a little sluggish. Similarities with results from other paradigms suggest that 100 ms may be a key value in attentional dynamics in general. **Humphreys** suggested that the time course may be not be set at 100 ms, but dependent on the ease with which distractors can be rejected. **Coull** mentioned that clonidine exerts strong effects on the temporal dynamics, and may affect the results of the attentional blink paradigm. Clonidine operates on the locus coeruleus - norepinephrine system. Both points deserve further investigation.

>Crosslinks
Humphreys: Time course distractor rejection (visual marking?)
Coull: psychopharmacological effects (see Nieuwenhuis)
Bundesen: First wave vs. second wave of processing, does it take 100 ms to complete the first wave?
Kyllingsbaek: TVA modelling of rapid serial visual presentations
Scharlau, **Ansorge**: Temporal order judgments vs. order reversals in the attentional blink

● **Jan Theeuwes** (Vrije Universiteit Amsterdam) talked about the relative impenetrability of early salience-based attention effects, except for location-information, which is modulated early in the visual system. It was argued that these initial salience effects are based on a bottom-up feedforward sweep, whereas top-down processes only exert their effects later, through recurrent processes. These recurrent processes only kick in after 100-150 ms (cf. Lamme). **Theeuwes** also reported on ERP studies showing an N2pc component corresponding to capture by the salient stimulus. According to **Orban**, some of **Theeuwes'** results may be explained by uncertainty effects rather than the presence or absence of top-down effects. He also deemed a recent Science paper from Michael Goldberg's lab highly relevant. According to Robertson, evidence for salience effects also comes form neglect patients, who can spontaneously make an eye movement to a salient stimulus of which they are not aware. **Olivers** mentioned that the N2pc component occurs around 250 ms post-stimulus onset, which appears too late for the early (<150 ms) effects.

>Crosslinks
Bundesen: What is the relationship between Theeuwes' first sweep of bottom-up processing and Bundesen's first wave of attentional weight settings?
Coull, **Olivers**: Capture may be contingent upon abrupt onset, what happens when stimuli appear more gradually.
Vanduffel: Is the FEF the source of the recurrent processing? Does the fact that FEF modulates V1 mean that there is early modulation after all? OR is it only early in *site*, not early in *time*? Vanduffel showed location modulation, but what about feature modulation? Can the dissociation between location and feature modulation suggested by **Theeuwes** be confirmed on a neuro-level?
Vandenberghe: Finds different parietal areas active in response to position changes and feature and/or rule changes.

● **Mieke Donk** (Vrije Universiteit Amsterdam) provided further evidence for very early salience-based effects that appear relatively independent of later top-down influences. In one type of paradigm subjects were required to make a fast eye movement to a target and ignore a distractor, The faster the eye movement, the more likely it went to the more salient rather than the more relevant of the two. A striking finding was that later in time, performance accuracy dropped, even when the target was the more salient one. In another paradigm, subjects were asked to decide which of two stimuli was the most salient. Subjects had more trouble doing this the longer the stimuli were presented. Apparently initial salience information is available only for a short period of time, perhaps 100 ms?

>Crosslinks
See also those for **Theeuwes**.
Humphreys also made a direct connection with his work, in which he shows an initial transient-based grouping effect. Perhaps there is a salience-base grouping effect. Does grouping occur due to the common onset, or due to the common time course?

• **Claus Bundesen** (University of Copenhagen) presented a neural version of his computational theory of visual attention (NTVA). NTVA is based on two main equations; one for filtering processes (selection of objects), another for pigeonholing (enhancement of features). Neurally, the two equations correspond to the number of neurons assigned to the processing of an object, and to the level of activation of the neurons, respectively. During a first wave of processing, possibly in a circuitry involving the LGN, (extra)striate cortex, and pulvinar, attentional weights are calculated. In a second wave of processing, cortical processing capacity (visual short-term memory) is redistributed on the basis of these weights, so that a small set of objects is assigned a large number of neurons. This second wave of processing is thought to involve a thalamico(TRN)-cortical feedback loop that keeps the selected items activated. **Orban** noted that we should distinguish between the sources and effects of attention and that TVA is mainly a theory of the effects of attention.

