Driving by the seat of your pants! A multisensory approach to capturing driver attention

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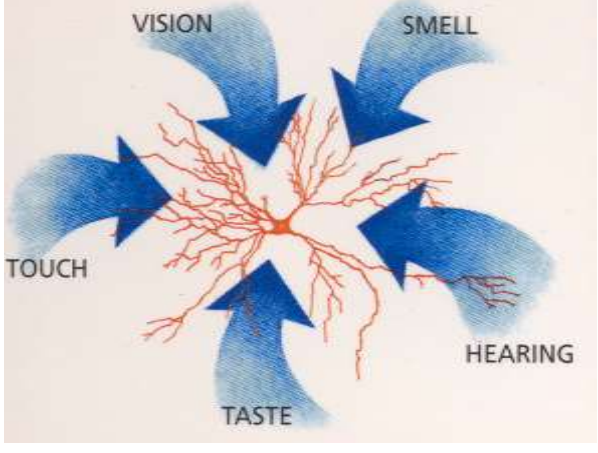
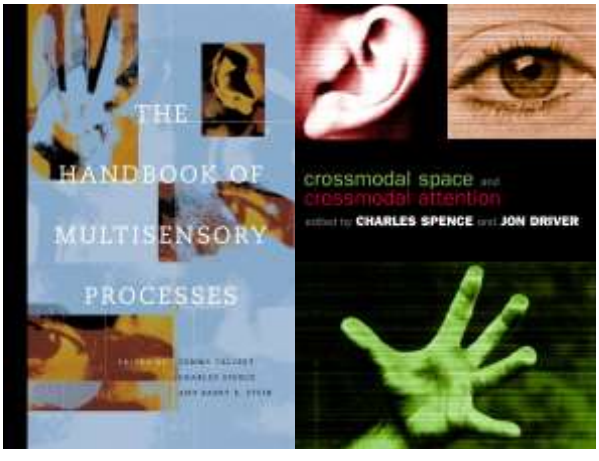
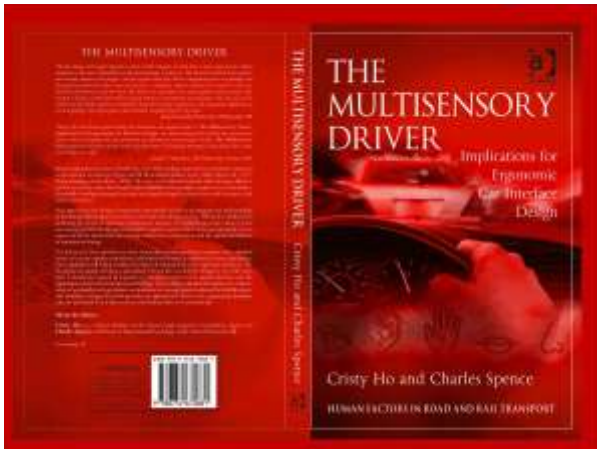
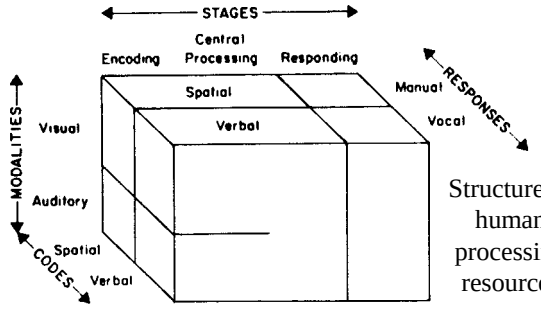






Neuroscience -inspired design

Wickens (1984, 1992, 2002…)

