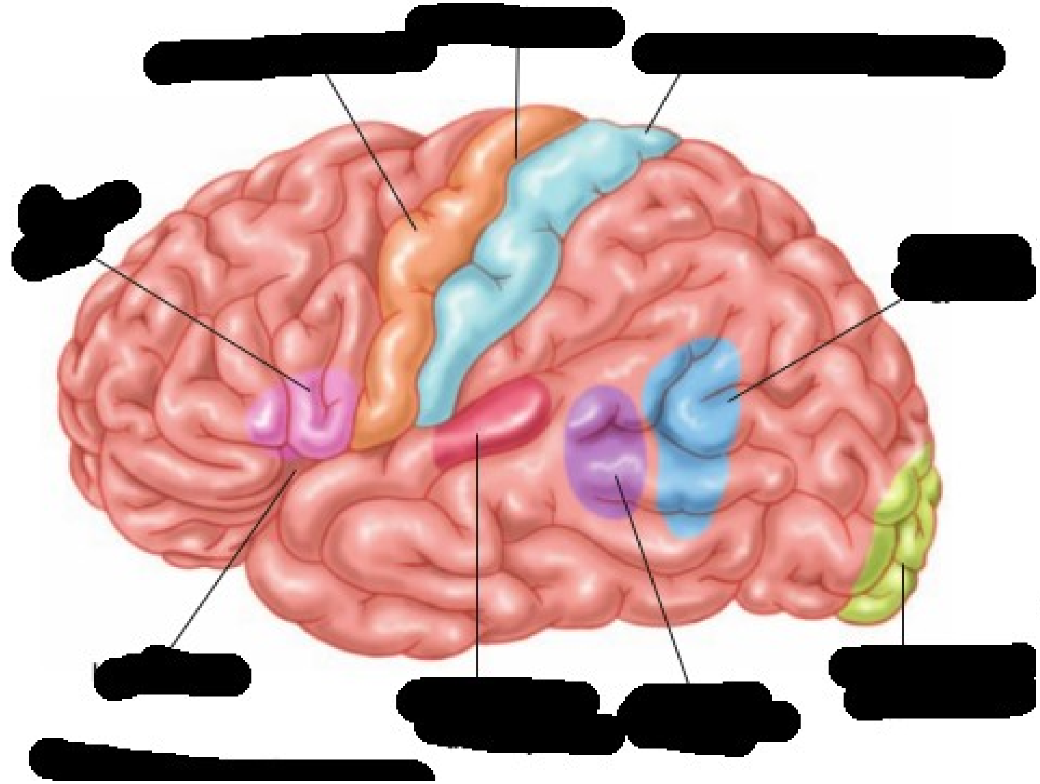
Language



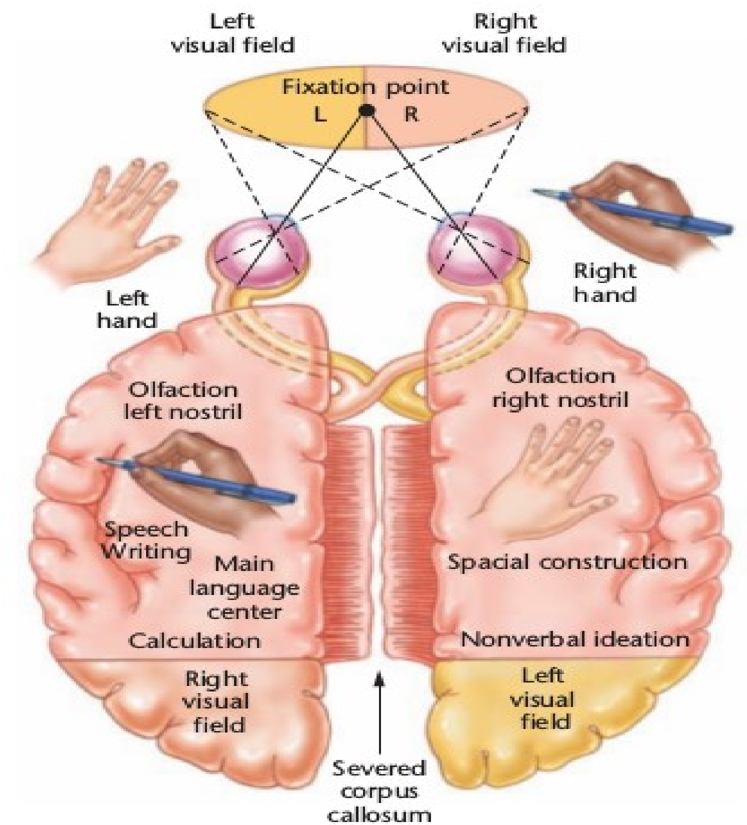
- Aphasia: language deficits caused by brain damage.
- 1861, Paul Broca, post-mortem dissection,
  - left hemisphere above the lateral fissure in frontal lobe.
  - Expressive aphasia. Broca's area involved in speech production.
- 1874, Carl Wernicke,
  - left hemisphere, temporal lobe, *receptive aphasia*. Wernicke's area. Unable to comprehend words.
  - No problem in word articulation
  - Speech tends to be meaningless

Language

- Wernicke-Geschwind model:
  - Broca's area stores articulatory codes.
  - Wernicke's area auditory codes and meanings of words
- How reading, speech comprehension, speech production are affected by
  - Damage limited to Broca's area...
  - Damage to Wernicke's area ….
  - Damage to angular gyrus ….
  - Damage in auditory area...

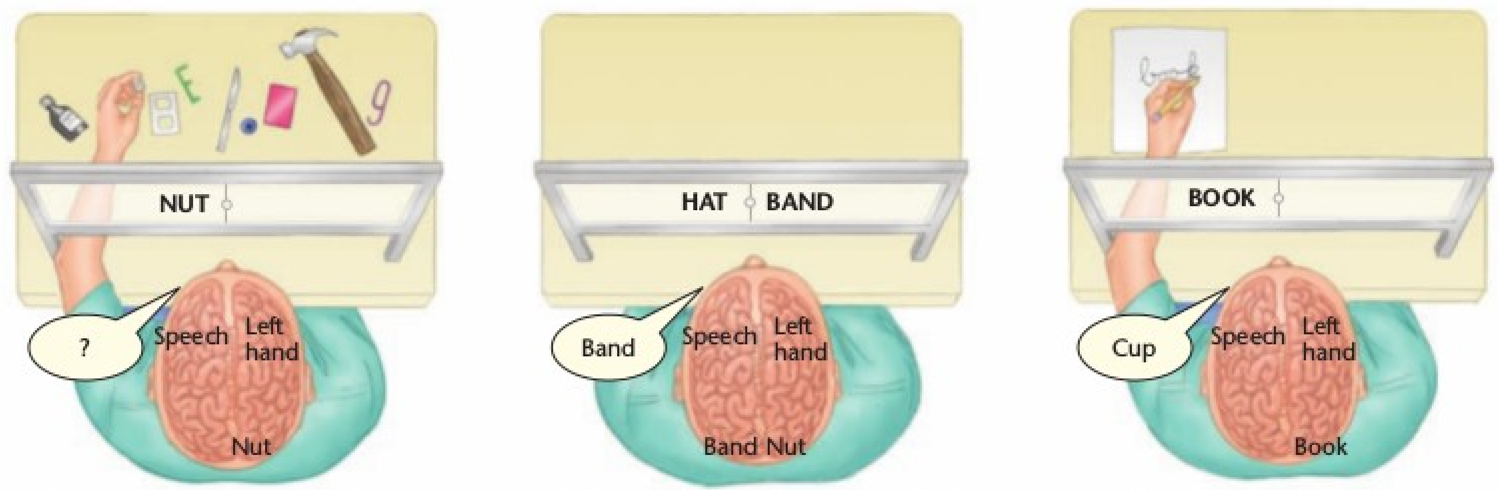
Split-brain research

- Corpus collasum
  - Epilepsy patients, seizure starting in one hemisphere may trigger massive response.
  - collasum is distrupted.
- Roger Sperry, Nobel Prize in 1981.



Split-brain research

- Roger Sperry, Nobel Prize in 1981.
- 'nut' was not transferred. When questioned, seems unaware of what his left hand is doing.
- 10 seconds, otherwise eye moves and info goes to both sides.
- If blindfolded, some object is placed on left hand, can use.



a) A split-brain patient correctly retrieves an object by touch with the left hand when its name is flashed to the right hemisphere, but he cannot name the object or describe what he has done.

b) The word 'hatband' is flashed so that 'hat' goes to the right cerebral hemisphere and 'band' goes to the left hemisphere. The patient reports that he sees the word 'band' but has no idea what kind of band.

c) A list of common objects (including 'book' and 'cup') is initially shown to both hemispheres. One word from the list ('book') is then projected to the right hemisphere. When given the command to do so, the left hand begins writing the word 'book', but when questioned, the patient does not know what his left hand has written and guesses 'cup'.

