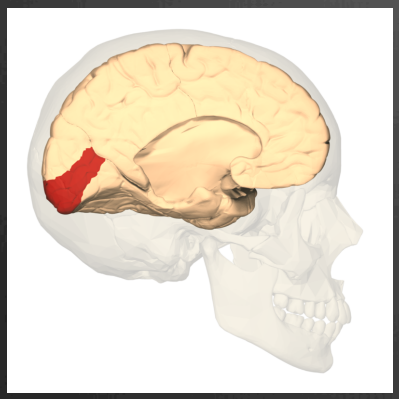
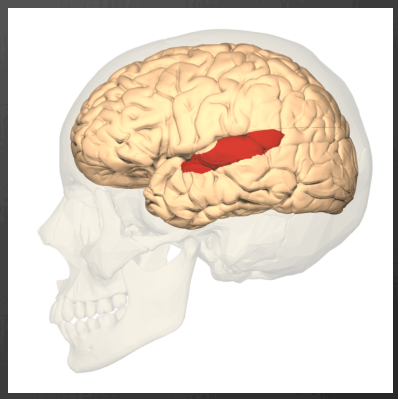
Auditory Display

a cognitive interaction perspective

Neural information channels

Opportunity: visual vs auditory cortex





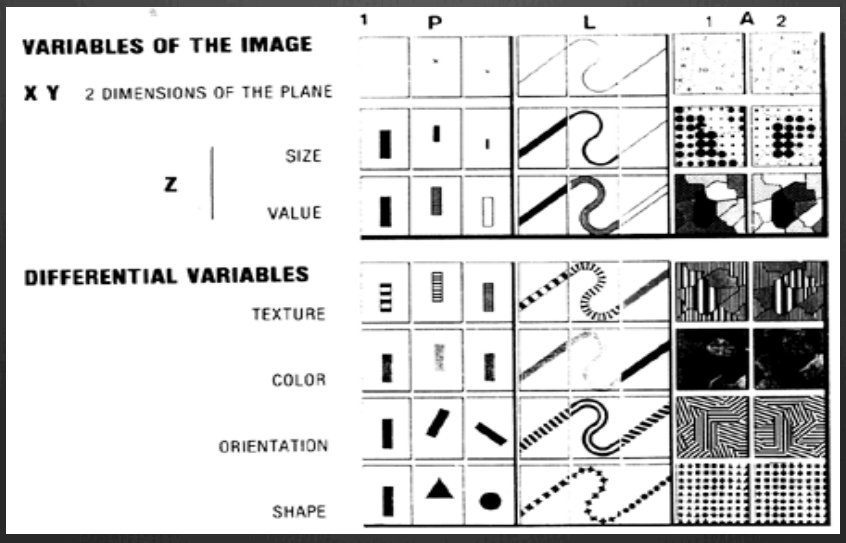
Some auditory channel properties

- The cochlea is an FFT machine (so 2D, not 1D)
  - Not just time-domain amplitude samples
  - Instantaneous & continuous frequency band energies
- Auditory mode is closely coupled to language centres
  - Lexical associations
  - (Musical) structure: syntax and rhythm
- Binaural perception provides orientation relative to head

