Applied Attention Theory

Christopher D. Wickens

Why applied attention theory?

- **Basic Research**: Many elegant models of visual search, attention capture

↔

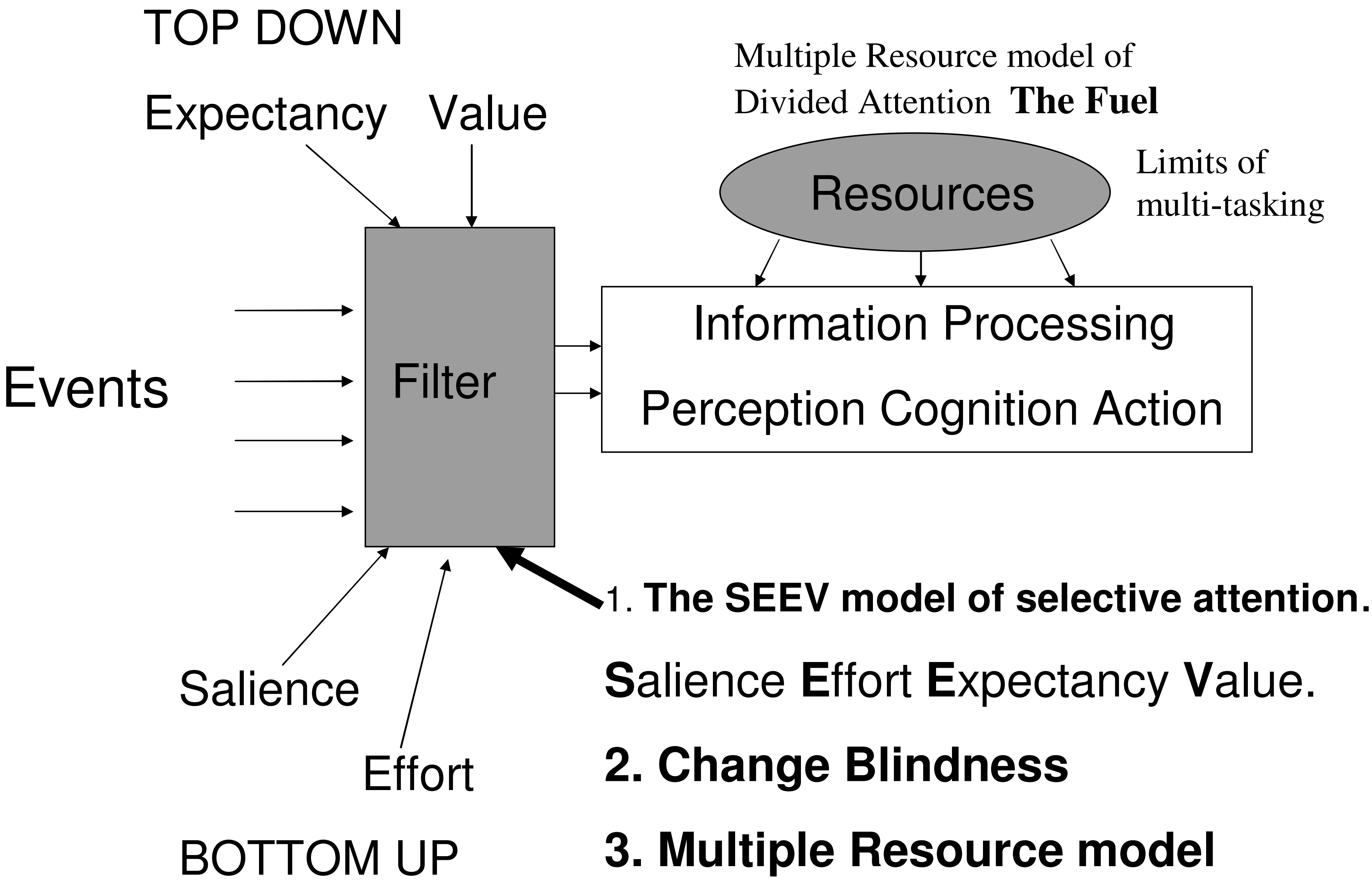
- **Applied Research:** Controlled flight into terrain: #1 killer in commercial aviation
- Up to "82%" of highway accidents result from distraction (inattention).
- The car as a "mobile office" ☹
- The "multi-tasking" next generation.

The gulf/gap.

Kahneman's book (Attention & Effort).

My 1974 Dissertation

A Simple Model of Attention: the Filter and the Fuel



SEEV JOINS:

- **Basic Research psychological models**
- Bundeson
- Cave & Wolfe
- Itti & Koch
- **Salience and attention capture**

- **Engineering models**
- Moray, Senders, Sheridan
- **Expected Value: optimization**

WE add EFFORT

PARAMETERS OF SEEV that drive the eyeball (visual attention) around the environment. (Also the "earball"and the "mindball" ?).

S: Salience: The bottom-up attention capturing properties of **events**, bright flashes, sounds, etc. The salient runway line in the Singapore Airlines crash

Ef: Effort: Inhibits the movement of attention across longer distances: bigger scans, head movements. Failure of drivers to "check the blind spot" before lane changing.

Ex: Expectancy: The likelihood of seeing an event at a particular location: a top-down cognitive factor that is calibrated to the **bandwidth** (frequency of occurrence) of events that occur at that location.

V: Value: The importance (value) of tasks served by the attended event, as well as the *relevance* of the event to a valued task. Also top-down

Probability of attending P(A) = s*S –ef*EF + | ex*EX + vV / (ex*EX * vV) | ← Which one?

SEEV as **Design optimization guidance**

S E E V

How people **do** allocate attention.

How people **should** optimally allocate their attention.

The "**gold standard**" of expected value theory.

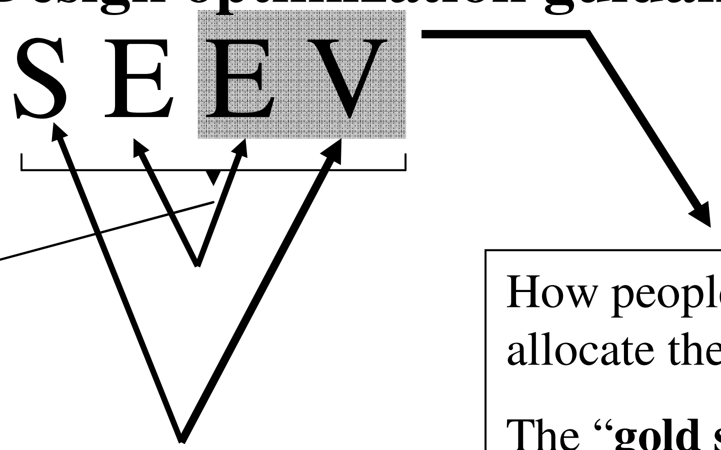
* Elimination of bottom up parameters of Salience and Effort.

* Calibration of Expectancy and Value with world values of bandwidth and true importance

Designer guidelines: **Optimization:** make valuable information salient. Reduce the effort of transitioning between sources with high expectancy or bandwidth.