>Crosslinks
Theeuwes: Does the first wave correspond to Theeuwes' first sweep? An obvious difference appears to be the cognitive penetrability of Bundesen's weight-setting.
Vanduffel: Is the microstimulation of the FEF a form of weight-setting? To which TVA parameters does the effect of microstimulation correspond? Has Vanduffel identified the source of attention that is "lacking" in TVA?
Vandenberghe: How does TVA account for the dynamic remapping of attentional priorities found by Vandenberghe, and allocated to specific parietal areas? Does NTVA indeed provide the bridge between cognition and neurophysiology?
Robertson: It may be fruitful to look at TVA's parameters under long-range vigilance/arousal/sustained attention effects. At present there is no arousal parameter in TVA, whereas arousal has obvious consequences for performance.

• The relevance of the (N)TVA work was further shown by **Soeren Kyllingsbaek** (University of Copenhagen), who adapted the theoretical framework to rapid serial visual presentations, to see if the model could account for phenomena such as the attentional blink. Such phenomena may arise because, on a short-term memory level, newly presented stimuli compete with older stimuli that are already present in short-term memory. Obviously, TVA's k parameter (for STM capacity) plays an important role in this. The approach appeared to be promising, even though the model exhibited some anomalies for items presented at the end of the stream. This was probably due to the absence of a proper (categorical) mask. **Olivers** made a suggestion for a more effective mask.

>Crosslinks
Olivers: TVA may be able to account for the general (500 ms) attentional blink pattern, and there are obvious connections here. However, it remains to be seen to what extent it can cover the microdynamics (at 100 ms). Also, the TVA version is in essence a limited-capacity/bottleneck account of the blink, something that is argued against by **Olivers**.
Scharlau: To what extent can STM competition between old and new account for temporal order reversals.

• **Thomas Habekost** (University of Copenhagen) presented a new perspective on visual processing capacity, namely that it may correlate with the condition of the cortical white matter (whereas most neuropsychological and neuroimaging studies focus on the grey matter). He showed that white matter lesions (stroke) and conditions of leukoaraiosis (myelin damage of the fibre tracts) relate to reductions in visual processing capacity (the C parameter within the TVA framework), and visual short term memory (the K parameter within TVA).

>Crosslinks
Robertson: Are white matter lesions and their corresponding reductions in general processing capacity related to arousal.
Vandenberghe: K and C parameters in other populations
Olivers: If white matter deterioration affects processing speed, does it affect the 100 ms mark?

● The theme then switched from modelling to neurophysiology with an exciting new technique presented by **Wim Vanduffel** (University of Leuven). The technique consisted of a combination of monkey fMRI with microstimulation in the frontal eye fields (FEF). Behaviourally, it was shown that FEF stimulation led to spatial attention shifts. This was exciting in itself, but on top of that the fMRI data showed that the FEF stimulation resulted in increased activity in parietal (IPS) and superior temporal areas, higher order visual areas, (V4/TEO), as well as in primary visual areas (striate cortex, V1). Such posterior activity occurred in absence as well as presence of actual stimuli in the attended location. This is the first study to demonstrate a direct causal link between FEF and posterior areas in attentional functioning. **Olivers** asked why FEF stimulation was applied 133 ms after stimulus onset, as its value appears very suggestive in relation ot the 100 ms mark mentioned above. Vanduffel replied that this value simply appeared to work best for the areas investigated, but that different values may be more optimal for other areas.

>Crosslinks
Theeuwes: Is the FEF the source of the recurrent processing? Does the fact that FEF modulates V1 mean that there is early modulation after all? OR is it only early in *site*, not early in *time*? Vanduffel showed location modulation, but what about feature modulation? Can the dissociation between location and feature modulation suggested by **Theeuwes** be confirmed on a neuro-level?
Bundesen: Feature modulation. To which parameters does the FEF microstimulation effect correspond? Is the effect multiplicative?
Olivers: Relation of the 133 ms onset asynchrony to the suggested 100 ms mark. Does this depend on target site of modulation?
Vandenberghe: Vdb found specific posterior activity in relation to a location change vs. feature change (or more general rule change). Will the same activity be found if the change is brought about by a change in frontal microstimulation?

● **Vandenberghe** (University of Leuven) presented work that sought to dissect specific functions of the parietal cortex, notably the superior parietal lobule and the intra parietal sulcus (horizontal segment), in response to dynamic changes in the environment (i.e. changes in locations and/or features of objects). He found that SPL activation was more pronounced (against a sustained attention baseline) when either the to-be-attended or the to-be-ignored stimulus changed position. IPS activation occurred in response to changes of a feature, or in response to changes of the *relevance* of a specific feature (even if the feature itself did not change). It appears that SPL adjusts for spatial changes, whereas IPS adjusts for any change in the attentional landscape.