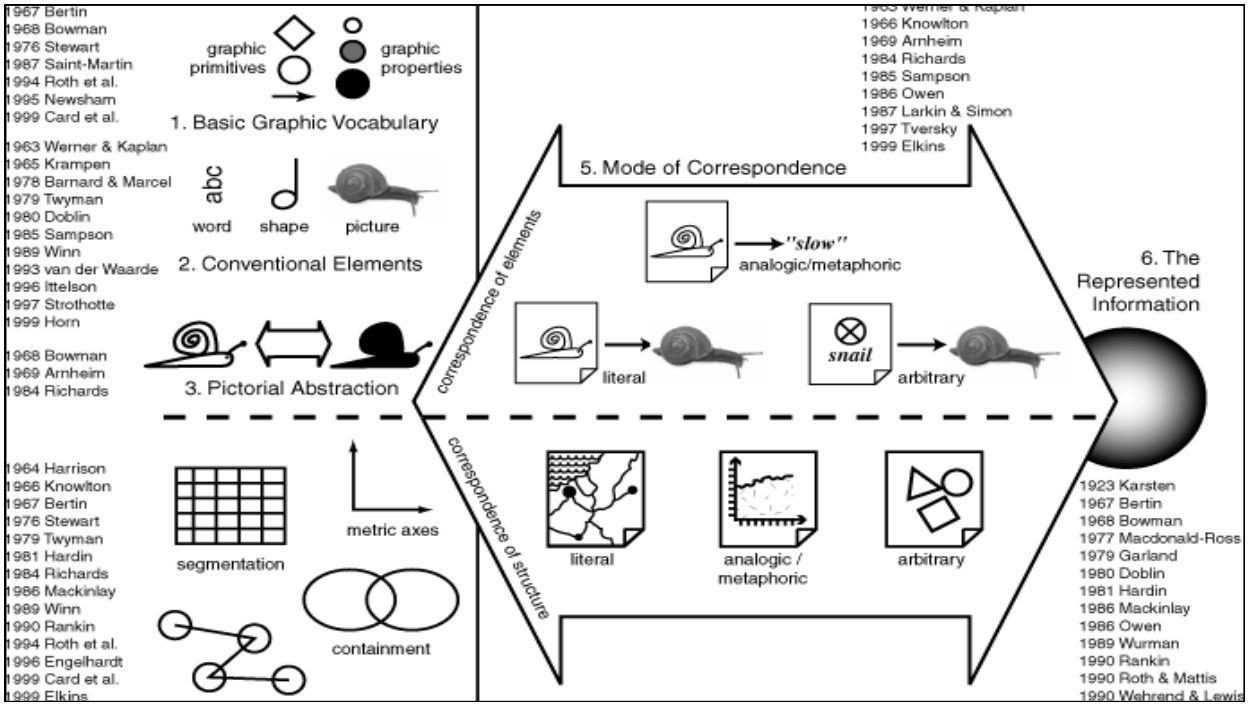
Display modes as information channels

Visual display	Auditory display	Haptic display
World coordinates over restricted field	Approximate head coordinates	Precise body coordinates
Encoded as image in visuo-spatial sketchpad	Encoded as chunks in phonological loop	Persistent nerve stimulus
Allows direct relational encodings	Allows direct linguistic encodings	Few temporal or semantic conventions
Suffers from occlusion, but not masking	Does not require ambient light	Requires physical contact for channel transmission

From HCI: visual display as semiotic system



From Jacques Bertin *Semiologie Graphique*



	Graphic Resources	Correspondence	Design Uses
Marks	Shape Orientation Size Texture Saturation Colour Line	Literal (visual imitation of physical features) Mapping (quantity, relative scale) Conventional (arbitrary)	Mark position, identify category (shape, texture colour) Indicate direction (orientation, line) Express magnitude (saturation, size, length) Simple symbols and colour codes
Symbols	Geometric elements Letter forms Logos and icons Picture elements Connective elements	Topological (linking) Depictive (pictorial conventions) Figurative (metonym, visual puns) Connotative (professional and cultural association) Acquired (specialist literacies)	Texts and symbolic calculi Diagram elements Branding Visual rhetoric Definition of regions
Regions	Alignment grids Borders and frames Area fills White space Gestalt integration	Containment Separation Framing (composition, photography) Layering	Identifying shared membership Segregating or nesting multiple surface conventions in panels Accommodating labels, captions or legends
Surfaces	The plane Material object on which the marks are imposed (paper, stone) Mounting, orientation and display context Display medium	Literal (map) Euclidean (scale and angle) Metrical (quantitative axes) Juxtaposed or ordered (regions, catalogues) Image-schematic Embodied/situated	Typographic layouts Graphs and charts Relational diagrams Visual interfaces Secondary notations Signs and displays

Auditory display as semiotic system

- What are the perceptual components?
  - Perceived primitives
  - Perceived relations
- What are the application referents?
  - Information entities
  - Information relations
- System design employs modes of correspondence

Does auditory display belong in a computer music course?