Multisensory integration in cortex

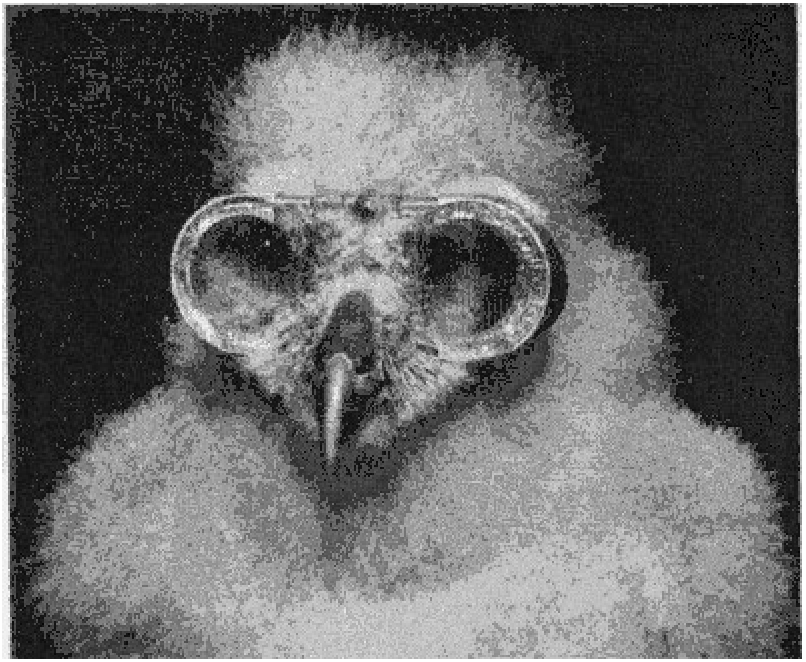
Perceptual fusion

- Individual senses
- Interactions between all “five” senses
- Types of fusion
  - Perceptual fusion
  - Immediate cross-modal bias
  - After effects

Prism experiments

- George Stratton, 1897
  - inverted vision
  - recalibration of touch, movement and sound perception
  - 6 days for adaptation
- Linden et al., 1999, “The myth of upright vision”
  - no inverted vision
  - but rapid adaptation
  - Rapid behavioural adaptation to the new spatial structure
  - learning of new motor patterns and increased skill at spatial
  - transformations
  - adjustment of the perception of the world, seen through the mirror or prism, to the conventional orientation.

Baby barn owl



Knudsen, E.I., P.F. Knudsen,
Science, vol.230, pp.545-548, 1985.

Sight and hearing: Mc Gurk effect

letters to nature

Nature **264**, 746 - 748 (23 December 1976); doi:10.1038/264746a0

Hearing lips and seeing voices

HARRY MCGURK & JOHN MACDONALD

Department of Psychology, University of Surrey, Guildford, Surrey GU2 5XH, UK

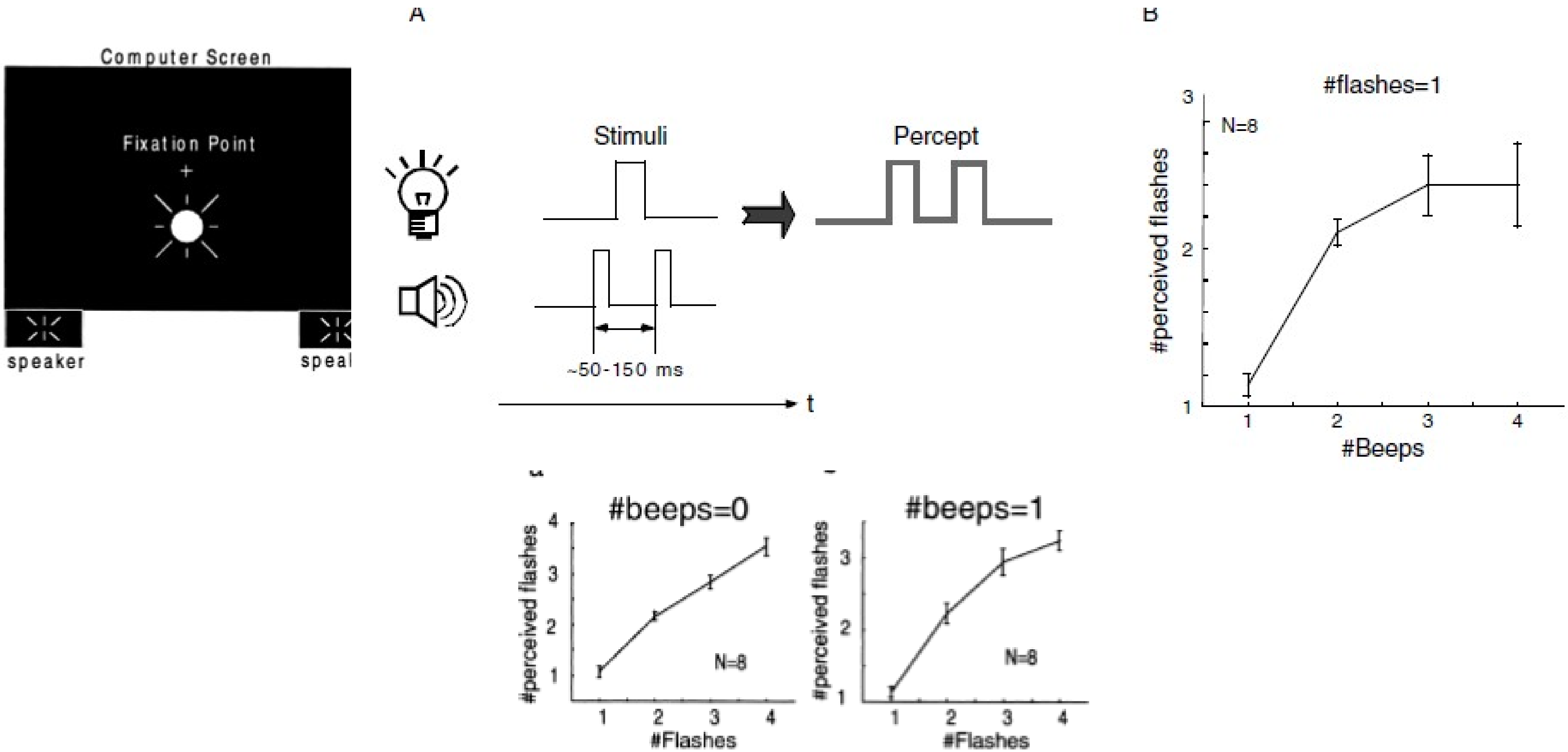
MOST verbal communication occurs in contexts where the listener can see the speaker as well as hear him. However, speech perception is normally regarded as a purely auditory process. The study reported here demonstrates a previously unrecognised influence of vision upon speech perception. It stems from an observation that, on being shown a film of a young woman's talking head, in which repeated utterances of the syllable [ba] had been dubbed on to lip movements for [ga], normal adults reported hearing [da]. With the reverse dubbing process, a majority reported hearing [bagba] or [gaba]. When these subjects listened to the soundtrack from the film, without visual input, or when they watched untreated film, they reported the syllables accurately as repetitions of [ba] or [ga]. Subsequent replications confirm the reliability of these findings; they have important implications for the understanding of speech perception.

https://www.youtube.com/watch?v=yJ81LLxfHY8

Sight and hearing: Ventriloquist illusion

- ventriloquist effect (Howard & Templeton,1966)

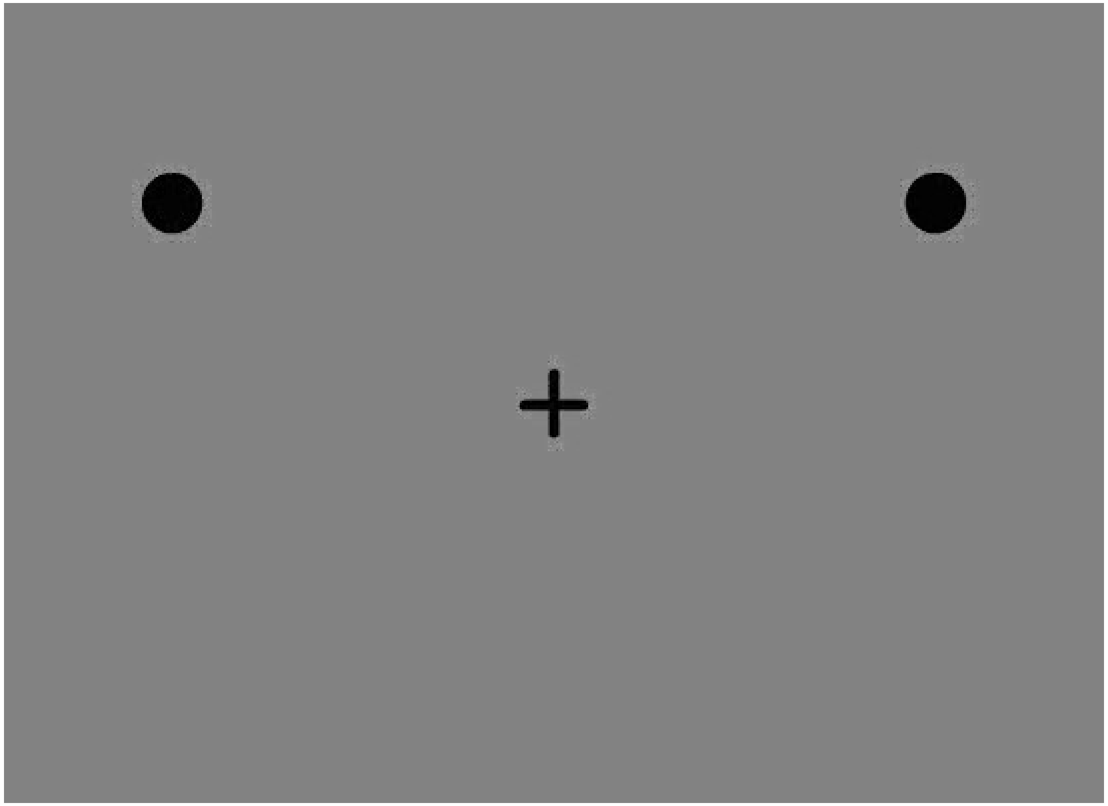
Sight and hearing: Flashes and beeps



Shams, L., Y. Kamitani, S. Shimojo, Nature, 2000.