>Crosslinks
Theeuwes: Location change vs. feature change
Bundesen: Dynamic reallocation of attentional weights. How to capture this in TVA? Humphreys, Olivers: Vandenberghe's paradigm important since it moves away from the trial as a unit of measurement, observer is continuously on-task.
Vanduffel: Vdb found specific posterior activity in relation to a location change vs. feature change (or more general rule change). Will the same activity be found if the change is brought about by a change in frontal microstimulation rather than by the task itself?

● The second day started with a presentation by **Guy Orban** (University of Leuven) on the role of attention in motion-detection. In general Orban pointed out the importance of separating the sources (e.g. areas FEF and LIP) and the targets (e.g. V4 and TEO or other content areas) of attention, as well as the importance of trying to bridge monkey and human physiology (e.g. through monkey fMRI). Monkey fMRI has, for example, been able to shift between several action related areas in the mirror-neuron system. The second half of the talk focused on a higher order motion system that depends on attention (i.e. the percept of motion occurs for attended stimuli). This motion system appears salience driven rather than the luminance driven lower order motion systems. It activates the intraparietal lobule (IPL), an area that also appears sensitive to long-range (7Hz) apparent motion. The IPL area seems sensitive to motion on signals that are "marked" by attention (e.g. through abrupt onset or salience).

>Crosslinks
Theeuwes: Salience-driven effects
Olivers: Long-range apparent motion + "marking" by attention may be related to maintenance of an object file (cf. Kahneman & Treisman). If timing is not right, then a spatio-temproal discontinuity is perceived → new object (cf. Yantis & Gibson, 1994)

● **Glyn Humphreys** (University of Birmingham) then talked about the role of stimulus dynamics and action on attention. He showed that extinction (the finding that after right parietal lesions stimuli in the left-visual field are not perceived when accompanied by a simultaneous stimulus in the right visual field) is relatively attenuated when the stimuli are presented only briefly. Humphreys proposes that the left and right stimuli are initially bound by their common onset or their common dynamics. This temporal binding is quickly lost after which the competition between stimuli (extinction) takes over. In the second part of his talk, he then showed that extinction is not only modulated by the temporal relationship between stimuli, but also by the *action*-relationship. For instance, when a corkscrew is presented in the left field, and a wine bottle in the right field, extinction is reduced when the corkscrew and bottle are in the canonical action position (i.e. corkscrew opens bottle). The reduced extinction was particularly strong for "active" objects (such as a corkscrew) as compared to "passive" objects (such as a bottle). Such action effects disappeared when the related objects were presented separated in time. As **Robertson** put it, apparently the action representations form a way of "rescuing fragile initial bindings between objects".

>Crosslinks
Donk, Olivers: Do the initial onsets or the initial dynamics related to the common onset of stimuli for them to be grouped? Is 100 ms special in this?
Orban: How does this temporal binding relate to higher order (attentional) motion effects? Now the actions are presented by way of static pictures, what if dynamic videos are used?

● The session continued with two talks on prior entry, as expressed through temporal order judgements (TOJ). The idea is that attended stimuli are processed faster and may therefore be perceived first (even if they were presented second). **Ulrich Ansorge** (University of Bielefeld) showed how TOJ depends on the relative saliency of the stimulus (bottom-up attentional effects) as well as the task relevance of stimulus features and advance information, (top-down influences). A further research objective is to assess the timing of TOJ through event-related potentials. The big question is which ERP components are related to the objective timing of the stimulus, and which to the perceived timing of the stimulus.

>Crosslinks
Theeuwes, Donk: Salience-driven effects vs. top-down attentional control. N2pc components of ERP related to both capture and prior entry?
Olivers: TOJ vs. order reversals in the attentional blink
Vanduffel: Can prior entry be artificially established through microstimulation of FEF?

● The second talk on TOJ was by **Ingrid Scharlau** (University of Bielefeld), who compared it to the phenomenon of illusory line motion, the phenomenon that a line appears to emanate from the side that is attended. This was the first time that the two effects were compared within the same paradigm. Attention allocation was manipulated using a cue preceding the onset of two objects and a line. Initial experiments with a fixed cueing time indicated that TOJ an ILM followed identical psychometric functions, suggesting that they reflect the same phenomenon. However, follow-up experiments looked more carefully at the time course of the two effects by systematically manipulating cue lead time. The results suggest a dissociation. Cue lead time has a much bigger effect on TOJ than on ILM. However, for both effects it was found that they grew larger with increasing SOA up to about 100-150 ms, after which the effects decreased again. Links were made with similar time courses found by Nakayama and Mackeben (1989) and Suzuki and Cavanaugh (1997).