- Music is "structured sound", so yes, because we are defining and exploiting structure through design of correspondences
- Music analysis offers a useful feature space for synthesis and analysis, better than trial-and-error, intuition or neuroscience:
  - Expressive dynamics
  - Pitch and chroma
  - Harmonic and tonal conventions
  - Timbre (everything else, including modulation envelope, filter design, instrumental technique, resonance and damping …)

Technical varieties of "non-speech audio"

- Alarms and notifications
- Sonification / audialisation
- Spatial navigation
- Audio games / game audio and sound toys
- And some specialised speech variants

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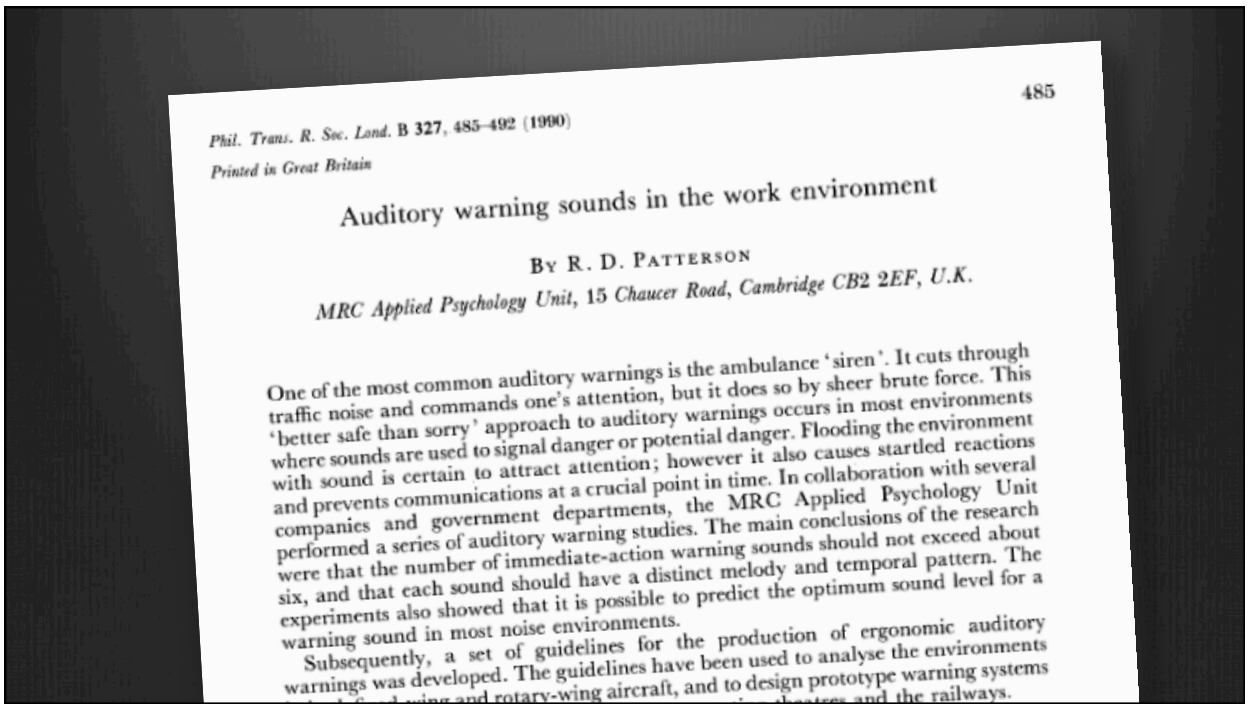
Alarms

- A classic area of interest in human factors
  - Characteristic of "first-wave HCI" – engineering specification of the human user as a system component
  - Relevant to aircraft cockpits, road safety, control rooms etc.
- Research questions and technical guidance include:
  - What sound properties are distinguishable?
  - What properties gain the user's attention?
  - What trade-offs exist between urgency and situation assessment?



Phil. Trans. R. Soc. Lond. B **327**, 485–492 (1990)
Printed in Great Britain

Auditory warning sounds in the work environment

BY R. D. PATTERSON
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One of the most common auditory warnings is the ambulance 'siren'. It cuts through traffic noise and commands one's attention, but it does so by sheer brute force. This 'better safe than sorry' approach to auditory warnings occurs in most environments where sounds are used to signal danger or potential danger. Flooding the environment with sound is certain to attract attention; however it also causes startled reactions and prevents communications at a crucial point in time. In collaboration with several companies and government departments, the MRC Applied Psychology Unit performed a series of auditory warning studies. The main conclusions of the research were that the number of immediate-action warning sounds should not exceed about six, and that each sound should have a distinct melody and temporal pattern. The experiments also showed that it is possible to predict the optimum sound level for a warning sound in most noise environments.