https://www.youtube.com/watch?v=D3Z1cxA2Tp0

Sight and hearing: Moving disks



Sekuler, Lau, Sekuler, Nature, 1997

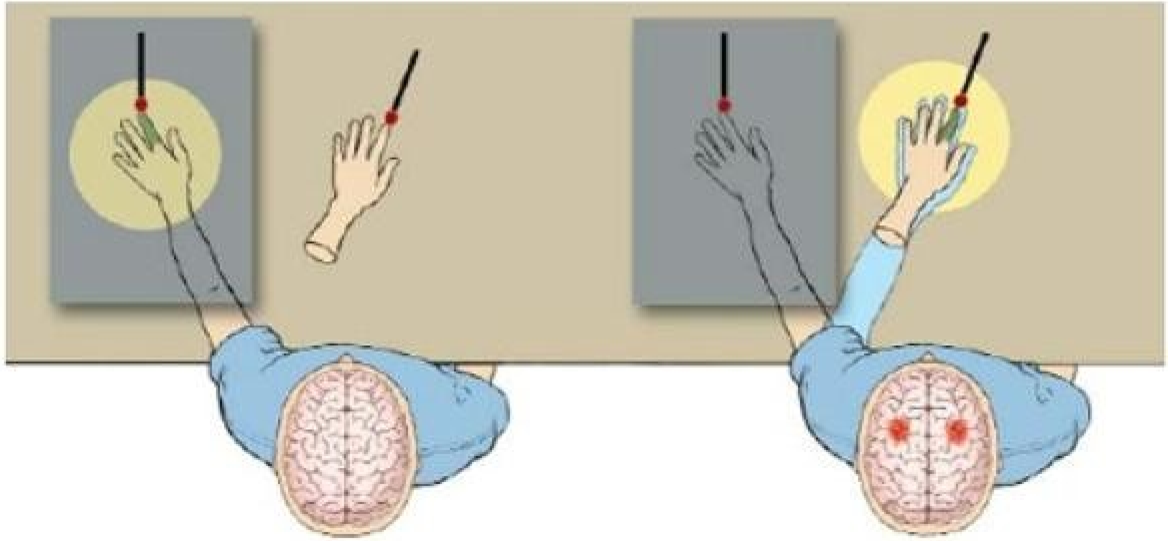
http://www.michaelbach.de/ot/mot_bounce/

Cocktail party effect

Sight and touch: Rubber hand illusion

H.H. Ehrsson,N.P. Holmes,R.E. Passingham, J. Neuroscience, 2006.
https://www.youtube.com/watch?v=DphlhmtGRqI

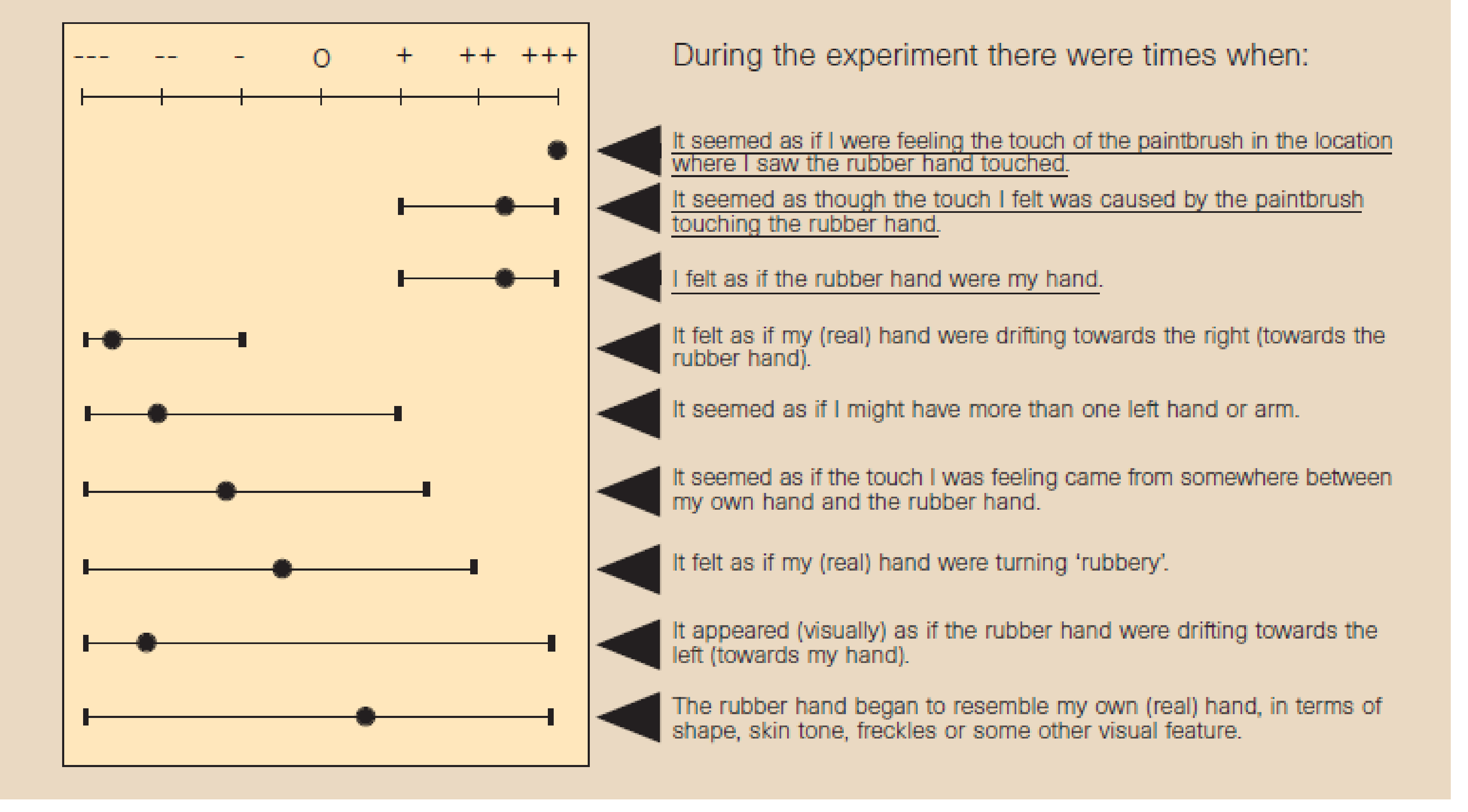
Sight and touch: Rubber hand illusion



Botvinick & Cohen,Nature 391, 1998

Rubber hands feel touch that eyes see

Sight and touch: Rubber hand illusion



Botvinick, M., J. Cohen, Nature, vol.391, pp.756, 1998.

Touch and hearing: Parchment illusion

- Jousmäki and Hari (1998)
- Rubbing hands while listening to sounds
- Changing frequency
- Subjective feeling of dry or moisturized hands obtained

Touch and smell: Silk stockings

- Among identical stockings, the one that smelled like flowers was found to be of higher quality (Laird, 1932)
- Subjects did not refer to olfaction to explain their decisions
- Smells are found to influence perceived softness of textiles.

Sight and smell: Wine tasting

- Fake color can mislead wine experts
- With closed eyes, the experts have a much higher success rate
- Facilitation of smell perception in the presence of correlated visual input (Gottfried and Dolan, 2003)
- Certains smells are consistently associated with certain colors in naming tasks (Gilbert et al. 1996)

Taste and smell: Apples and potatoes

- Without smell, taste perception is impaired
- Some taste perceptions increase sensitivity to smells with which they are associated (Diamond et al. 2005)
- It is possible to teach subjects new taste-smell pairings
- Areas that respond to both smell and taste are in the caudal orbitofrontal cortex, amygdala, insular cortex and its adjoining areas, and anterior cingulate cortex (De Araujo et al., 2003).