>Crosslinks
Olivers, Kyllingsbaek: Temporal order judgments vs. order reversals in the attentional blink. Plus, the time course of TOJ is very similar to the 100 transient component of attention referref to by Olivers (as found by Nakayama and Mackeben, 1989).
Donk, Theeuwes: Do the initially strong but later weaker TOJ/ILM effects reflect first feedforward/bottom-up processes?

● The topic then switched to long range effects such as those under tasks of sustained attention and vigilance, effects thought to relate to levels of arousal. **Ian Robertson** (Trinity College Dublin) discussed these long range effects within the larger framework of attentional components of selection, control and vigilance, as seen from a neuropsychological perspective. Vigilance has proven to be an important factor in predicting and facilitating recovery from attention-related clinical disorders. An important tool in measuring vigilance has been the SART (Sustained Attention to Response Task), in which a person is required to respond repetitively to a series of stimuli but withhold response to one particular stimulus. Drops in vigilance are typically expressed in a failure to withhold (commission error) or a failure to respond (omission error). Interestingly, performance improves with increased effort, when the task becomes more difficult. Performance on the SART task is associated with activity in the inferior frontal and parietal areas that have proven active in other attention tasks. It has been shown that vigilance modulates spatial attention in normals and neglect patients. Furthermore, Robertson and colleagues have shown that neglect and traumatic brain injury symptoms and can improve in everyday life with vigilance training. They also found evidence that vigilance is related to awareness, at least the observer's awareness of his or her own errors. Finally, the SART and spatial asymmetry tasks have proven to be useful tools in genotyping sustained attention deficits in various forms of ADHD. In relation to short-range temporal factors, vigilance has shown to affect variability in RTs and time estimation. Furthermore, it remains an important question as to what the "refresh cycle" of vigilant attention is (i.e. the time between peaks of attention). **Orban** asked why in the SART task you need to withhold your response to the critical stimulus (and respond to the non-critical ones). **Robertson** argued that a stimulus in itself, by nature of its (abrupt) appearance may trigger a tendency to respond. **Orban** further wondered whether effort and difficulty are the same, to which **Robertson** responded that difficulty is one way of inducing more effort.

>Crosslinks
In essence Robertson's work connects to all others, since vigilance forms a prerequisite in most if not all attention tasks. Here we mention a few examples.
Theeuwes, Donk: How is attentional capture affected by vigilance? Will it increase or reduce. Which component of attention (bottom-up/top-down) will be most affected by vigilance?
Bundesen: How is vigilance modelled within TVA? Which parameters can be adjusted? Or are new parameters needed?
Vandenberghe, Humphreys, Olivers: Sustained attention tasks moving away from the trial as a unit of measurement. Tasks are longer and more continuous, therefore more reminiscent of everyday life tasks. It is important to also assess shorter-range attentional effects under such circumstances.
Olivers: How does vigilance relate to the time course of attention, such as in the attentional blink?

● **Paul Dockree** (Trinity College Dublin) then followed up on Robertson's presentation by showing tonic and phasic markers of sustained attention in EEG patterns. For example, people suffering from traumatic brain injury and sustained attention problems fail to show a gradual decrease in alpha power in anticipation of the target. Within non-patients, high levels of tonic alpha power also predict good performance on vigilance tasks (SART). However, it is as yet unclear what the (reduction in) alpha power reflects. Does it reflect changes in signal-to-noise ratio, cortical idling or active deactivation of irrelevant networks. Finally, Dockree presents evidence that commission errors on the SART task correlate with increased variance not only in RTs but also in the P1 ERP signal. **Olivers** asked if there are also effects with regard to the variability of the P3/P300 component, but this is as yet unknown.

>Crosslinks
See also **Robertson**
Humphreys, Olivers, Vandenberghe: Also here, sustained attention tasks moving away from the trial as a unit of measurement. Tasks are longer and more continuous, therefore more reminiscent of everyday life tasks. It is important to also asses shorter-range attentional effects under such circumstances.

- The final presentation was by **Katherine Johnson** (Trinity College Dublin), who used RT variability in the SART task as a window on ADHD (Attention Deficit Hyperactivity Disorder) and HFA (High Functioning Autism). She argued that this variability may reflect functioning of the frontal cortex and in particular the dorsolateral prefrontal cortex. Increased intra-individual variability in RT may reflect fluctuating top-down attentional control, which may underpin sustained attention deficits in ADHD. Using a Fast Fourier Transform of the RT data, **Johnson** et al were able to temporally differentiate two forms of variability: slow- and fast-frequency contributions. ADHD children progressively slowed in RT over the course of the 5 minute task, as reflected in the significantly greater slow frequency variability, compared to controls. These children were also significantly more variable than the controls in the fast frequency domain (moment-to-moment variability), but this variability did not change over the task. There are a number of implications for this work. HFA cases also showed increased variability but could be dissociated from the ADHD group. It appears that HFAs use external cues to maintain attentional control. What are the physiological and anatomical underpinnings of this variability? Are there genetic influences on slow and fast varieties of variability? Will psychiatric groups provide further information about the systems in the brain involved in sustained attention and arousal?