(Correlating design of bottom up, with top down parameters)

SEEV as **Design optimization guidance**



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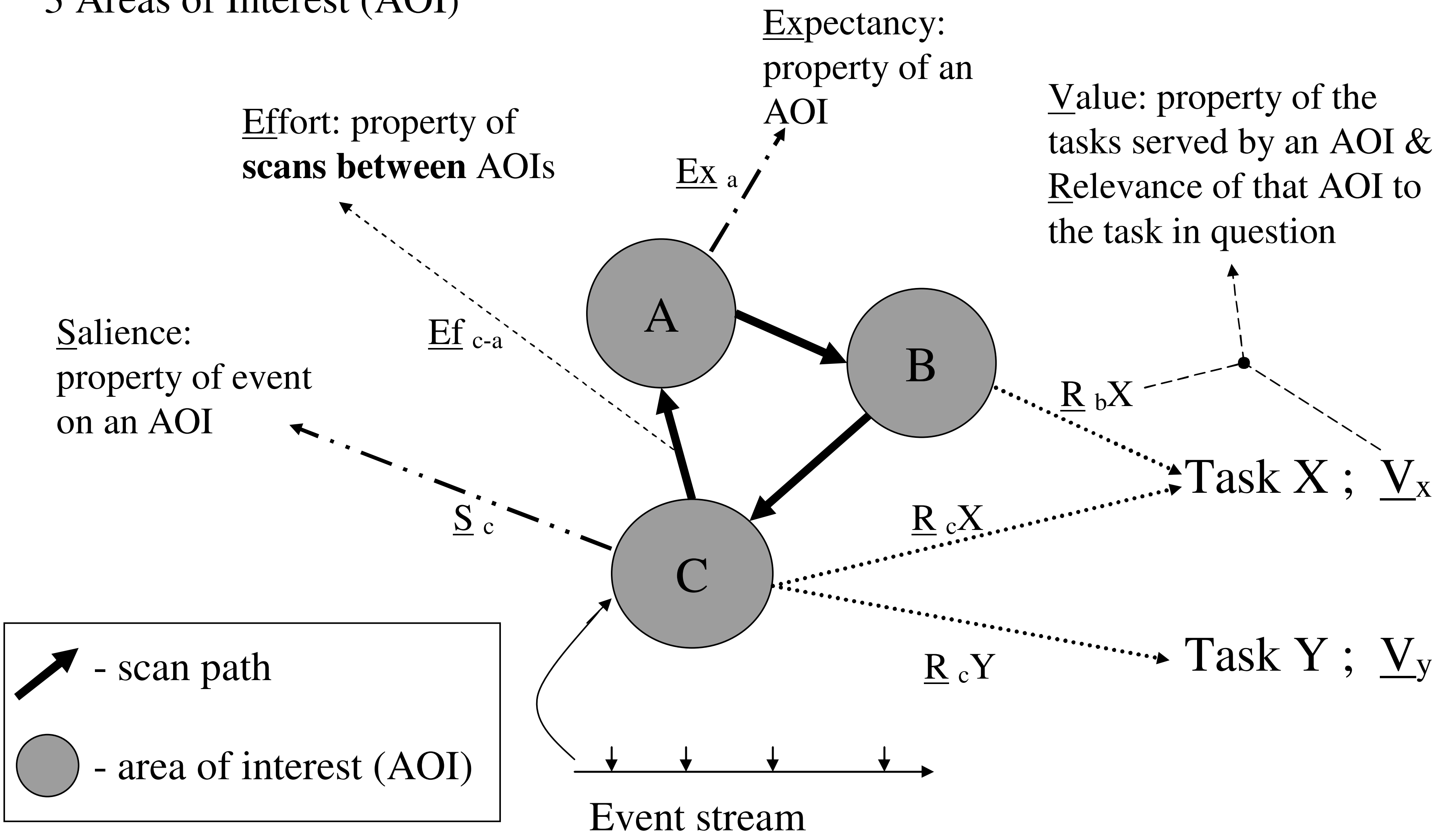
Implementing the computational model

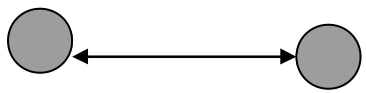
$$P(A) = S - Ef + Ex + V$$

3 Areas of Interest (AOI)



Where do SEEV parameters come from?

1. Salience: salience models (expanded Itti & Koch)
2. Effort: Distance between areas of interest

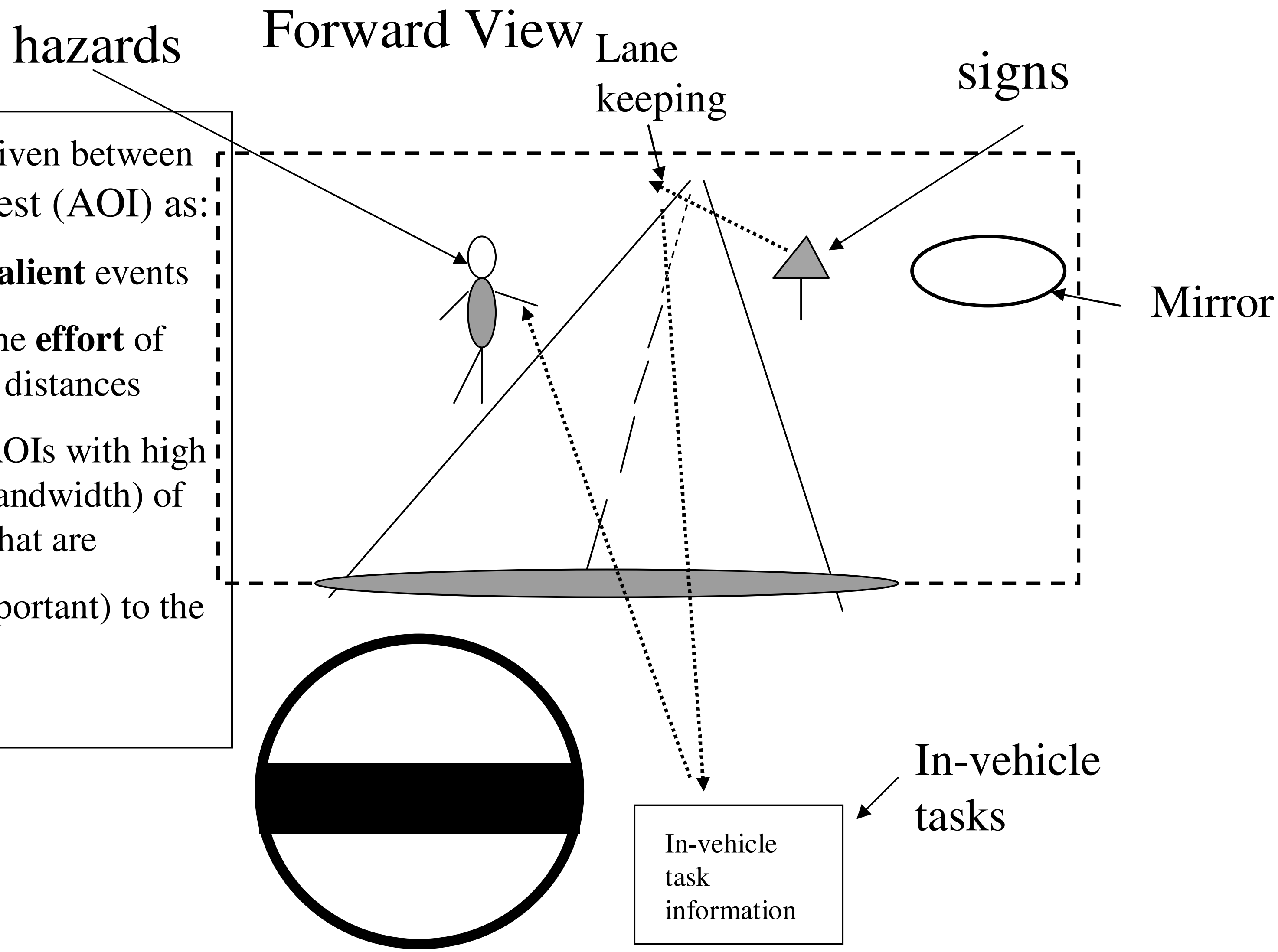


3. Expectancy: Bandwidth: Event rate within an AOI.
4. Value: Relative importance of an AOI as determined by relative importance of the task that it serves. (Driving: lane keeping > radio tuning.) Flying: navigating > communications

The SEEV model applied to Driving

Scan path driven between areas of interest (AOI) as:

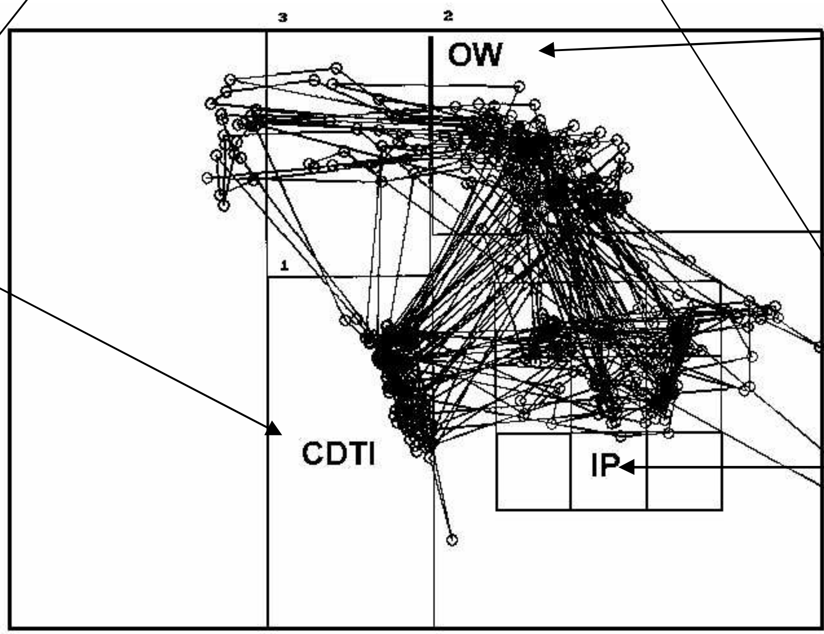
- Captured by **salient** events
- Inhibited by the **effort** of moving longer distances
- Attracted to AOIs with high **expectancy** (bandwidth) of seeing events that are
- **Valuable** (important) to the driver's tasks.
- **SEEV**



The In-Vehicle Task: Voice Dialing a Cell Phone
Head Down Vs. Head Up (HUD) vs. Auditory

New Technology of the **Cockpit Display of traffic information** designed to allow pilots to serve as their own air traffic controllers: maintain self-separation.

Free flight



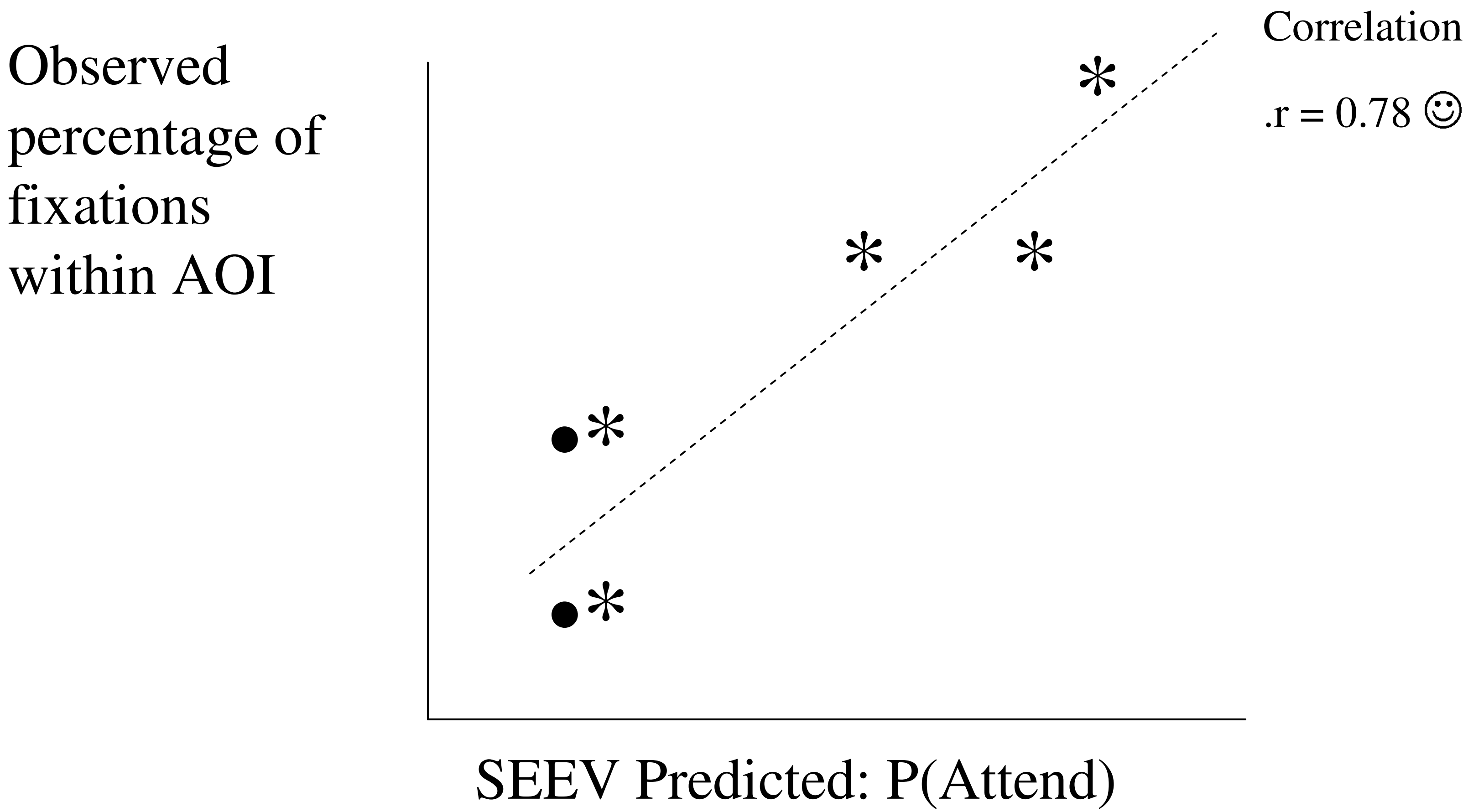
How well could we have predicted this from seev

Aviation Model Fitting & Validation

- P(A) measured by proportion of scan within an AOI.
- Three flight simulation experiments. (skilled flight instructors)
- 2, 3, 4or 5 AOIs and

  4-6 experimental conditions generated:
- 8 -10 Different Ex, R, and V values/experiment: Predicted P(A)
- Correlated obtained P(A) – scan proportion – with EV model prediction. This is our criterion for model validation.

Correlational Model Validation



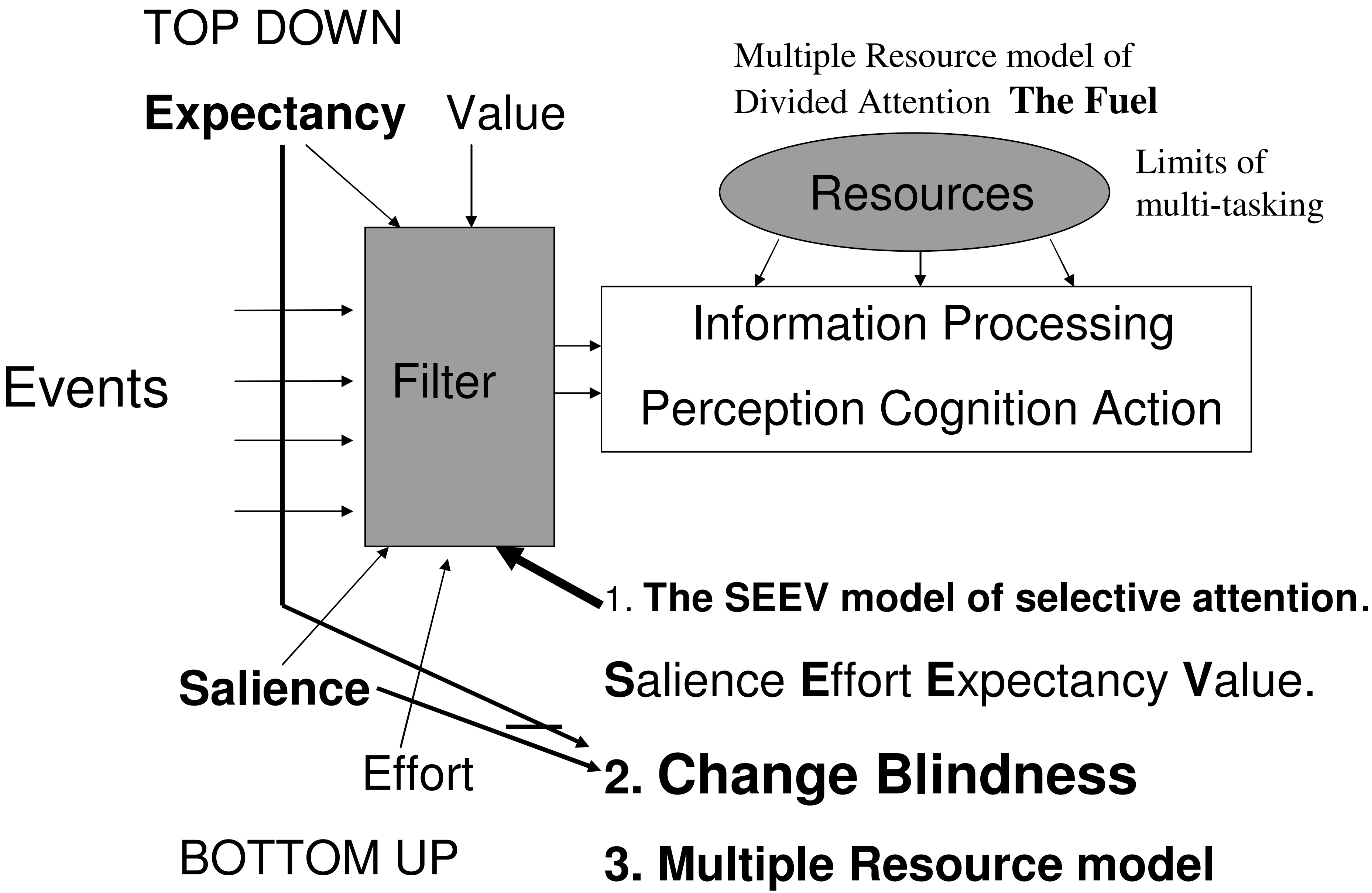
The SEEV simulation model predicts:

- The glance time P(A) and mean duration in various areas of interest
- The time spent away from the forward view (vulnerability to hazard detection).
- The delay of attention capture by events, as a function of their salience, and location of visual attention at the instance when events occur.
- How salience effects are moderated by distance of in-vehicle task (IVT) from forward view, by demands/compellingness of the IVT, by effort demands (mental workload) of concurrent non-visual tasks.

Summary of key findings of six SEEV model studies in Flying and Driving

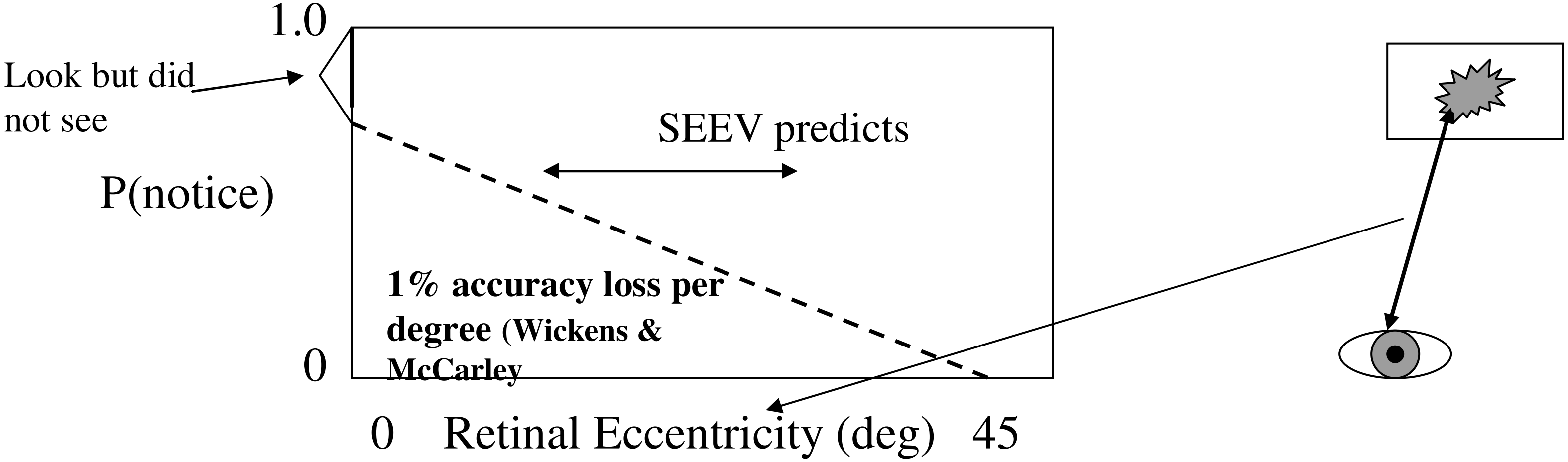
- Model fit (r) >0.90
- Effort (of longer attention moves) does not inhibit scanning for expert pilots
- Pilots who are better time-sharers show better fits to the **expected value** components of SE**EV:** More optimal scanning → better multi-task performance
- SEEV predicts the **attention capture** of realistic synthetic vision aviation displays: **change blindness**

A Simple Model of Attention: the Filter and the Fuel



Change and Inattentional blindness.
SEEV predicts where and when you will look, but:

- Where you look does not guarantee you will **see** what is there. "Look but did not see" phenomenon of **Change Blindness.**
- However, when you **don't** look at an area that changes, seeing (noticing) events at that area declines as a function of the retinal eccentricity. The SEEV model predicts this.



Change Blindness and inattentional blindness:

A critical link between basic and applied research.

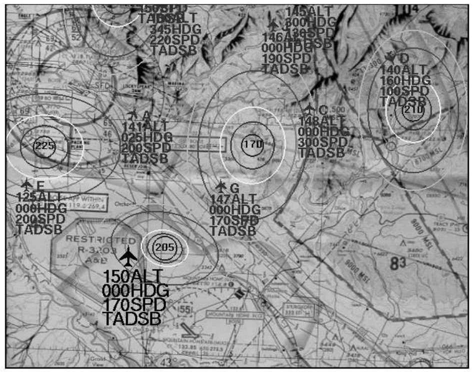
Expectancy: people (pilots) poor at noticing, responding to unexpected events (surprises)

The psychology of "Change blindness"

Simons' Gorilla

Applications to Aviation, where noticing the change is **valuable**, even if it is unexpected.

Muthard: Noticing traffic changes on cockpit traffic Display



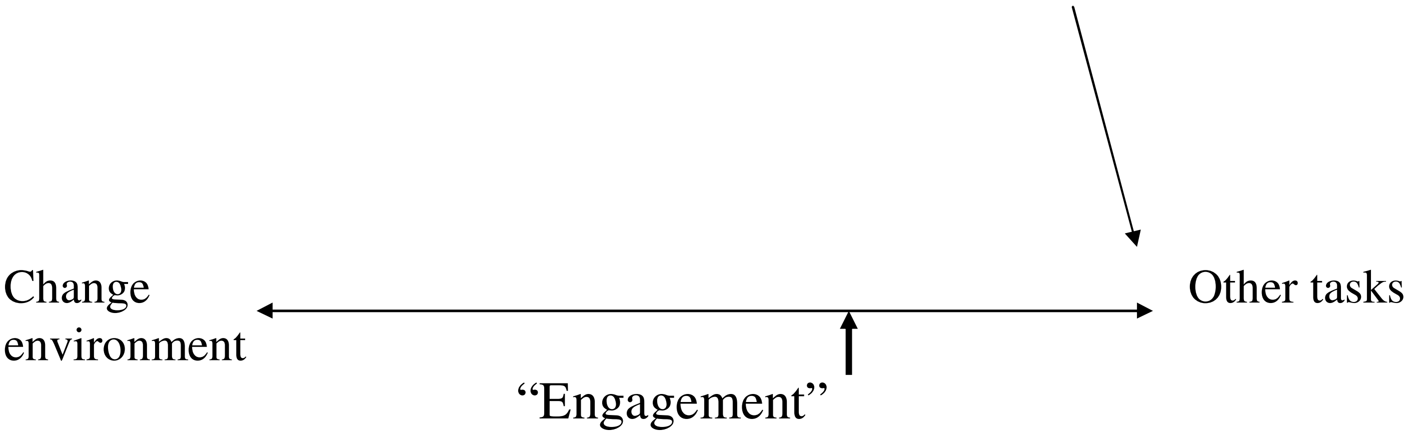
While flying, pilots show

Less than .50% Detection Rate

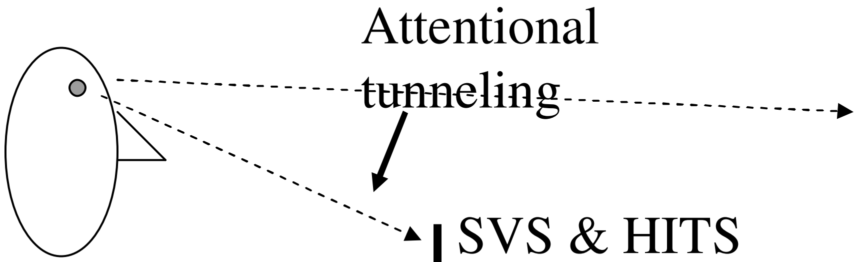
of changes to traffic flow that could cause conflict