Modulations of Visual Perception by Sound

- Vision alters other modalities (vision dominance)
  - McGurk effect, ventriloquist effect
  - Rubber hand, Touch/view → draw
- Sound changes temporal resolution, duration, rate, → modality appropriateness
  - Vision has higher spatial resolution
  - Audition has higher temporal resolution
- Sound can
  - alter the interpretation of ambiguous visual motion event
  - alter perception of non-ambiguous visual events
  - create new perception. induced rabbit from Kamitani group.
  - Alter vision in motion perception.
-

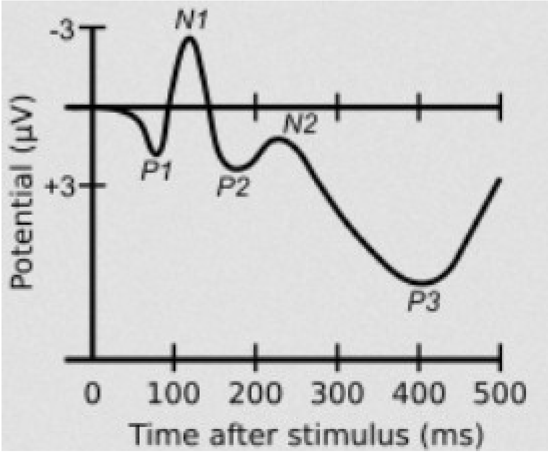
Modulations of Visual Perception by Sound – Neural evidence

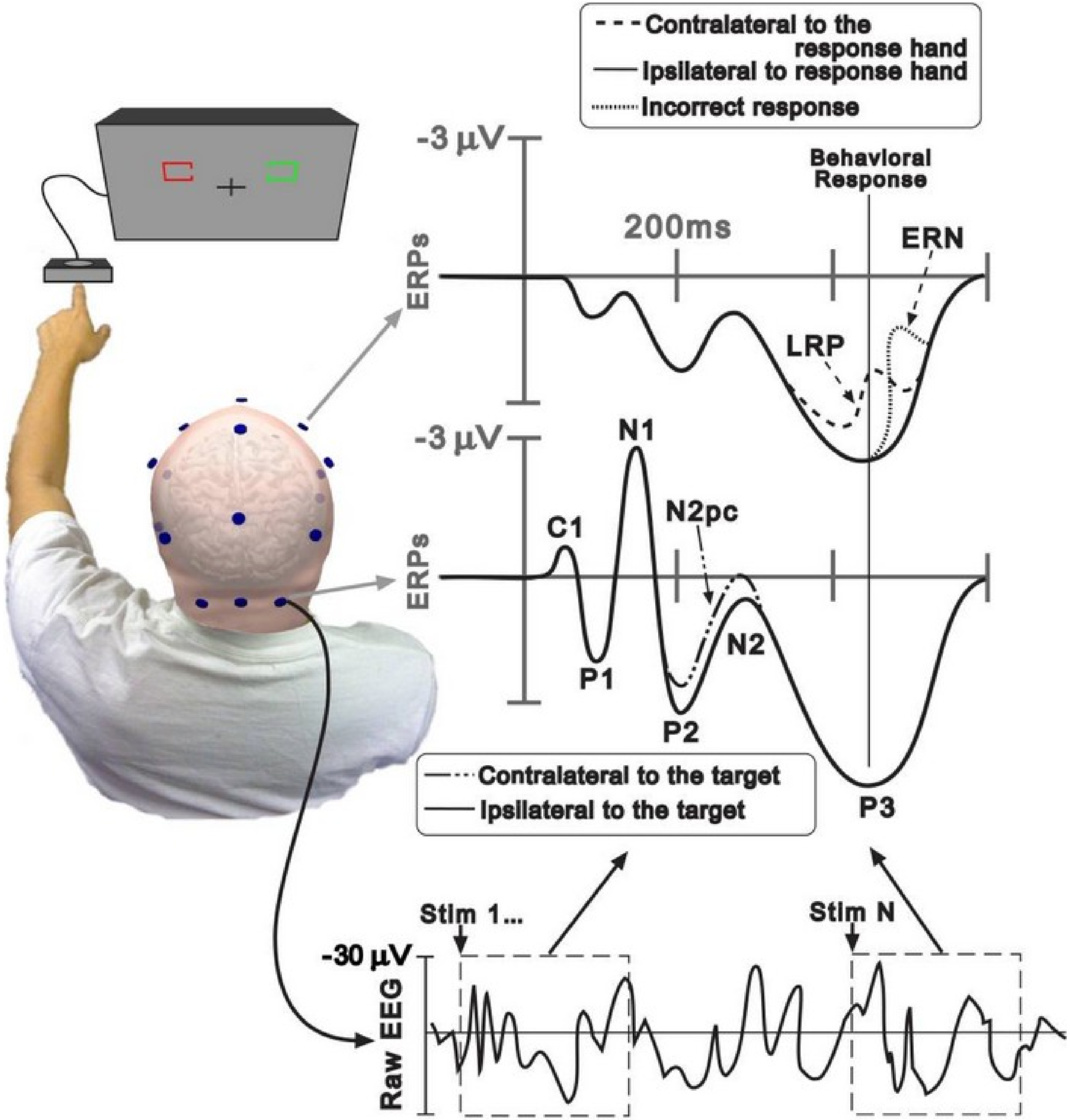
- Cross-modal effects and integration, at what level of perceptual processing?
  - Subcortical regions, visual cortical regions, associative cortical regions?

Modulations of Visual Perception by Sound – Neural evidence

- Cross-modal effects and integration, at what level of perceptual processing?
  - Subcortical regions, visual cortical regions, associative cortical regions?

- Event-related potential, Shams, Kamitani, Thompson & Shimojo, 2001.
- Brief tones and flashes
- Introduced sound, modulate VEP: the representation of the illusory flash also involves activity in the visual cortex.
- recent anatomical studies suggest a cortical pathway – direct projections





https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3816929/figure/F1/

Activity

- Which modality dominates, and why?
- How can you test this?

- Hint: Think about the factors that may play a role, and write these down to make it concrete...

Dominance of modalities

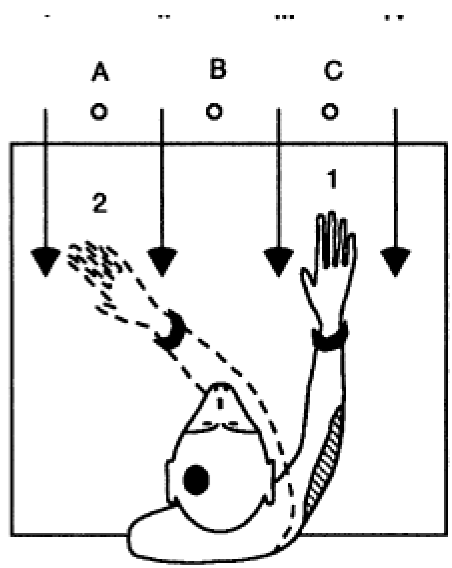
- *Discontinuity Hypothesis*
  - Shams, Kamitani ve Shimojo, 2002
  - The modality where perception is discontinued is dominant
- *Modality Appropriateness Hypothesis*
  - Welch ve Warren, 1980
  - The modality that facilitates the task is dominant
- *Information Reliability Hypothesis*
  - Schwartz, Robert-Ribes ve Escudier, 1998
  - The reliable modality is dominant
- *Directed Attention Hypothesis*
  - Welch ve Warren, 1980
  - The attended modality is dominant

Body schema

Coding of Visual Space by Premotor Neurons

Michael S. A. Graziano,* Gregory S. Yap, Charles G. Gross

In primates, the premotor cortex is involved in the sensory guidance of movement. Many neurons in ventral premotor cortex respond to visual stimuli in the space adjacent to the hand or arm. These visual receptive fields were found to move when the arm moved but not when the eye moved; that is, they are in arm-centered, not retinocentric, coordinates. Thus, they provide a representation of space near the body that may be useful for the visual control of reaching.