>Crosslinks
See also **Robertson**.
Olivers, Donk were charmed by the Fourier analyses of RTs and wonder whether it is applicable to other attention paradigms. Again, the moving away from trials as a discrete unit of measurement seems relevant also to shorter range attentional processes. Furthermore, the method may be a nice way of profiling individual differences (e.g. differences in vigilance refresh cycles).

3. Assessment of the Results, Contributions to Future Directions

The workshop discussions were aimed at finding common ground for future research collaborations. For this purpose a graphical network was set up and the participants were asked to fill in what they thought were the connections between labs. From these connections several important conceptual clusters emerged. Figure 1 shows the outcome of this exercise. It reveals how the different researchers are linked to the different concepts (and hence, through these concepts, to each other). These clusters are not meant to be mutually exclusive. As the network shows, there is a large amount of overlap between researchers and therefore also likely between the concepts they are trying to investigate.

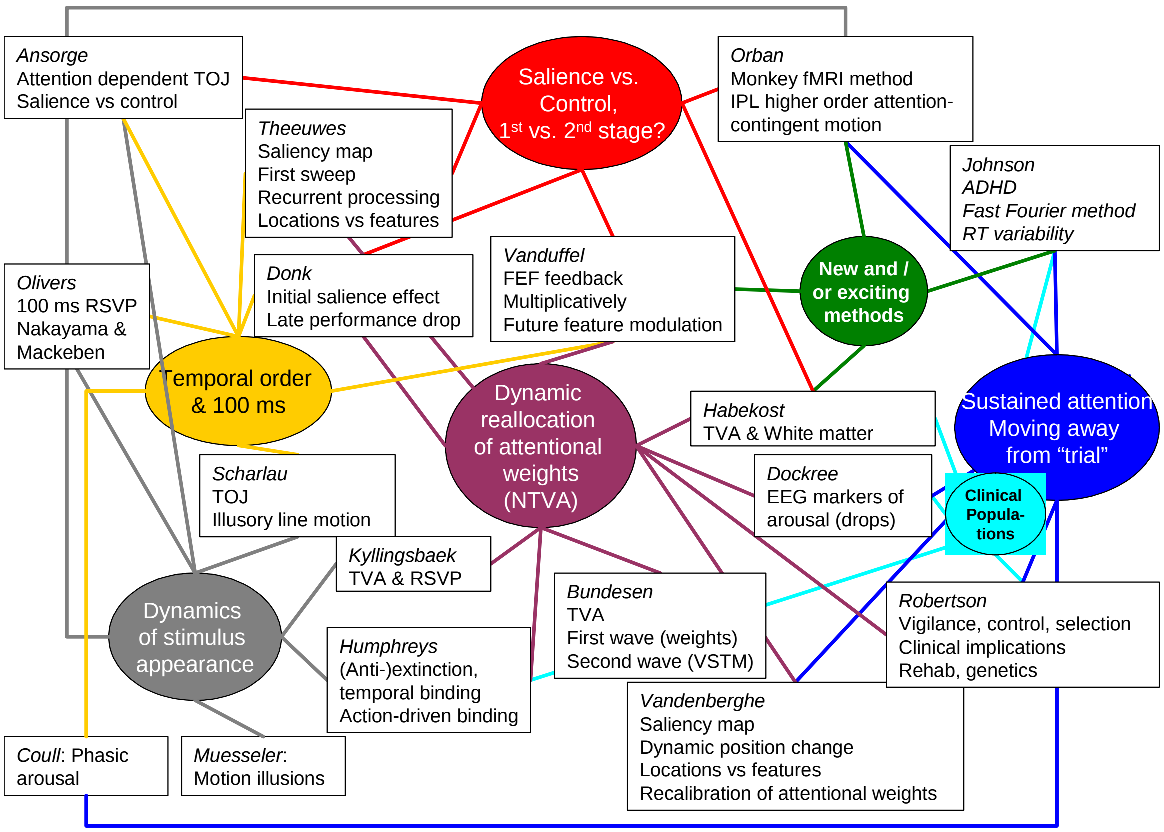

Figure 1. Conceptual network linking the workshop participants.