Change blindness and visual scanning in a **multi-task** environment

- .
- Humans are particularly vulnerable to change blindness during periods of **attentional tunneling**



The "compelling" attentional tunneling of the synthetic vision system (SVS) and highway-in-the-sky (HITS) in the pilot's cockpit. Do these cause change blindness in the world beyond the cockpit? (Wickens & Alexander)

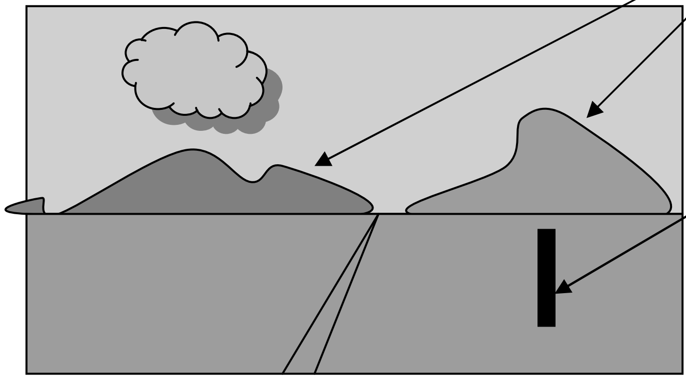


SVS & HITS

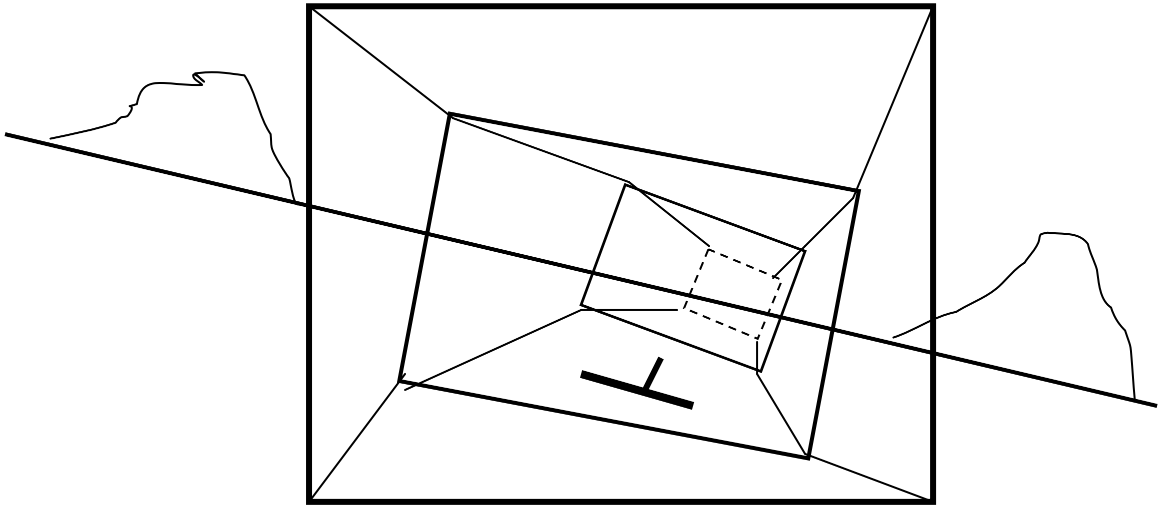
3D dynamic portrayal of the outside world and flight path as a **virtual** world

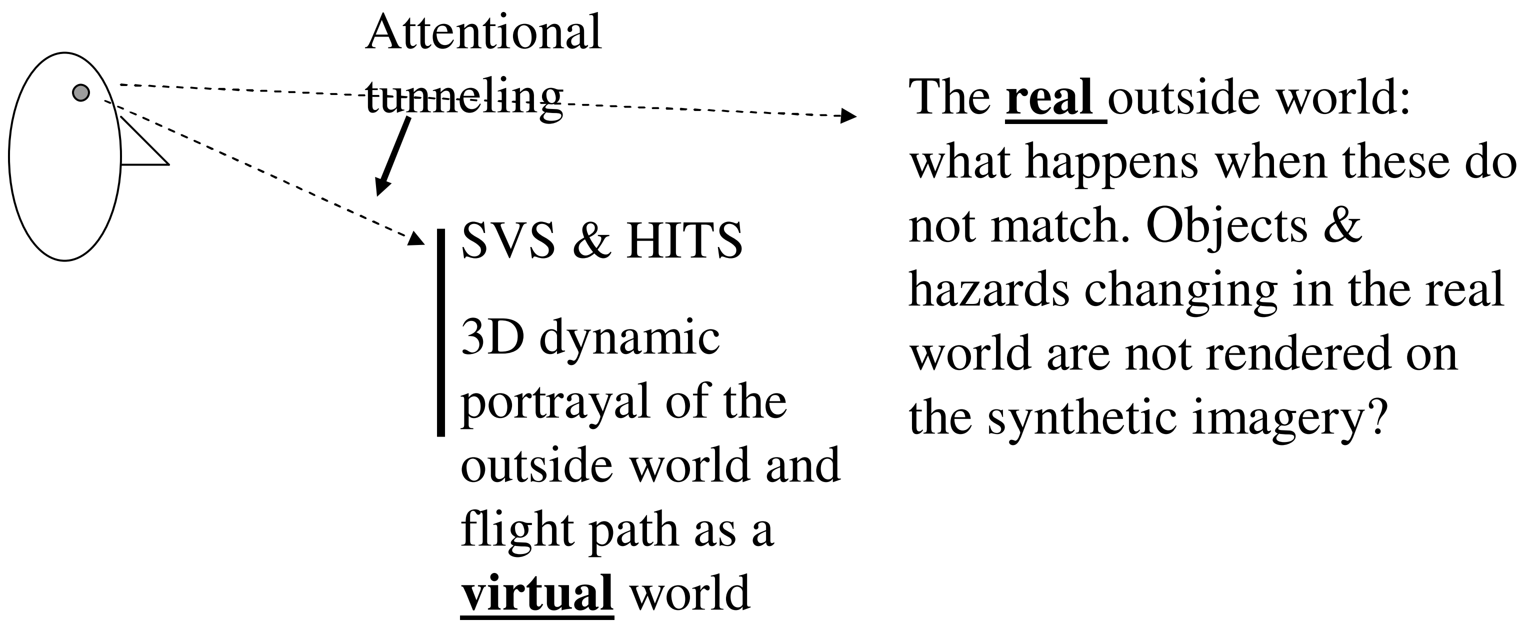
The **real** outside world: what happens when these do not match. Objects & hazards changing in the real world are not rendered on the synthetic imagery?

SVS: the 3D synthetic vision system display: a **status display**: Where is the terrain? Other hazards?



HITS: the 3D highway in the sky. A **command** Display. Where should I fly?





Attentional tunneling
SVS & HITS
3D dynamic portrayal of the outside world and flight path as a **virtual** world
The **real** outside world: what happens when these do not match. Objects & hazards changing in the real world are not rendered on the synthetic imagery?

Does the HITS and SVS lead the pilot "down the garden path" of complacency: What is on the display **is** reality. The problem of **attentional tunneling** and **change blindness**. We don't notice changes that are outside of the focus of attention.

Off-Normal Outside-World Traffic

Suppose automation **fails** to contain all pertinent information in its data base. (The **virtual reality** of the display does not quite reflect the **true reality** of the outside world): An example of **imperfect automation.**

Will pilots flying with the SVS HITS, notice the "**off-normal**" rogue blimp tower, or runwayt offset which is only visible in the outside world. This is automation-induced attentional tunneling to the compelling display.