CmpE 489: Cognitive Science

From sensation to cognition

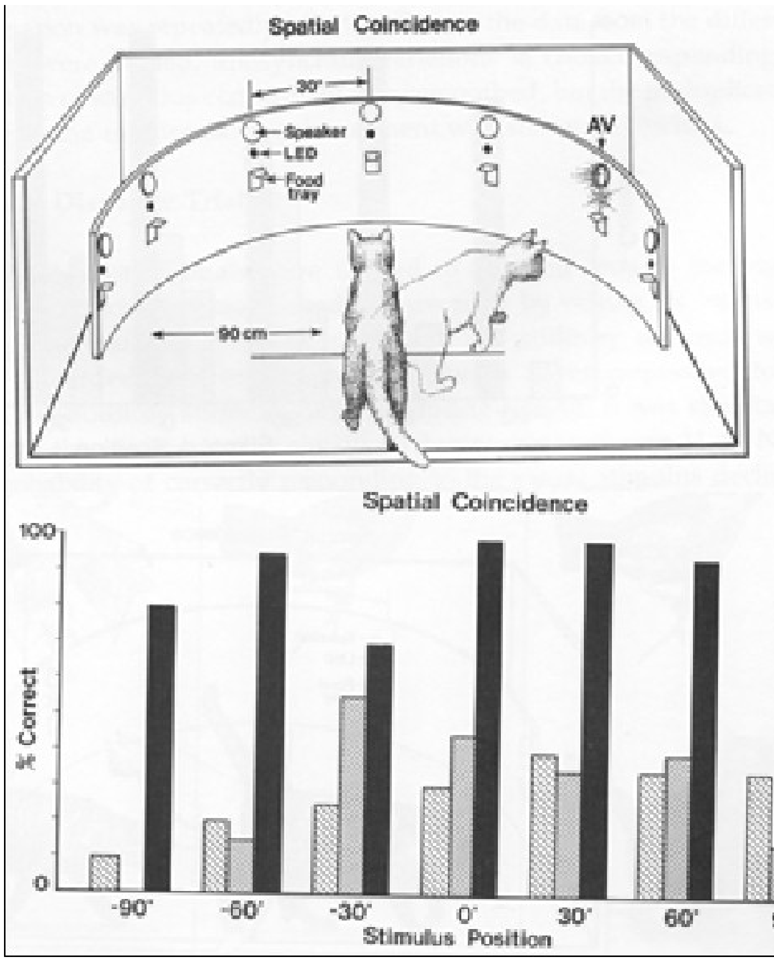
Overview

- Multisensory integration in cortex
- Information fusion
- From sensation to cognition
- Cognitivist and emergent standpoints
- A robotic perspective

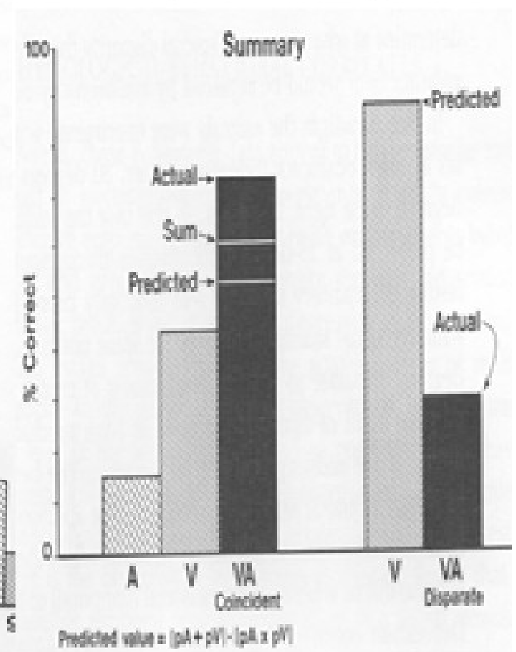
Which senses affect each other?

- Sight and hearing
- Sight and touch
- Touch and hearing
- Touch and smell
- Sight and smell
- Taste and smell

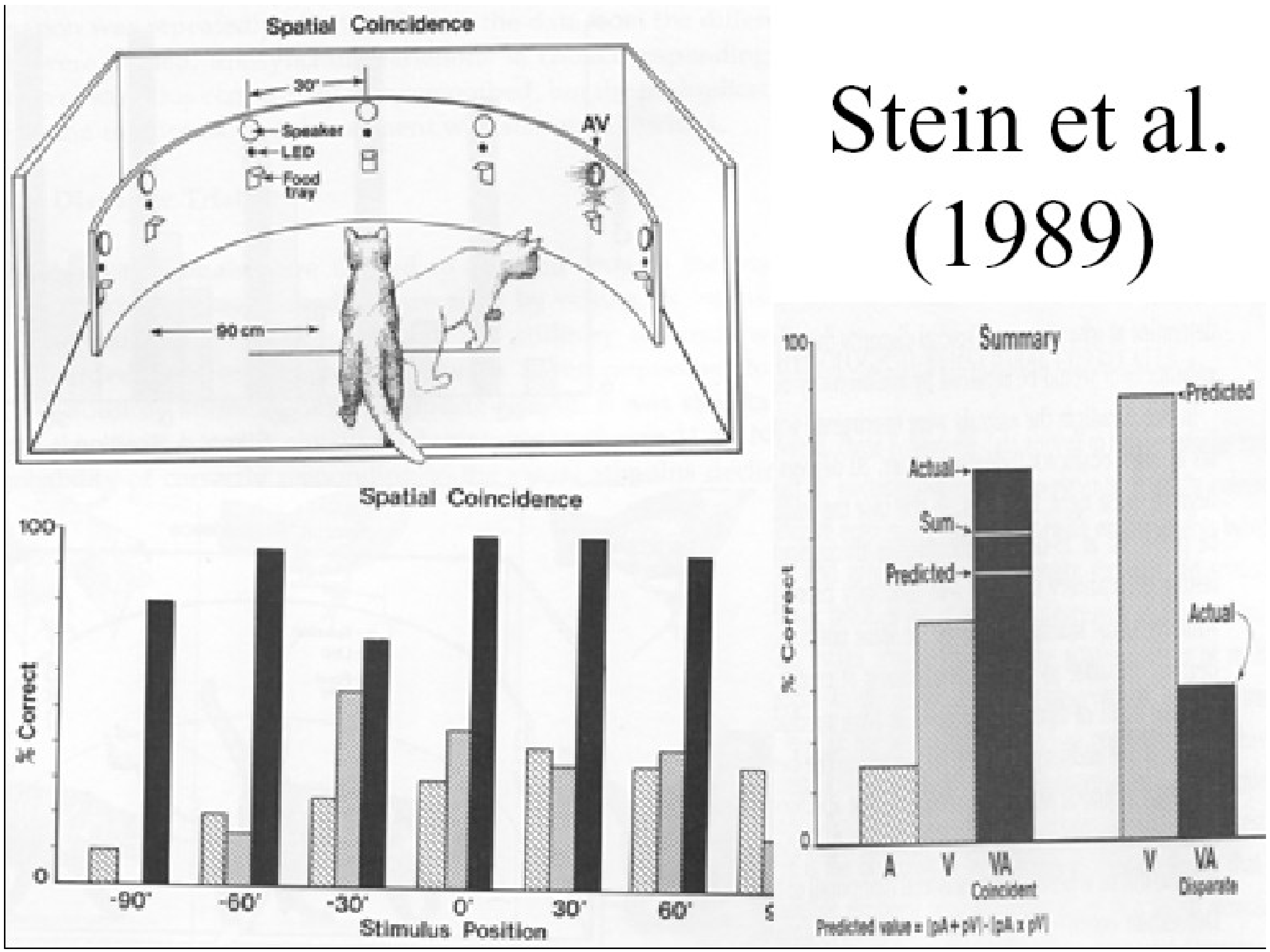
Multisensory integration in cortex



Stein et al. (1989)