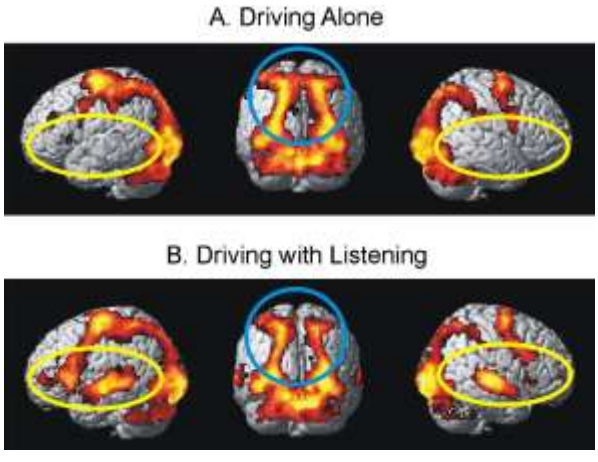


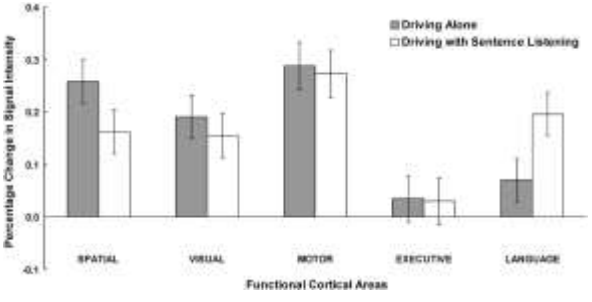
Structure of human processing resources

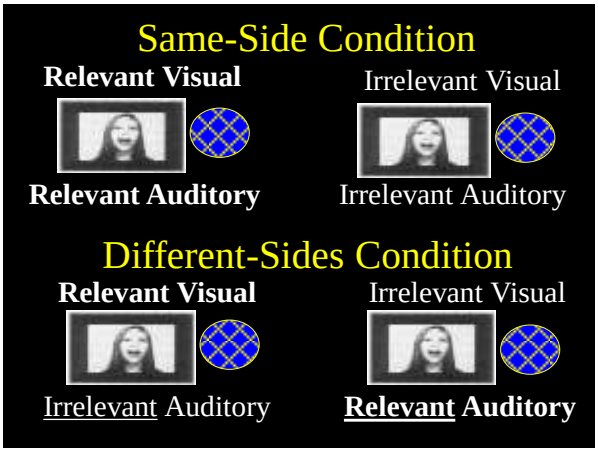
- Note separate resources for auditory & visual I-P
- Hugely influential model in field of ergonomics

Just, Keller, & Cynkar (2008)

fMRI of simulated driving showed a significant deterioration in driving accuracy when talking

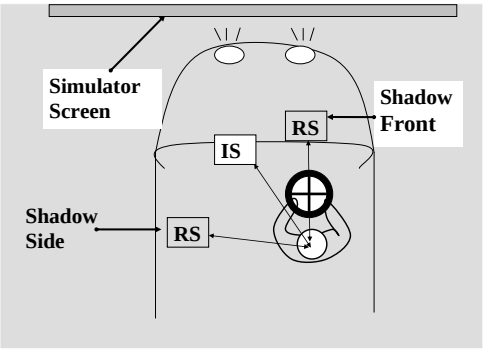






Don't Talk & Drive?...

Spence & Read (2003)



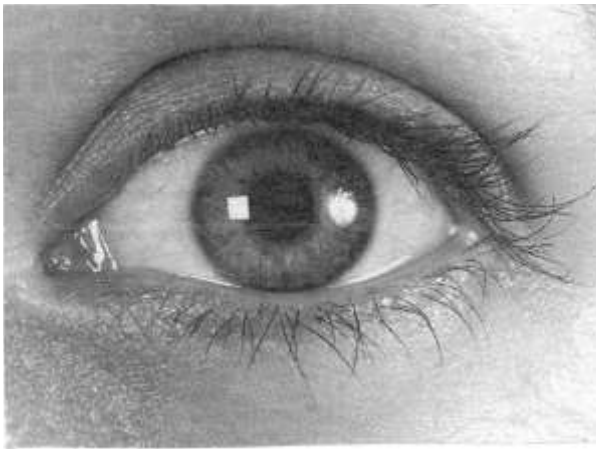
Driver Inattention

- Inattention one of leading causes of car accidents, estimated to account for 26-56% of all road traffic accidents
- Increased technology in cars (mobile phones, satnav, email…) means this problem can only get worse!
- Given the development of radar detection systems, what's the best way to alert drivers to potentially dangerous events?