SVS studies summary data
(Wickens & Alexander)

•7 studies in high fidelity simulations of pilots flying with SVS and HITS. Several normal approaches and landings

•Percentage of pilots who **failed to detect** unexpected outside world event (not rendered on SVS) on last trial when flying with a head down SVS display:

•Without HITS 17%

•**WITH** a highway in the sky (HITS): 38% ☹

•The HITS – a compelling 3D command display is responsible for attentional tunneling, more so than the SVS image, a 3D status display.

•Applications to driving. In-vehicle 3D maps

How does this relate to visual scanning? (Thomas & Wickens)

Heads up (outside world) scanning behavior of:

2 "Detectors"	2 "non-Detectors"

On the "Off normal" hazard trials.

14% outside	1% outside

On all trials (average)

16% outside	5% outside

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The SEEV model predicts the statistical likelihood of scanning and therefore visual neglect:

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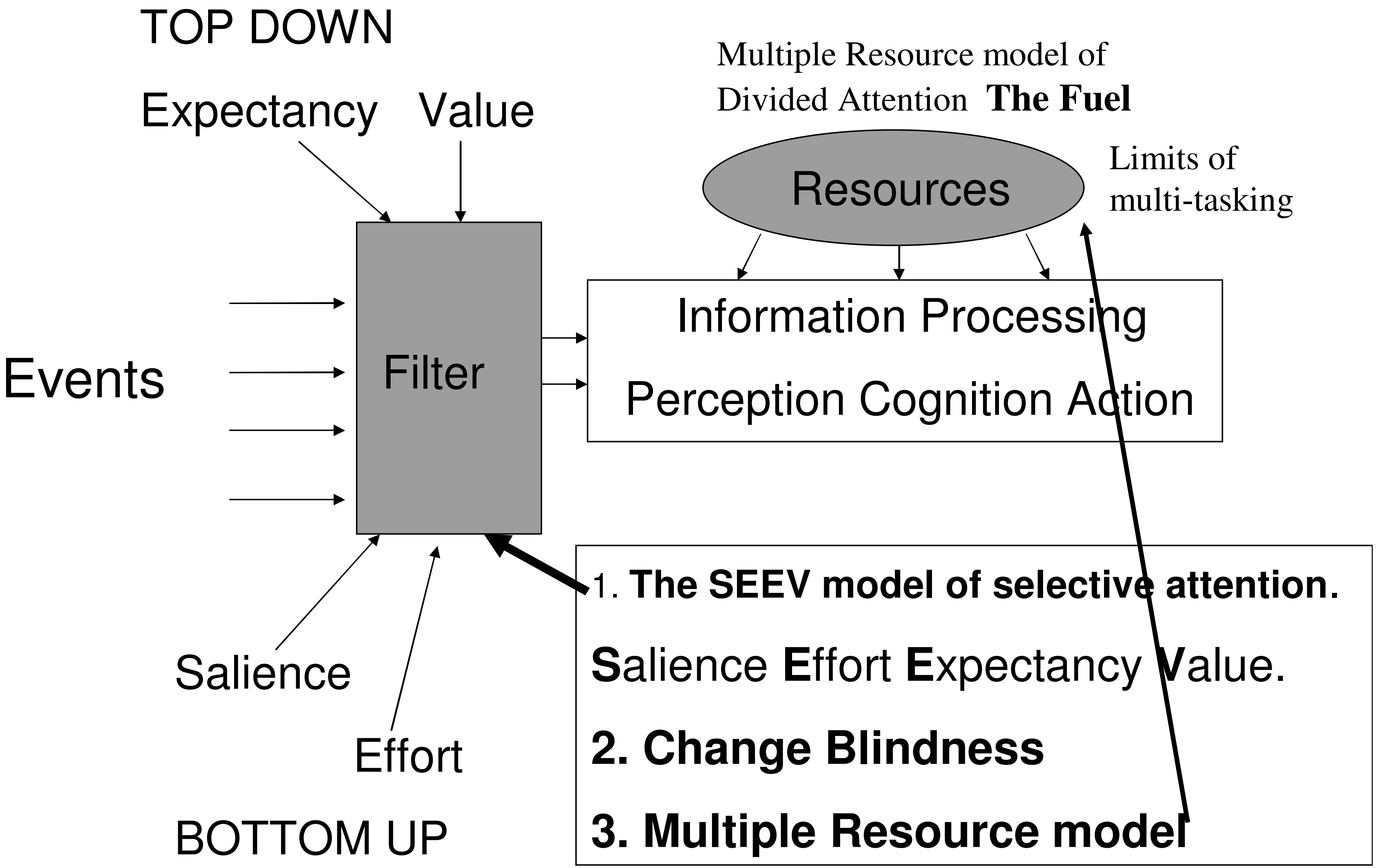


Multiple Resource Model predicts success in multi-tasking

The Architecture: 3 Factors of:

1. Resource Demand

   Task difficulty

2. Structure

→ Dual Task Decrement

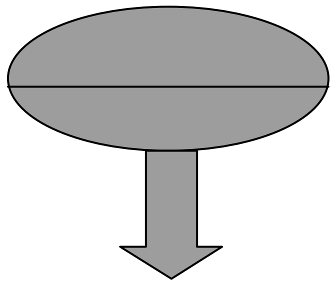
3. Allocation of the Decrement: Which task suffers?

•**Experimentally plausible**: accounts for experimental data on time-sharing success.

•**Neurophysiologically plausible**: Dichotomies of resource structure associated with dichotomies in the brain.

•**A useful human factors tool**. Dichotomies correspond with design decisions a designer can make (should I use voice synthesis or print? Graphs or text?)

Resource Demand: How difficult is a task?
The issue of Mental Workload



Less Difficulty for:

*Easier tasks

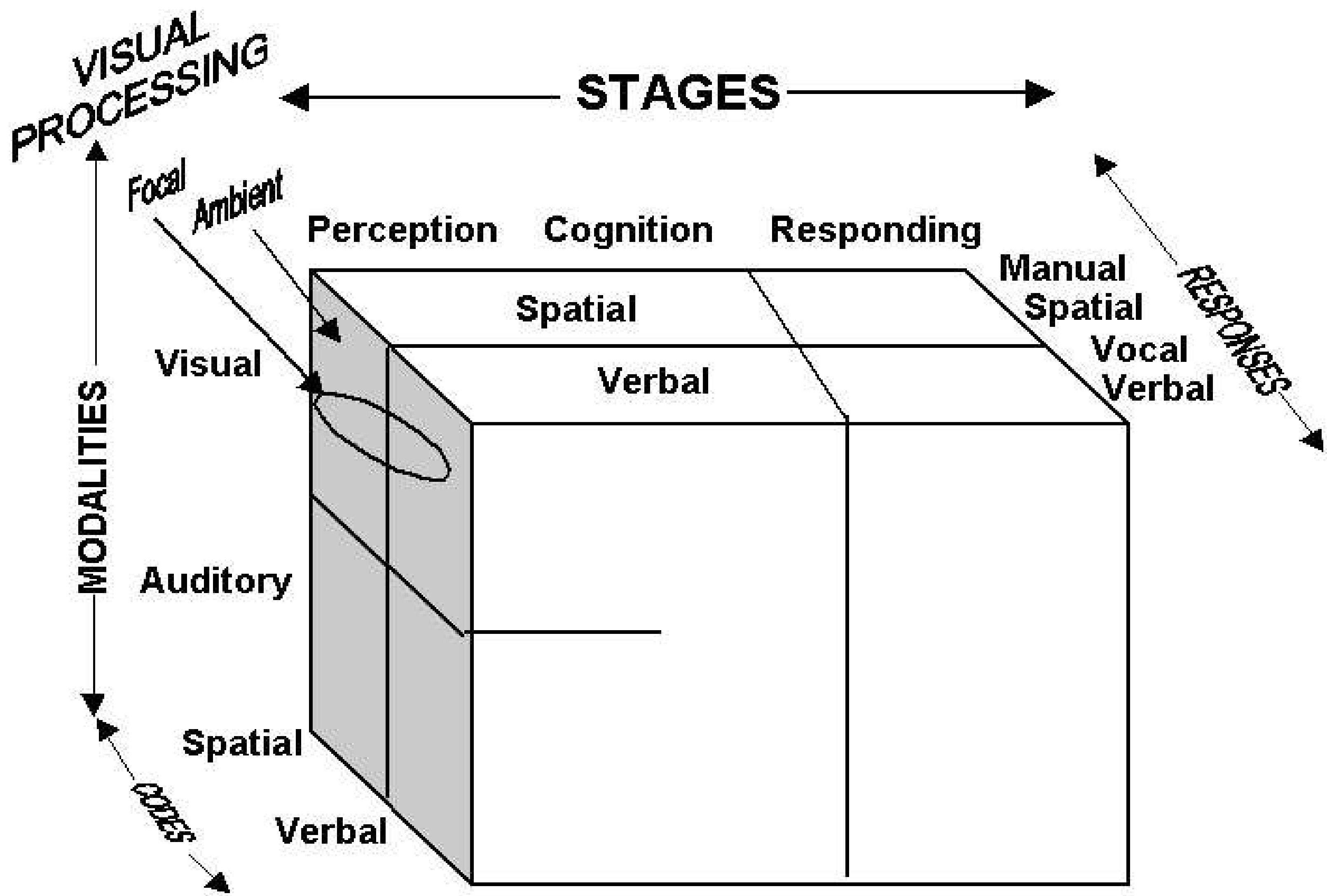
*More skilled performer (expert)