Below we will identify what we think are the most important clusters in terms of scientific content. But in addition to content, Figure 1 also shows how some investigators have adopted new (at least to neighbouring field) and/or exciting methods that may prove promising for the future. Orban and Vanduffel closed the gap between human fMRI and monkey single cell investigations by using monkey fMRI research. Vanduffel presented an exciting new method of cortical microstimulation in combination with monkey fMRI, thereby tracing the functional tracts in the brain. Habekost provided crucial insight in the functional relevance of white matter measurements. So far white matter had been largely ignored. Finally, Johnson presented a fast Fourier analysis of RT variability in different populations, and showed that these populations show different profiles. Although this method is not new, it may prove fruitful also in shorter-range attention paradigms that typically focus on single mean RTs rather than variability across the time course of the task.

Cluster 1: Salience vs. Attentional control

(Ansorge, Bundesen, Donk, Habekost, Orban, Theeuwes, Vanduffel)

The important question remains as to what the relative influences of bottom-up (salience-driven) and top-down (concept-driven) mechanisms on attention are. The consensus during the workshop was more or less that the question is not whether bottom-up or top-down mechanisms play a role, but *when* (and, related, *where* in the brain). Are there two independent stages as proposed by Theeuwes and Donk, one feedforward and completely bottom-up, a second recurrent top-down process on which salience has no longer an influence? Or are these processes interwoven, as in NTVA, in which both bottom-up and top-down processes affect initial attentional weight setting (first wave) and maintenance (second wave)? Does location have a special status (it allows for early selection), or is it just like feature selection? What effects do bottom-up and top-down mechanisms have on the speed of processing (Ansorge), and can they be dissociated through the effects they have on processing dynamics? Other questions that were raised were: Is it all a matter of how to define "selection"? Are there different activity levels that initially remain but that are ultimately overwritten by recurrent processing or are there only different velocities with which the different activity levels increase until one maximal level? Is there still a necessity for Inhibition of Return in suppressing salience information? Is the saliency map changing every time an eye movement is made? It was foreseen that NTVA (Bundesen) may provide an important framework for these questions, and that cortical microstimulation (Vanduffel) may become an important new method.

Cluster 2: Dynamic reallocation of attentional weights
(Bundesen, Humphreys, Dockree, Donk, Kyllingsbaek, Olivers, Robertson, Theeuwes, Vandenberghe, Vanduffel)

Another important question is how attention adapts or remaps to changing circumstances in either the stimulus environment or the task requirements. In other words, how does the spatiotemporal (or « featurotemporal ») landscape evolve? Here one should think of changing dynamics on a scale of milliseconds (within a trial, e.g. Donk), seconds (between trials, e.g. Vandenberghe) or minutes to hours (e.g. SART, Robertson). From an NTVA perspective, one could ask questions such as whether the attentional dwell time (attentional blink) is caused by a consolidation process (i.e. VSTM) or a limit in perceptual processing capacity (Kyllingsbaek). Vandenberghe raised questions such as whether the different re-mapping procedures can be knocked out in a selective manner in stroke. Is it possible to directly model information flow between IPL, IPS, SPL and occipital areas, i.e. the areas that appear relevant in the adjustments of attention? Can attention be dynamically adjusted on the basis of action codes, and what are the temporal constraints on action coding? (Humphreys). Humphreys also wonders how do transient effects of temporal binding interact with sustained attention processes. How can sustained attention and arousal be quantified and implemented in a computational model, perhaps NTVA (Robertson)? How can we measure the time course of sustained/vigilant attention and its interaction with arousal? What is the role of frontal, parietal, cingulate and subcortical systems in controlling vigilance (Robertson)? What are the physiological and anatomical underpinnings of slow and fast types of variability in vigilance (Johnson)? And how are the attentional dynamics affected by reductions in white matter (Habekost).

A recurrent theme in our field of research, and also in the workshop is the importance to separate the source of attention and the effects it exerts. For example, TVA (Bundesen) may be regarded as modelling the effects of attention, whereas NTVA also postulates some hypotheses about its source. Vanduffel's microstimulation work provide compelling evidence for the frontal eye fields as at least one clear source of attention, as its stimulation leads to activity in posterior areas. Do Vandenberghe's findings of posterior activity with an attentional change reflect a similar source of attention? Furthermore, selective attention appears conditional upon a certain level of vigilance or arousal. Also, to a large extent, sustained and selective processes appear to involve the same brain areas. But does this mean that arousal (and its corresponding brain stem activity) is the source of attention? Or is it an effect of target selection? How do these sustained and selective processes interact in time?