Greece puts brakes on its racy billboards

'There is no real political will to do anything about it'

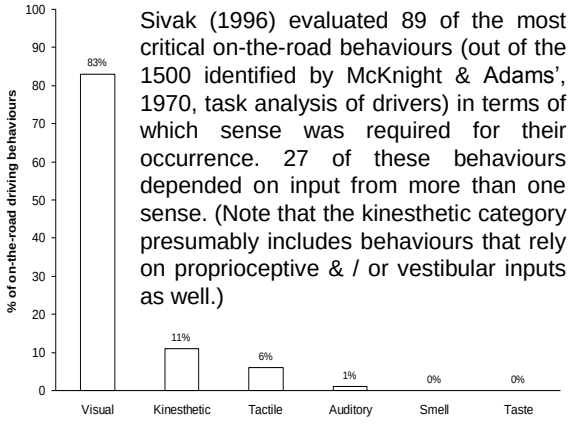
Using multisensory integration to enhance the dynamic range of your touch screen technology (Lee & Spence, 2008, 2009)



Sensory system	N. of sensors	N. of afferents	Channel capacity (bits/s)	Psychophysical channel capacity (bits/s)	% Attentional capture	% Neocortex
Vision	$2*10^8$	$2*10^8$	10^7	40	70%	30%
Audition	$3*10^4$	$2*10^4$	10^5	30	20%	3.4%
Touch	10^7	10^8	10^8	5	4%	11.5%
Taste	$3*10^3$	10^3	10^3	1(?)	1%	0.5%
Smell	$7*10^7$	10^7	10^7	1(?)	5%	n.a.

Gallace et al. (2012)

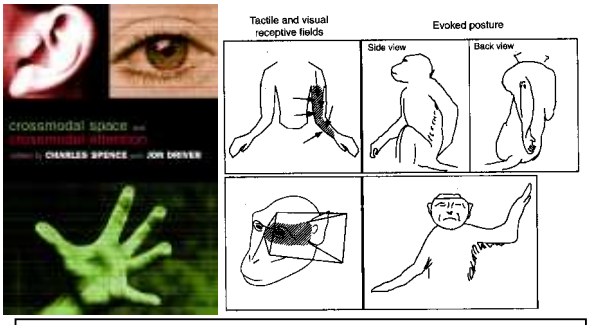
Estimates suggest that driving > 90% visual (though see Sivak, 1996)



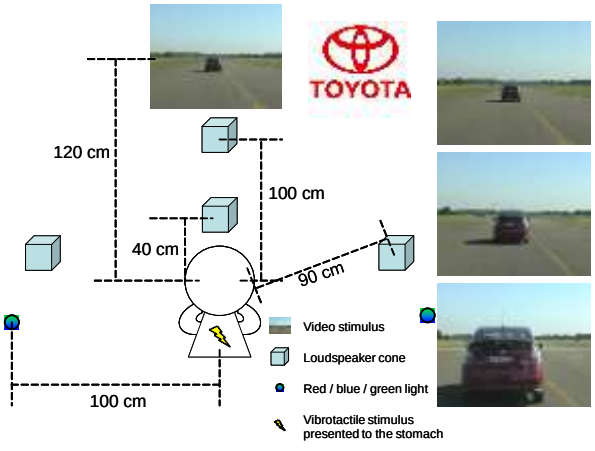
Sivak (1996) evaluated 89 of the most critical on-the-road behaviours (out of the 1500 identified by McKnight & Adams', 1970, task analysis of drivers) in terms of which sense was required for their occurrence. 27 of these behaviours depended on input from more than one sense. (Note that the kinesthetic category presumably includes behaviours that rely on proprioceptive & / or vestibular inputs as well.)

TOYOTA

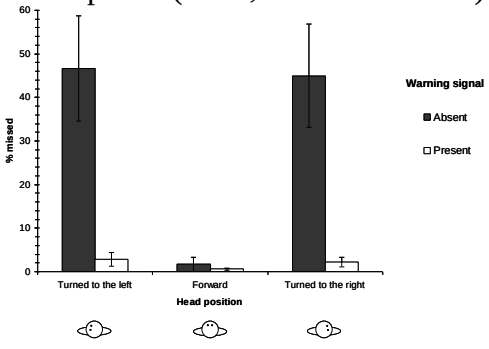
<u>The challenge:</u> To demonstrate that cognitive neuroscience can help to design multisensory warning signal for drivers that are significantly better that a smart (i.e., intuitive) engineer can come up with



Electrical microstimulation of the polysensory zone in the monkey elicits stereotypical defensive movements such as movements of the monkey's arm behind its back, or complex defensive posture involving a facial squint, a head turn, and the arm and hand moving to a guarding position (taken from Graziano et al., 2004).