Less neural activity (fMRI evidence)

Resource Structure: Two ways of considering the four dimensions of the Multiple Resource Model.

THE CUBE   THE LIST

Resource Structure



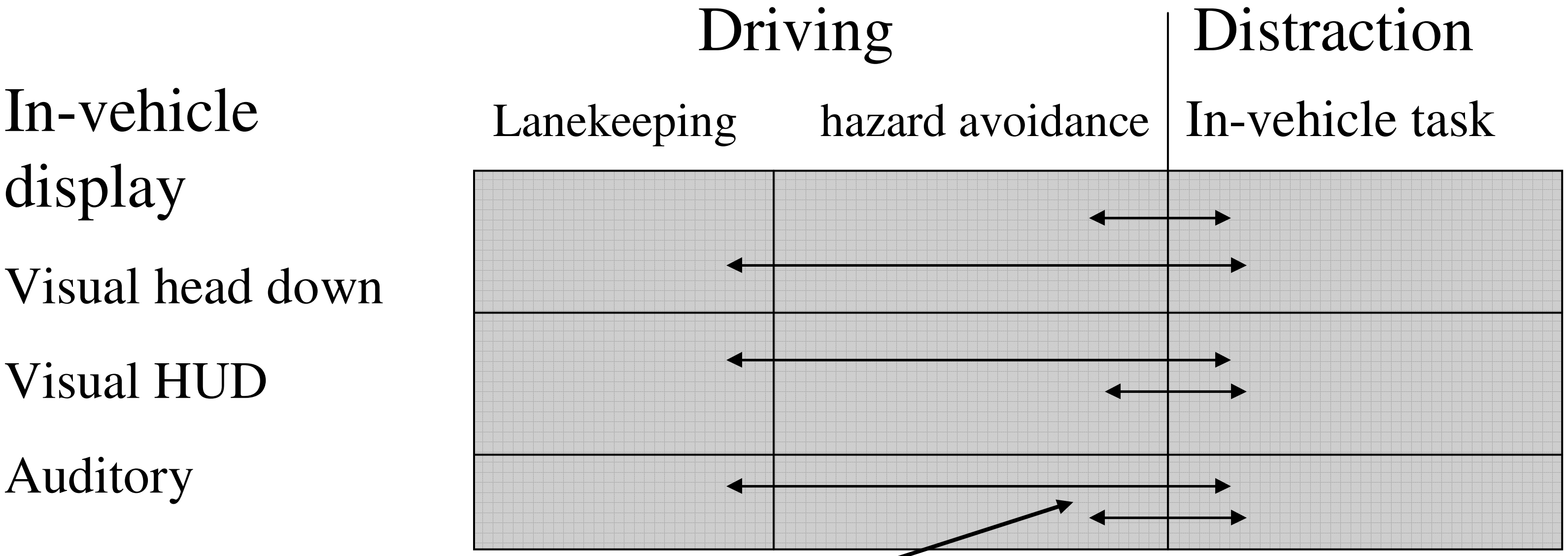
Structure of Multiple Resources: Four 2-level dimensions.

1. Modalities — Visual ⟷ Auditory
2. Visual Channels — Focal ⟷ Ambient (Visual ↓ Focal/Ambient)
   - Focal: Object recognition
   - Ambient: Ego motion
3. Codes: Spatial (manual) ⟷ Verbal

4. Stages: Perceptual/cognitive ⟷ Action/response.
   - Perceptual/cognitive: Visual search, listening, rehearsal
   - Action/response: steering, buttons, speaking

- Any task can be represented by some combination of levels along any or all of the four dimensions.
- To the extent that **two** tasks share **common** levels along any dimension, their dual task decrement (task interference) will be greater. Common levels = [0,1,2,3,4]

A validation experiment: (Horrey & Wickens, 2003, 2004). Prediction of task interference of in-vehicle technology with safe driving.



Interference computations across three different driving conditions. Urban, rural, curved.

Experimental Design: 3X3 (conditions X displays)
3 dependent variables.

Unexpected Hazard Response tasks.

Lane Drift

Bicycle

Pullout

Turn

What we found:

Model Validation: Predicted vs obtained interference

r = 0.02 r = 0.92 r = 0.98

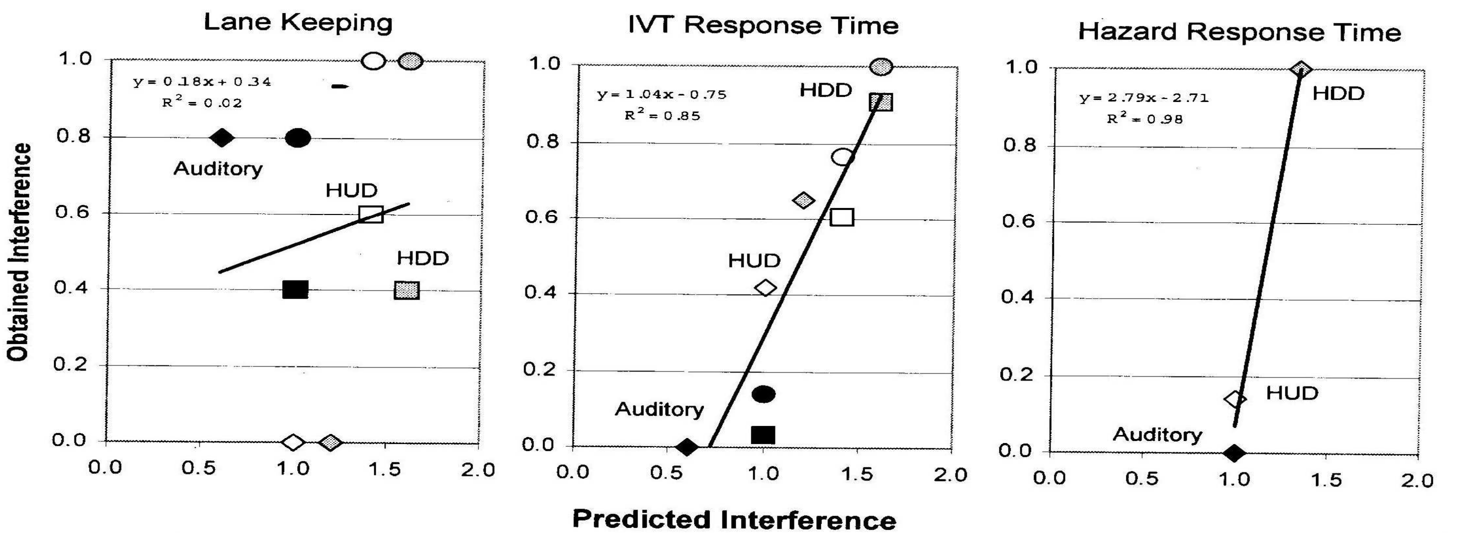


Figure 1. Obtained interference as a function of model-predicted interference for the (a) lane keeping (driving) task, (b) response times to the IVT task, and (c) hazard RTs. The HUD condition is represented by white markers, the HDD condition by light gray, and the auditory by black markers. Diamonds represent the straight rural roads, circles represent curved rural roads, and squares indicate straight urban roads.