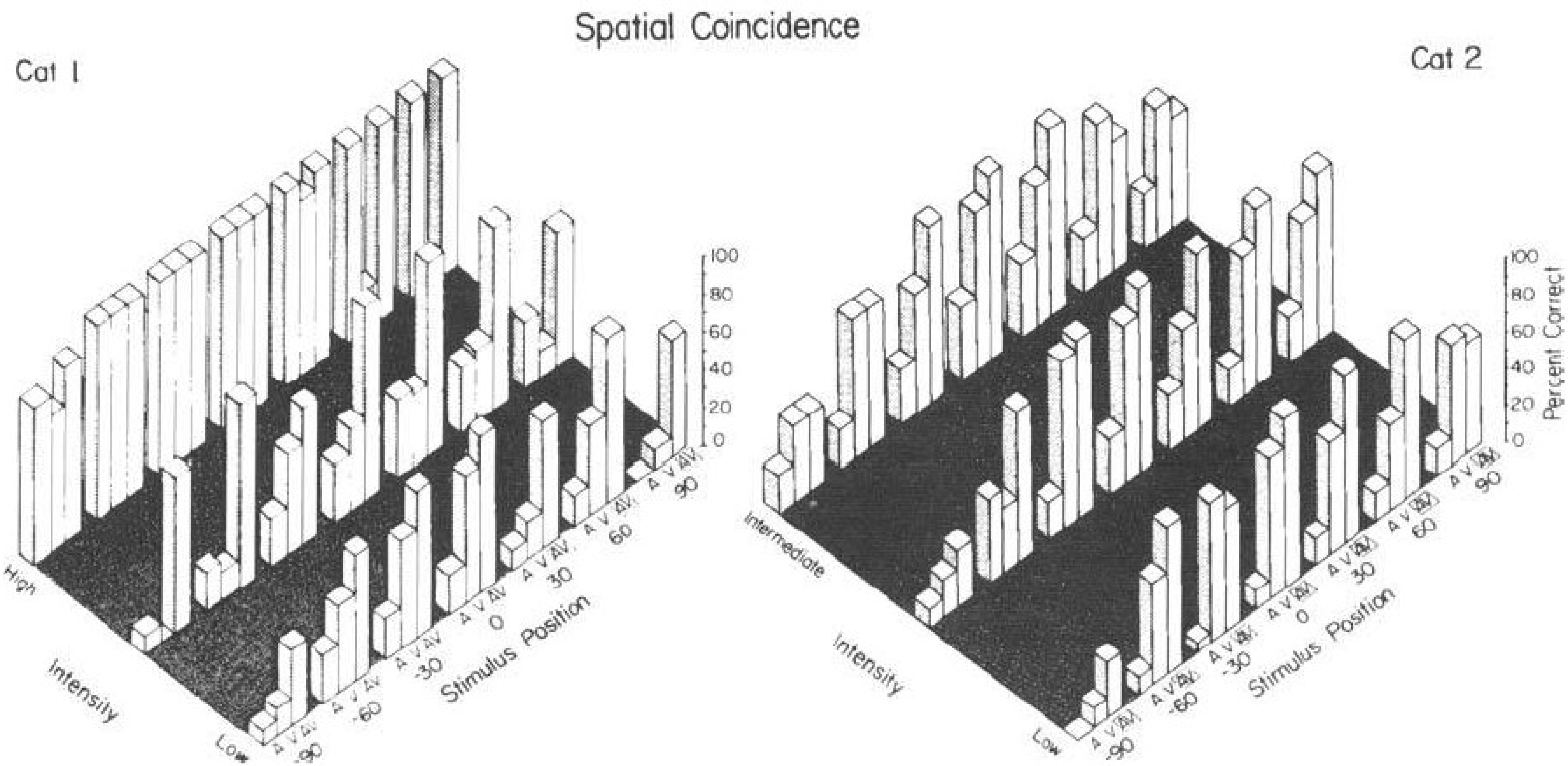


Multisensory integration in cortex



Stein et al. (1989)

Multisensory integration in cortex



Multisensory integration in cortex

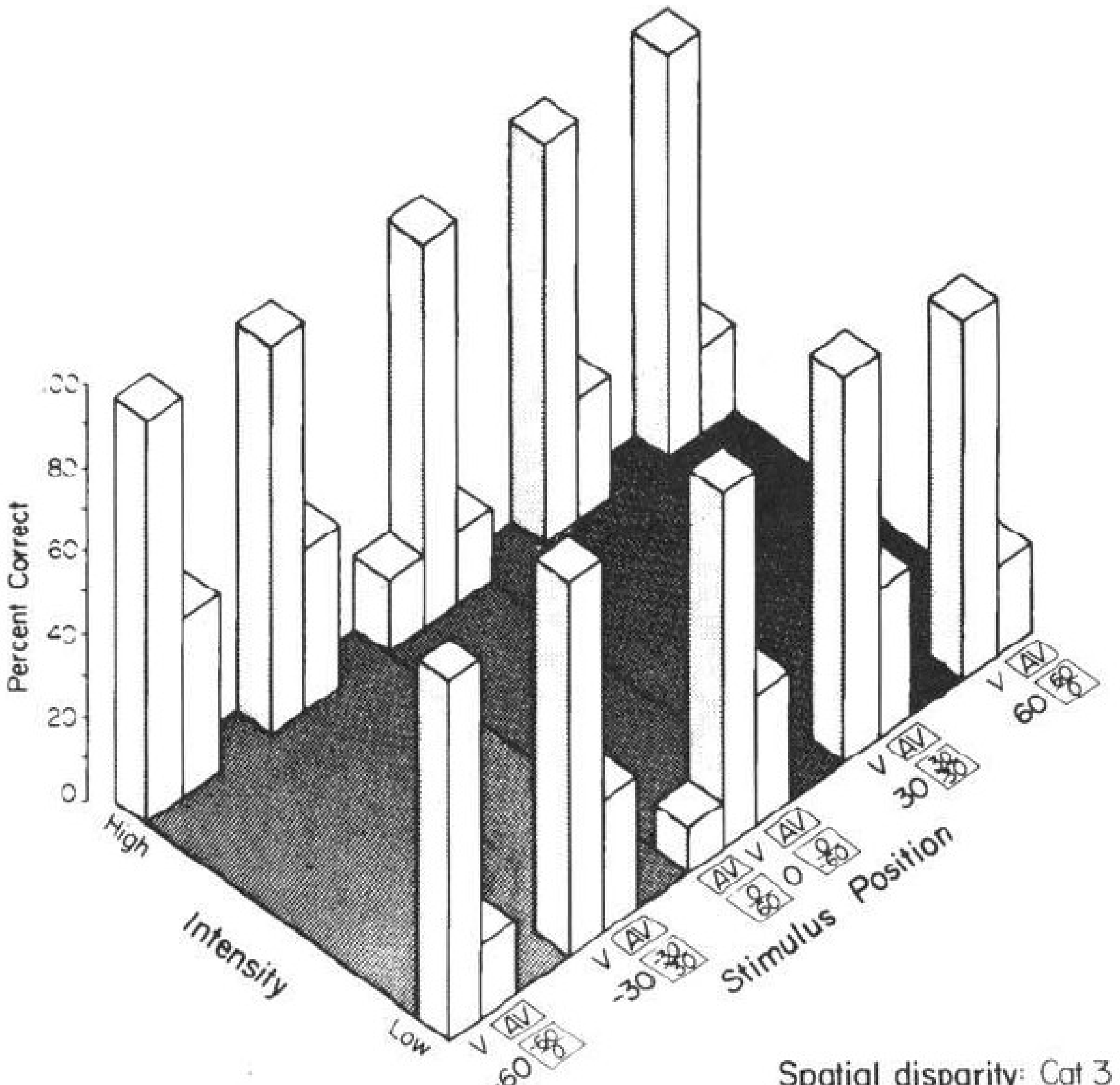
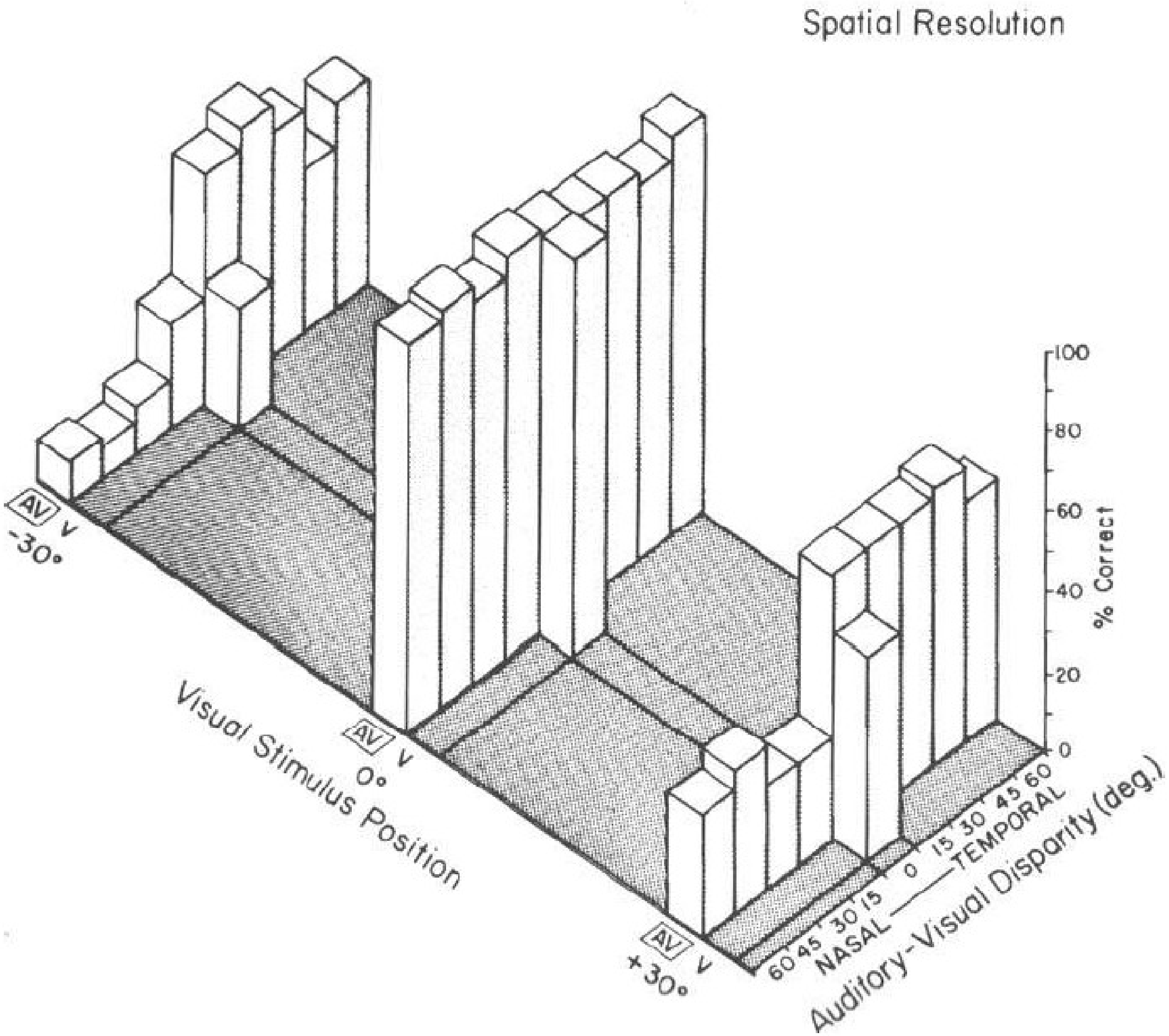


Figure 5: When the visual stimulus (0.20 and 0.17 mcd) was paired with a spatially disparate auditory stimulus (27.75 dB SPL), correct responding was depressed. The animal never approached the auditory stimulus, and incorrect responses consisted of failure to move or an approach to the wrong location. Response depression was exhibited regardless of the visual stimulus eccentricity, and among the animals studied the magnitude of depression was not systematically related to eccentricity. The location of the visual stimulus is indicated by the top number of the vertical pair (e.g. 0 /-60 represents visual at 0° and auditory at 60° left).