Ho & Spence (2009; *Human Factors*)



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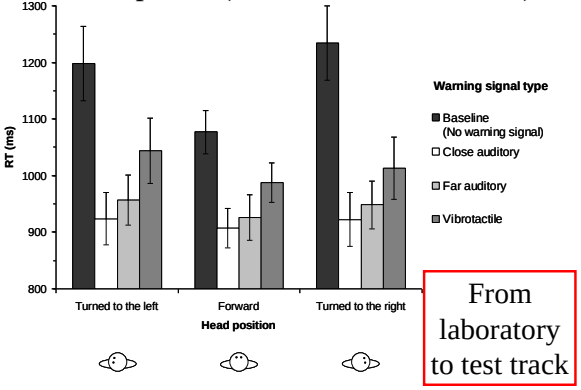


From laboratory to test track

We need intuitive warning signals that will prime the likely response

Latest point at which a warning signal can facilitate a crash avoidance response

Moment of impact

Time to impact!

If a warning signal is presented too early, it is likely to be judged as annoying or else to represent a **false alarm**

Optimal window in which to present a warning signal

Warning signal presented too late to be effective

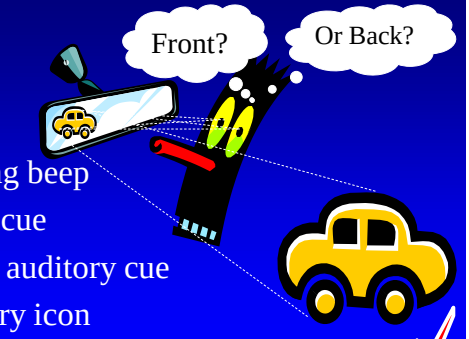
(Spence & Ho, 2008, TiES)

Model front-to-rear-end collision

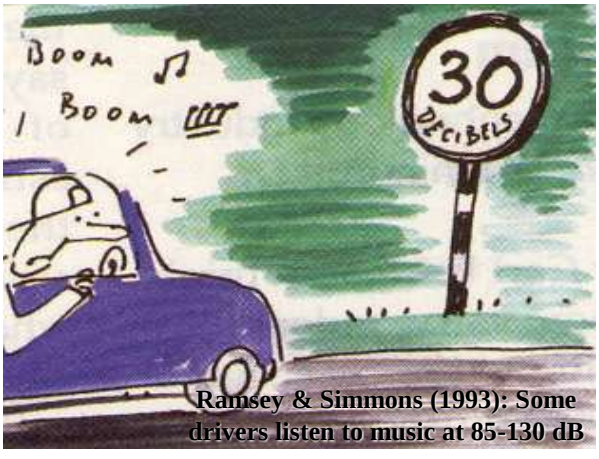
Driving task: Upon hearing auditory cue, check windscreen & rearview mirror, decide if there is a potential collision, & accelerate / brake / make no response

Rapid Serial Visual Presentation task
Occasional target digits presented every 2-6 sec simulating attention-demanding situation

Ho & Spence (2005; *JEP:Applied*)



- Warning beep
- Verbal cue
- Spatial auditory cue
- Auditory icon
- Spatial auditory icon (car horn sound)