Subsequently, a set of guidelines for the production of ergonomic auditory warnings was developed. The guidelines have been used to analyse the environments [illegible] and rotary-wing aircraft, and to design prototype warning systems [illegible] theatres and the railways.

Beyond the ambulance siren

- Brute force ('better safe than sorry') approach, where sounds are used to signal danger or potential danger
- Flooding the environment with sound:
  - (+) Is certain to attract attention
  - (–) Causes startled reactions
  - (–) Prevents communications at a crucial point in time

Patterson's design guidance:

- The number of immediate-action warning sounds should not exceed about six
- Each sound should have a distinct melody and temporal pattern
- It is possible to predict the optimum sound level for a warning sound in most noise environments

R. D. Patterson (1990). Auditory Warning Sounds in the Work Environment. Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences, Vol. 327, No. 1241, Human Factors in Hazardous Situations (Apr. 12, 1990), pp. 485-492

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Bill Gaver's *Sonic Finder* (1987)

- https://vimeo.com/158610127
- Auditory icons or "earcons"
  - Now a familiar system feature
  - Either unsolicited event notification ("alert")
  - Or status change confirmation (tap, click, etc)
  - Secondary multimodal information channel
- Classic opportunity for semiotic design – what is the mode of correspondence? (Csapó & Wersényi try some formal defs)

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The design logic of visualisation/sonification

- We have a set of data, and believe there are patterns within that data that we (or the users) are not aware of
- The data is used to generate sensory stimuli, in the expectation that patterns in the data will result in perceptual regularities.
  - In visualisation, these are visual 'patterns' (e.g. time series)
  - In sonification, these have to be auditory patterns

Effectiveness of sonification

- The technical view: identify perceptible differences
  - e.g. https://muse.union.edu/2017capstone-cowdenp/audification-and-sonification-audio-samples/
- The design view: the expected relations must be designed
  - Program code – hasn't worked yet
  - Scientific/financial/media data – might at least entertain:
    - e.g. https://www.youtube.com/watch?v=0lKSFlB_-Qo
  - Status and alerts (surgical 'ping', EDSAC) – see Patterson
  - Structural coupling – e.g. filling a wine glass?
- As with visualisation, correspondences must be designed

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Real-world navigation

- Mcgookin, Brewster & Priego (2009). Audio bubbles: Employing non-speech audio to support tourist wayfinding. Int. Conf. Haptic and Audio Interaction Design, pp. 41-50
- Wilson, Walker, Lindsay, Cambias & Dellaert (2007). Swan: System for wearable audio navigation. IEEE Int. Symp. Wearable Computers, pp. 91-98

Virtual-world navigation

- In Menus: Brewster (1998). Using nonspeech sounds to provide navigation cues. ACM Trans. on CHI, 5(3), 224-259.
  - Earcons indicate position within hierarchy
- In Games: Papa Sangre II
  - Follow direction cues and sound effects without visuals

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'Sound toys' as interactive compositions

- Dolphin, A. (2014). Defining sound toys: play as composition. In *The Oxford Handbook of Interactive Audio*.
  - Interactive, sonic-centric systems in which the user may trigger, generate, modify, or transform sound.
  - Playful approaches to novice composition through symbolic representation of complex underlying systems.
- e.g. Eno & Chilvers *Bloom*, Bjork *Biophilia*, Coldcut *Ninja Jamm*

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Using recognisable sounds

- Spearcons (earcons with speech): compressed speech extracts with pitch preserved
- Spindex (speech index): audio with letter sounds or words when scrolling through an index
- Musicons: Recognisable short extracts of music
  - cf leitmotifs in Wagner, or samples of James Brown

Some researchers to follow

- Bruce Walker at Georgia Tech
  - Sonification and Spearcons
- Tony Stockman at Queen Mary
  - Especially for assistive technology
- Steve Brewster in Glasgow
  - Especially for haptic and multimodal mobile