Multisensory integration in cortex



JOURNAL OF NEUROPHYSIOLOGY
Vol. 76, No. 2, August 1996. *Printed in U.S.A.*

Representation and Integration of Multiple Sensory Inputs in Primate Superior Colliculus

M. T. WALLACE, L. K. WILKINSON, AND B. E. STEIN
Department of Neurobiology and Anatomy, Bowman Gray School of Medicine/Wake Forest University, Winston-Salem, North Carolina 27157

- visual-, auditory-, and somatosensory-responsive neurons, and multisensory in the superior colliculus of the rhesus monkey.
- >27.8% of the deep layer population more than a single sensory modality.
- 37% responded only to visual cues, 17.6% to auditory cues, and 17.6% to somatosensory cues.
- Unimodal- and multisensory-responsive neurons were clustered by modality.
- Each of these modalities was represented in map-like fashion, and the different representations were in alignment with one another.
- The spatial congruence among the different receptive fields of their ability to synthesize cross-modal information.

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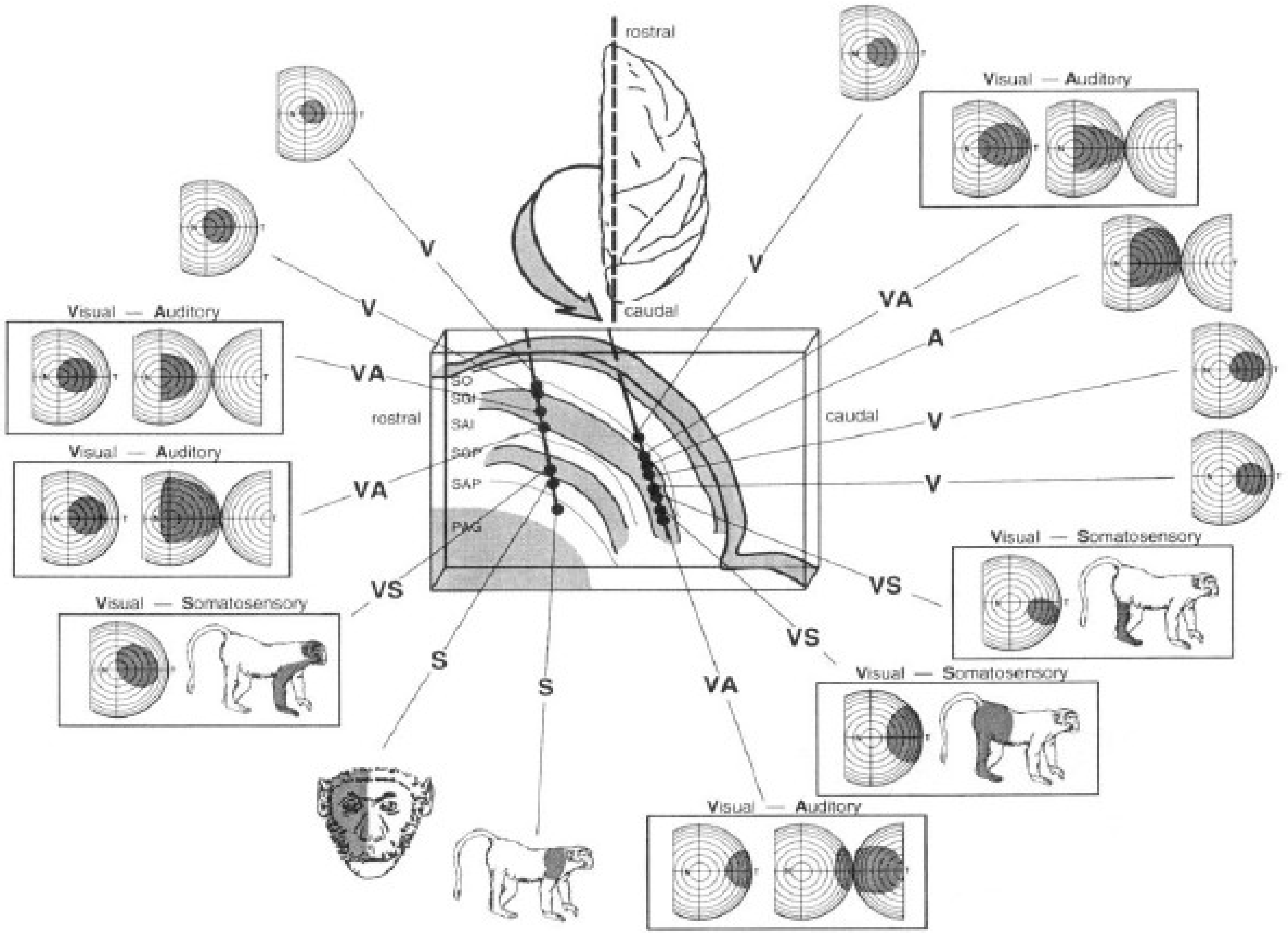
- Combinations of stimuli could have very different consequences in the same neuron, depending on their temporal and spatial relationships.
- Maximal response: stimuli originated from similar locations in space
  - Because they fell within the excitatory receptive fields of the same multisensory
- If, the stimuli were spatially disparate such that one fell beyond the excitatory borders of its receptive field, no interaction or depressed. Furthermore, maximal response interactions
- Maximal response interactions were seen with the pairing of weakly effective unimodal stimuli. As the individual unimodal stimuli became increasingly effective, the levels of response enhancement to stimulus combinations declined, a principle referred to as inverse effectiveness.
- Many of the integrative principles seen here in the primate superior colliculus are strikingly similar to cat behavioral responses.


rostral
caudal
Visual — Auditory
Visual — Auditory
Visual — Auditory
Visual — Auditory
Visual — Somatosensory
Visual — Somatosensory
Visual — Somatosensory
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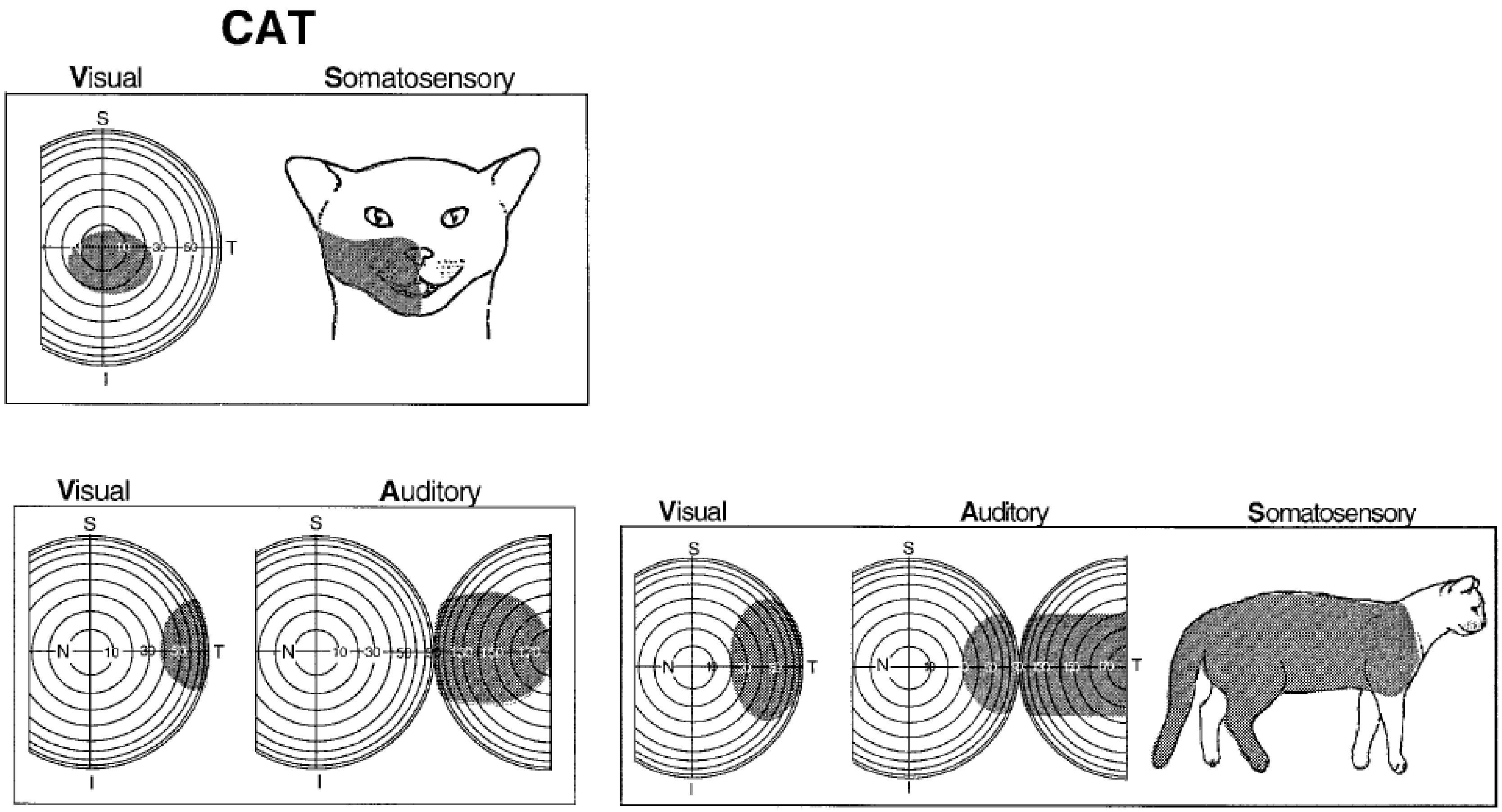
SAI
SGP
SAP
PAG
rostral
caudal