Cluster 3: Temporal order and the special status of 100 ms.
(Ansorge, Coull, Donk, Olivers, Scharlau, Theeuwes, Vanduffel)

Several lines of work appear to converge on the idea that 100 ms may be an important value in attentional processing. Olivers showed that attention adapts to a stimulus stream within about 100 ms ; Donk showed saliency effects for about the first 100 ms ; Theeuwes argues that attention is initially driven by a feedforward sweep that takes about 100 ms before recurrent processing kicks in; Vanduffel found that microstimulation of the FEF worked best at latencies of about133 ms ; and Scharlau found temporal order judgements to be maximally affected by an attentional cue when the cue preceded the target stimuli by about 100 ms. Similar findings have been done in the past by Nakayama & Mackeben (1989) and Weichselgartner and Sperling (1987). An important question for the future is therefore whether 100 ms is indeed special. Another interesting phenomenon is that of order reversals within different paradigms. For example, within the attentional blink paradigm perceptual order reversals between targets occur even at temporal separations of 100 ms or more. In the TOJ paradigm, order reversals usually occur only for separations in the order of 40 ms at maximum. Are these order reversals of the same type, and if not what makes them different? What are important differences between the paradigms, such as spatial separation and the presence of distractors? Other questions raised were whether 100 ms is the latency of phasic arousal and how this relates to tonic arousal/sustained attention (Olivers). How does temporal order judgment relate to other temporal illusions such as the illusory line motion (Scharlau).

Cluster 4: Dynamics of stimulus appearance
(Ansorge, Coull, Donk, Humphreys, Kyllingsbaek, Olivers, Orban, Scharlau)

Where most questions focus on the dynamics of attention itself, the other important aspect is the influence that the dynamics of the stimulus have on attention. Humphreys has shown the relevance of temporal binding and action affordances on attention. Orban showed the special status of salience in higher-order motion stimuli and long-range apparent motion. Olivers and Kyllingsbaek addressed the dynamics of stimuli that are dragged out in time (rather than the more typical spatial lay-out). Coull suggested that attention may operate differently (e.g. in attentional capture paradigms) when stimuli appear gradually, a point also considered important by Olivers. So important questions for the future are: Would attention have a different time course if stimuli appear with different dynamics (Olivers)? how do temporal characteristics of the stimulus interact with VSTM capacity? (Kyllingsbaek) What is the parallel between the psychophysics of long-range apparent motion) and MR activity in IPL (Orban)? How does long-range apparent motion interfere with saliency (bottom up and top down) effects in MR act in IPL (Orban)? What is the level of representation involved – e.g. Change in the coordination system, priming via pantomime? What are the brain regions involved in processing stimulus dynamics– given inferior parietal lesions typical in patients? And how do transient effects of temporal binding interact with sustained attention processes (Humphreys)?

Cluster 5: Sustained attention. Moving away from the "trial".
Subcluster: Investigation of clinical populations.
(Coull, Dockree, Habekost, Humphreys, Johnson, Orban, Robertson, Vandenberghe)

The long-range dynamics of attention will no doubt become a crucial topic for the future, because they not only form the basis for the shorter-range selection processes we have been investigating for decades (if not centuries), but also because they prove to be an extremely important component in characterizing, and rehabilitating clinical populations (stroke, ADHD, traumatic brain injury, autism). Furthermore, they form a window on individual differences and the genotypes underlying these differences. The genotyping of attention will prove to be an explosive new field (both in terms of growth as in terms of implications). Another important development is the moving away from the "trial" as a unit of measurement. Standard attention tasks are divided up in what are regarded as independent units of measurement - the "trial" – during which, in a rather staccato manner, a single stimulus is presented followed by a response. This is rather far from real world tasks, which usually involve prolonged dealing with objects or tasks. Sustained attention research is much more familiar with such continuous tasks and may serve as an inspiration for other areas. Further issues of importance raised were the psycho-pharmacology of arousal and sustained attention (Coull, Robertson); the relationship of vigilant attention with conscious awareness/monitoring; Can arousal variables be quantified and implemented in a computational model? Measuring the time course of vigilant attention; Modelling the interaction of arousal and vigilant attention systems (Robertson). Role of frontal, parietal, cingulate and subcortical systems in controlling vigilance; Signal variability and prefrontal control; ERP components, phase coherence between prefrontal and occipito-parietal areas and phasic fluctuations in the wider sustained attention network; Endophenotypes for dysfunctional SA networks; Signal variability as markers for cognitive decline (Dockree); Are there genetic influences on slow and fast varieties of variability? Will psychiatric groups provide further information about the systems in the brain involved in sustained attention and arousal (Johnson)? How does the neuroanatomically defined re-mapping processes translate into in terms of sustained and selective visual attention (Vandenberghe)? What is the relationship between phasic arousal and tonic arousal (Olivers)?