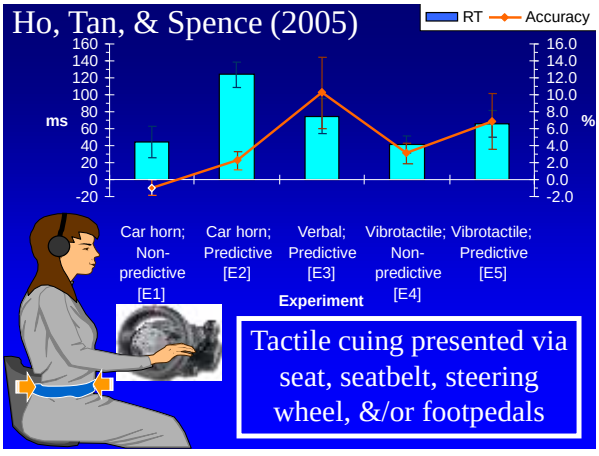


Ramsey & Simmons (1993): Some drivers listen to music at 85-130 dB

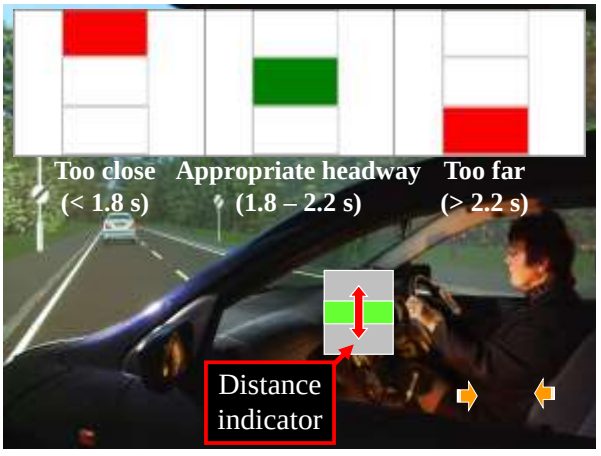
Benefits of Tactile Signals

- Skin (18% of body mass) currently not used (much) while driving so tactile signals won't overload driver
- Unaffected by background noise
- Automatically attention-capturing but not irritating. Claimed to be intuitive
- Good for presenting directional cues
- Personal to driver; Technology cheap

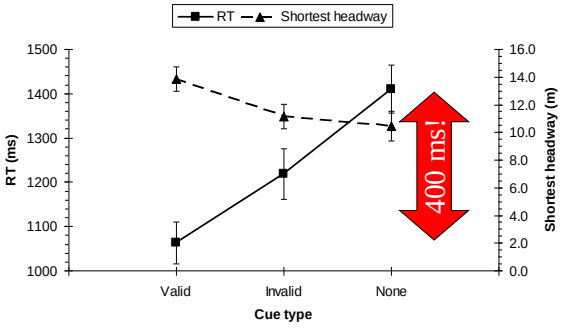
Ho, Tan, & Spence (2005)



Tactile cuing presented via seat, seatbelt, steering wheel, &/or footpedals



Ho, Reed, & Spence (2006)



Mohebbi, Gray, & Tan (2009)

TABLE 1: Questions in the Simple Conversation Condition

No.	Question
1	What is your major? What do you do?
2	Where were you born? If not Arizona, how did you end up in Arizona?
3	Are you married and do you have any kids?
4	Did you have a nice summer? Did you go anywhere fun?
5	Do you like to go to the movie theater? What is the latest movie you have seen?
6	Which radio station do you listen to?
7	What sport do you like to play?
8	What car do you drive? Do you like it?

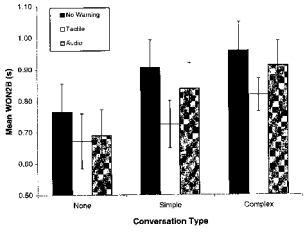
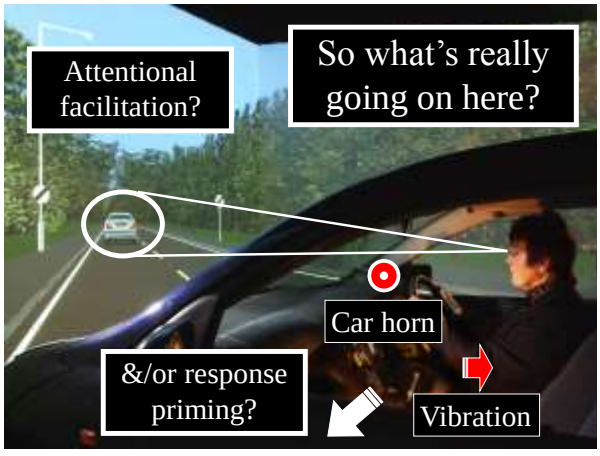
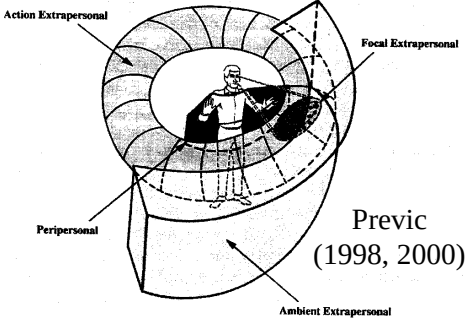


Figure 1. Mean times from warning onset to brake initiation. Error bars are standard errors.