The model predicts in-vehicle task performance and hazard response very well. These benefit from HUD and auditory presentation. It does not predict lane keeping well. This is because subjects prioritized lane keeping as the most important task.They prevented it from disruption by changes in IVT task location and demands. A **resource allocation effect.**.

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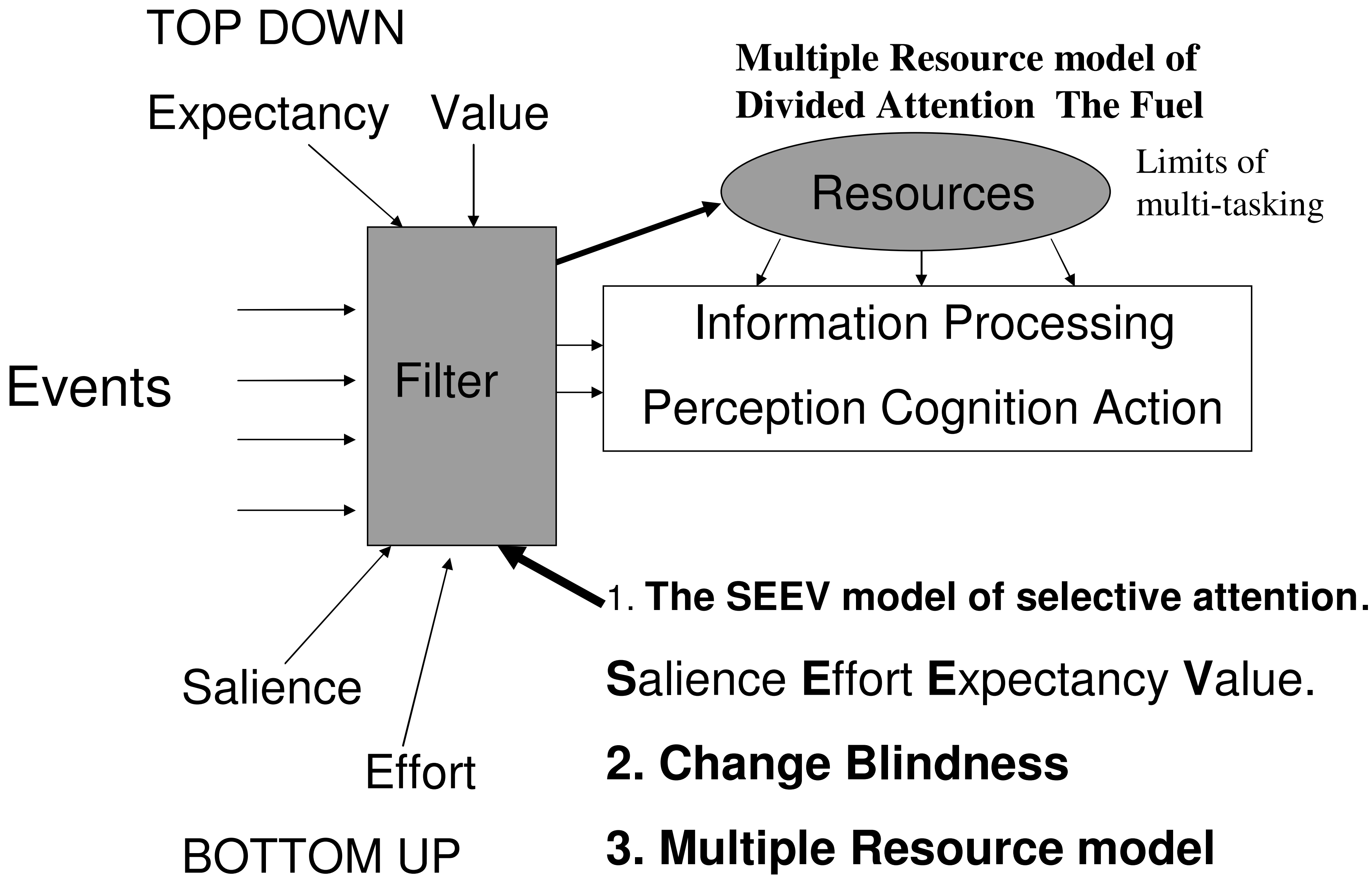
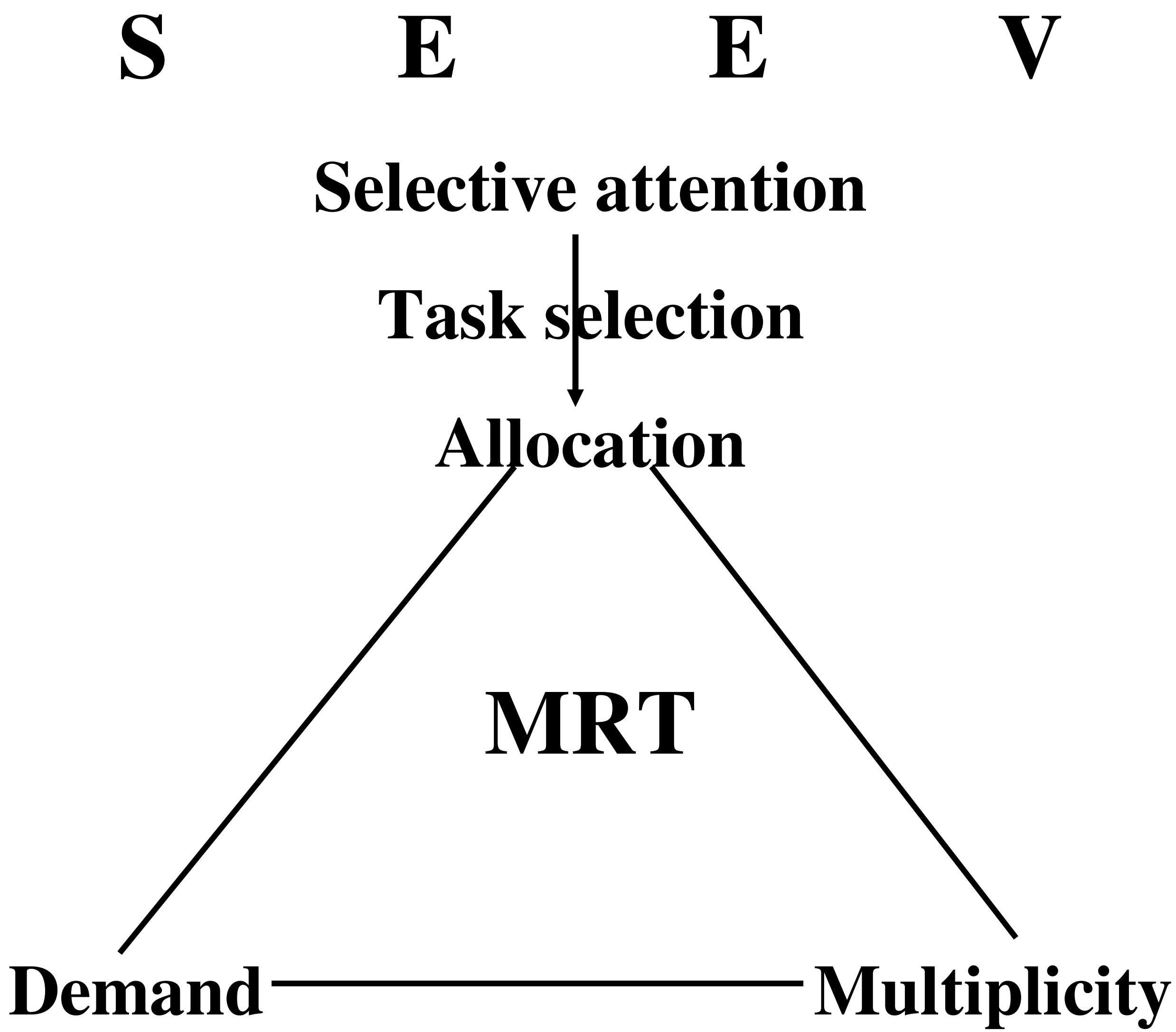


Linking Between the two Models



There is work to be done.

- Thank you.
- Any questions?
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