Future objectives

The above analysis shows that there is plenty of common ground for the participants to embark on collaborations. In fact, a number of researchers already indicated during the workshop that they would set up something together. These collaborations could take several forms, with the simplest form being a bilateral relationship between two labs. Furthermore, small groups could be set up on the basis of the clusters outlined above. However, our major aim for the near future is to coordinate these efforts within the overarching research theme of *attentional dynamics*. Such larger-scale pan-European collaborations may be viable for funding, e.g. under the EUROCORES flag (see www.esf.org).

We plan to take the following steps:

1. Disseminate this research report under the participants
2. Invite participants to partake in an overarching collaborative setup (and if so within which cluster).
3. Convenors write an overarching programme.
4. Participants write individual project proposals.
5. Proposals are submitted to ESF under the EUROCORES/ECRP flag.

Naturally, the above depends on the willingness of participants to partake, and the success in finding common research questions.

4. Final Programme

Tuesday 7 March 2006

Evening	*Arrival*
	Welcome drink

Wednesday 8 March 2006

Session 1: Opening & introduction

09.00 - 09.20	**Presentation of the European Science Foundation (ESF)**
	Thomas Bruhn (Standing Committee European Medical Research Councils)
09.20 - 10.00	**Chris Olivers**
10.00 - 10.10	Discussion

Session 2: Short-range dynamics of attention: Bottom-up and top-down control

10.10 - 10.50	**Jan Theeuwes**
10.50 - 11.00	Discussion
11.00 - 11.10	*Coffee*
11.10 - 11.50	**Mieke Donk**
11.50 - 12.00	Discussion
12.00 - 12.40	**Claus Bundesen**
12.40 - 12.50	Discussion
12.50 - 13.40	*Lunch*

Session 3: Short-range dynamics of attention: Models and brains

13.40 - 14.20	**Søren Kyllingsbæk**
14.20 - 14.30	Discussion
14.30 - 15.10	**Thomas Habekost**
15.10 - 15.20	Discussion
15.20 - 15.30	*Coffee*
15.30 - 16.10	**Wim Vanduffel**
16.10 - 16.20	Discussion
16.20 - 17.00	**Rik Vandenberghe**
17.00 - 17.10	Discussion
17.10 - 18.00	**Collaborative exercise aimed at investigating potential collaborative actions**
19.00	*Dinner at Onder Ons, Lijnbaansgracht 246 (18.45: Gather in hotel lobby)*

Thursday 9 March 2006

Session 4: Attention and dynamic stimuli

09.00 - 09.40	**Guy Orban**
09.40 - 09.50	Discussion
09.50 - 10.30	**Glyn Humphreys**
10.30 - 10.40	Discussion
10.40 - 10.50	*Coffee*
10.50 - 11.30	**Ulrich Ansorge**
11.30 - 11.40	Discussion
11.40 - 12.20	**Ingrid Scharlau**
12.20 - 12.30	Discussion
12.30 - 13.20	*Lunch*

Session 5: Long-range dynamics of attention: Sustained attention and arousal

13.20 - 14.00	**Ian Robertson**
14.00 - 14.10	Discussion
14.10 - 14.50	**Paul Dockree**
14.50 - 15.00	Discussion
15.00 - 15.10	*Coffee*
15.10 - 15.50	**Katherine Johnson**
15.50 - 16.00	Discussion
16.00 - 17.00	**Collaborative exercise aimed at investigating potential collaborative actions**
17.00 - 19.00	*Drinks & food at Vertigo (From 18.30: Taxis to airport & train station)*

5. Final List of Participants

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6. Statistical Information on Participants

Total: 17 (Excluding the representative)

Per country:

Netherlands	3	Ireland	3
Germany	3	France	1
Denmark	3	Belgium	3
UK	1		

Per sex:

Male	13
Female	4

Per academic position:

Junior (PhD/Post-doc/assistant professor)	9
Senior (Associate professor/full professor)	8

Per academic background:

Biology	1
Cognitive psychology	11
Medicine	2
Neuropsychology	2
Pharmacology	1