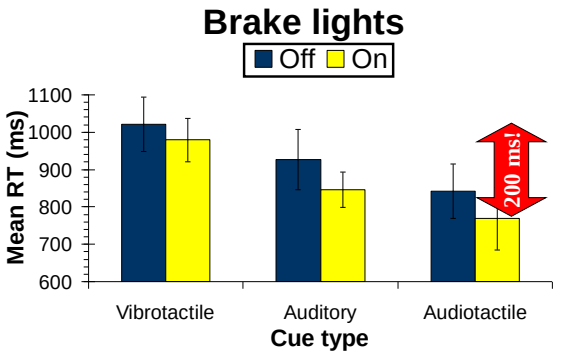


Peripersonal vs. Extrapersonal Space



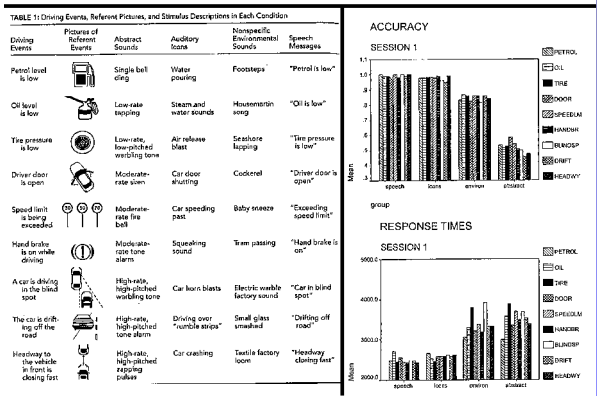
Previc (1998, 2000)

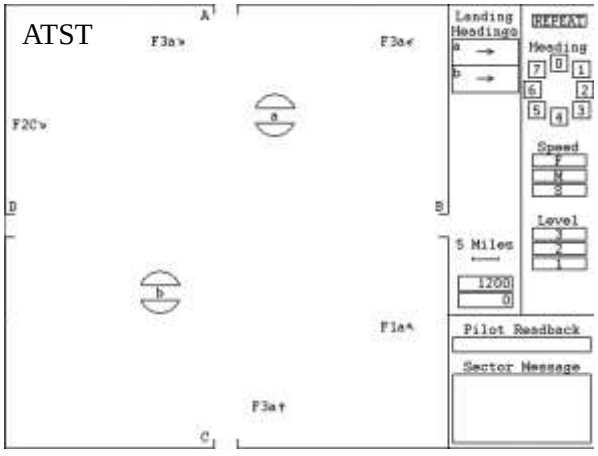
Ho, Reed, & Spence (2007)



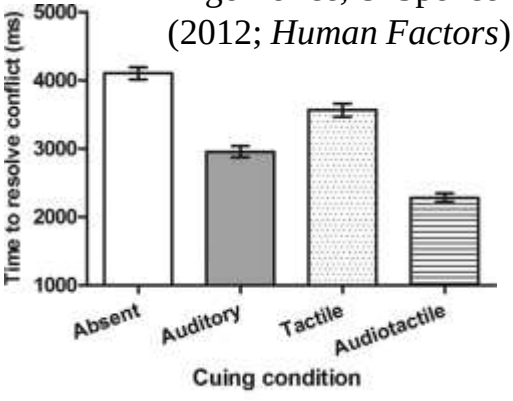
Suetomi & Kido (1997) estimate that 500 ms reduction in braking reaction times would reduce front-to-rear-end collisions by up to 60%!

McKeown & Isherwood (2007)

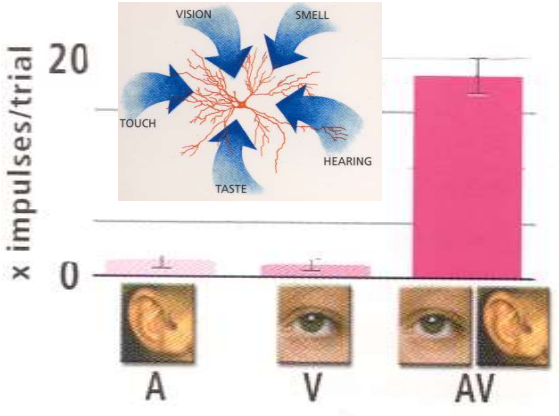




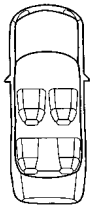
Ngo Peirce, & Spence (2012; *Human Factors*)