Receptive fields

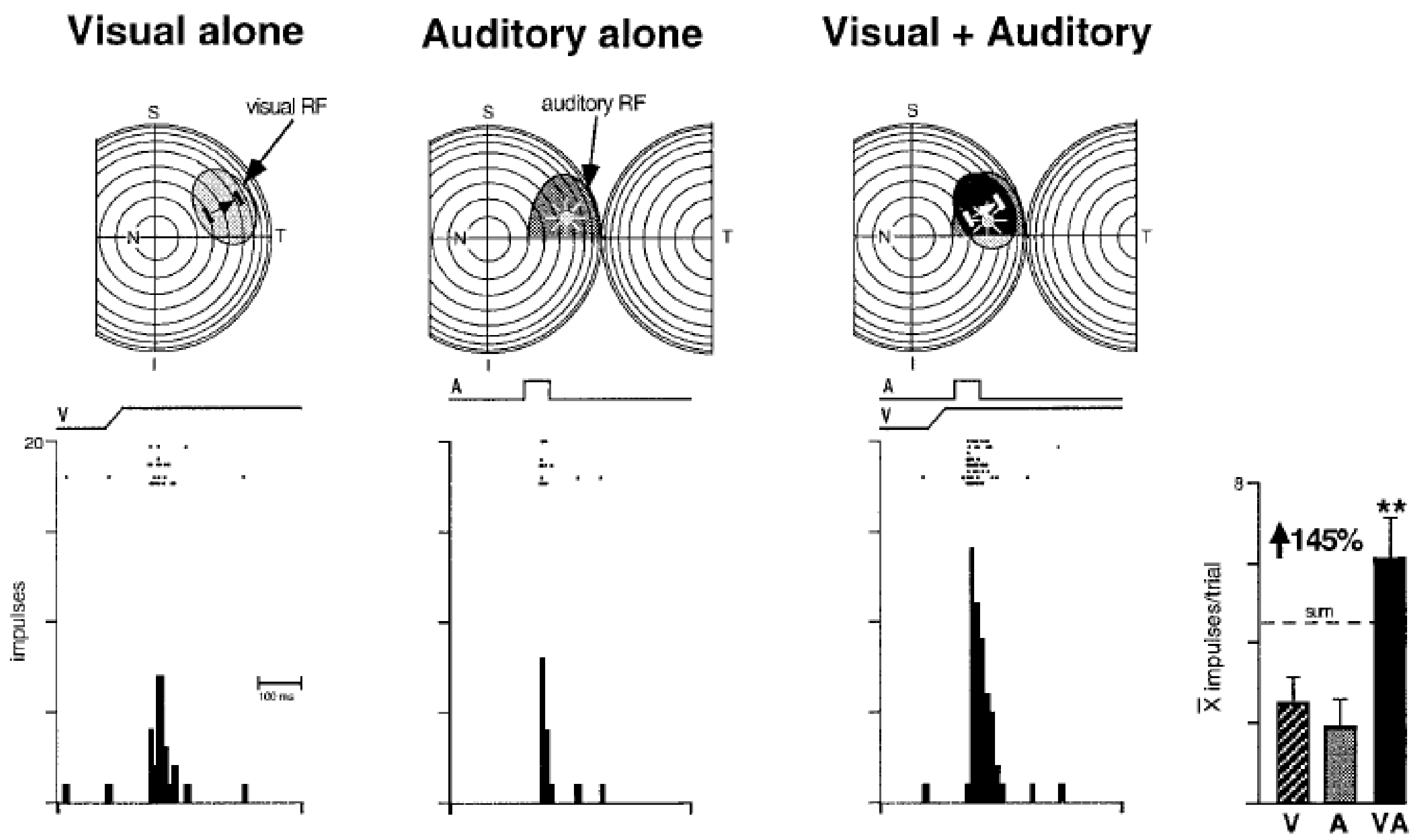


Wallace and Stein, 1996

Topologically ordered multisensory areas

- At the cortical level:
  - superior temporal sulcus,
  - intraparietal sulcus,
  - parieto-preoccipital cortex,
  - posterior insula,
  - the frontal cortex including premotor, prefrontal and anterior cingulate.
- At the sub-cortical level:
  - claustrum,
  - superior colliculus,
  - suprageniculate and medial pulvinar nuclei of the thalamus,
  - rhinal cortex,
  - amygdala-hippocampus

Multisensory enhancement



Wallace and Stein, 1996

Principle of information fusion

- Why should we fuse?
  - To increase robustness
  - To improve accuracy
  - To cope with missing information
  - To speed up processing – faster reaction times
  - To transfer knowledge across modalities

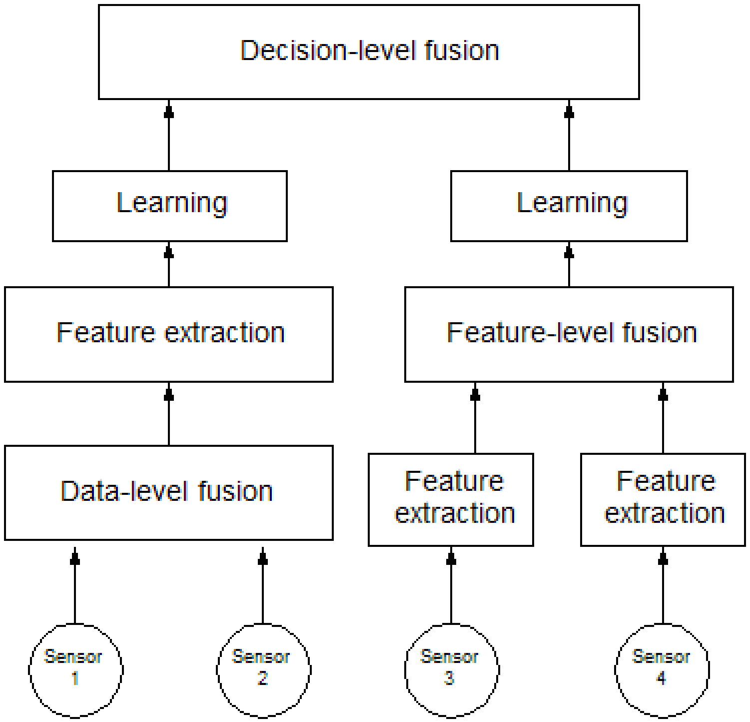
Multiple sensor systems

- *Complementary sensors*:
  - Operate independently, and produce complementary information.
  - The eye and the ear are complementary sensors.
- *Competitive sensors*:
  - Measure the same phenomenon
  - Fusing the output lowers *expected measurement error*.
  - Pressure sensors closely placed in a finger are an example
- C*ooperative sensors*:
  - Sometimes, a single sensor is not enough to measure a phenomenon
  - Depth perception is achieved with two eyes.

Perceptual processing in computers

- Perceptual function
- Perceptual learning
- Models
  - Parametric models
  - Non-parametric models
- Noise resilience

Information fusion



- Feature normalization
- Multidimensionality
- Feature extraction vs selection
- Curse of dimensionality
- Diversity
- Meta-learning

Biological considerations

- Simple crosstalk
- Optimality considerations
  - Bock’86: “space occupied by a perceived object is coded with an eye-centered coordinate system in all modalities”
  - Pouget et al.’05: “such coding will not be optimal”
- Measuring performance
  - solving a problem as well as humans
  - solving a problem the way humans do
- Abstraction