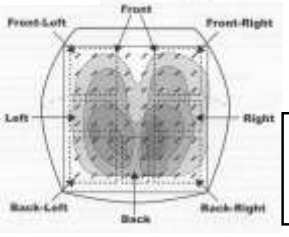


"A 1-millisecond advantage in trading applications can be worth $100 million a year to a major brokerage firm." (see http://www.informationweek.com/news/199200297).



Fitch et al. (2007)





Compared drivers' ability to verbally localize direction (8 in total) of warning signals on road:

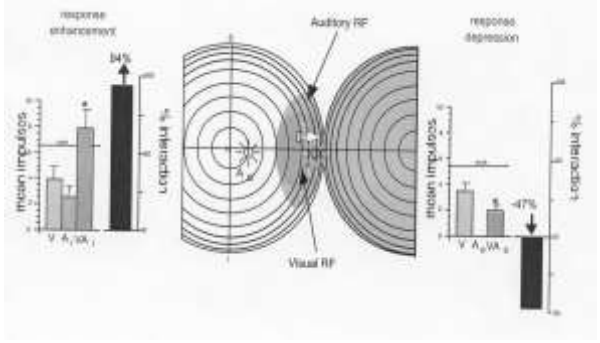
auditory (32%; 2.8 sec)

tactile (86%; 2.4 sec) &

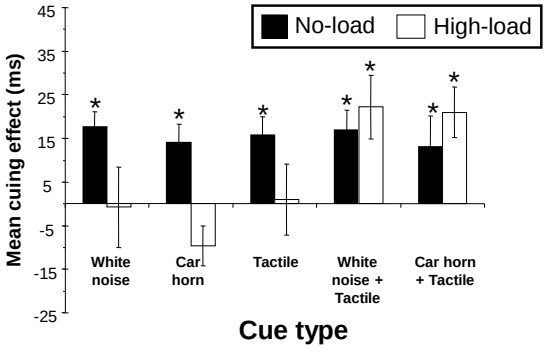
audiotactile (81%; 2.4 sec)

Results highlight driver difficulty in localizing sounds inside car. No multisensory enhancement effect observed.

Superior Colliculus

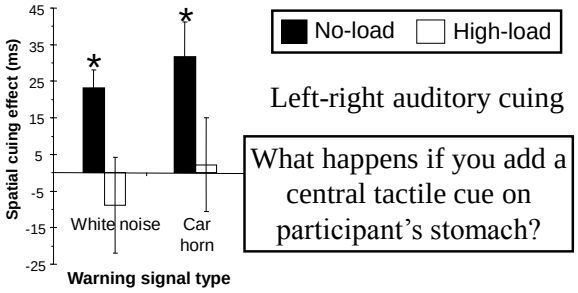


Ho, Santangelo, & Spence (2009)



Ho, Santangelo, & Spence (2009)

Is spatial/directional coincidence a pre-requisite for bimodal cuing advantage?

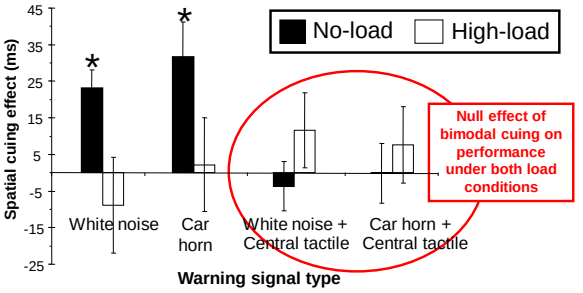


Left-right auditory cuing

What happens if you add a central tactile cue on participant's stomach?

Ho, Santangelo, & Spence (2009)

Is spatial coincidence a pre-requisite for bimodal cuing advantage?



Neuroscience-inspired design

- Spatial coincidence can be critical
- Near-rear peripersonal signals
- Multisensory > unisensory signals
- Asynchronous warning signals to simulate distance/optimal distance?
- BUT: High incidence of 1 warning signal in studies reported so far, &
- What about compensatory behaviour?