

Spatial Soundscape Superposition



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Modern Acoustics and Signal Processing

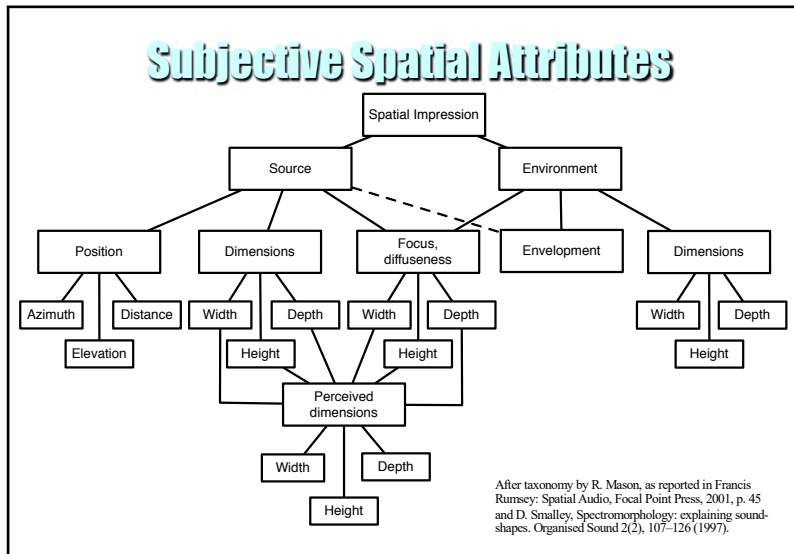
Jens Blauert
Jonas Braasch *Editors*

The Technology of Binaural Understanding

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 Modern Acoustics and Signal Processing
 Springer

Michael Cohen and William L. Martens. "Spatial Soundscape Superposition and Multimodal Interaction". In: *The Technology of Binaural Understanding*. Ed. by Jens Blauert and Jonas Braasch. Modern Acoustics and Signal Processing. Dec. 2020. Chap. 13, pp. 351–390. isbn: 978-3-030-00385-2, 3-030-00385-X, 978-3-030-00386-9. doi: 10.1007/978-3-030-00386-9_13. url: <https://link.springer.com/book/10.1007/978-3-030-00386-9>.

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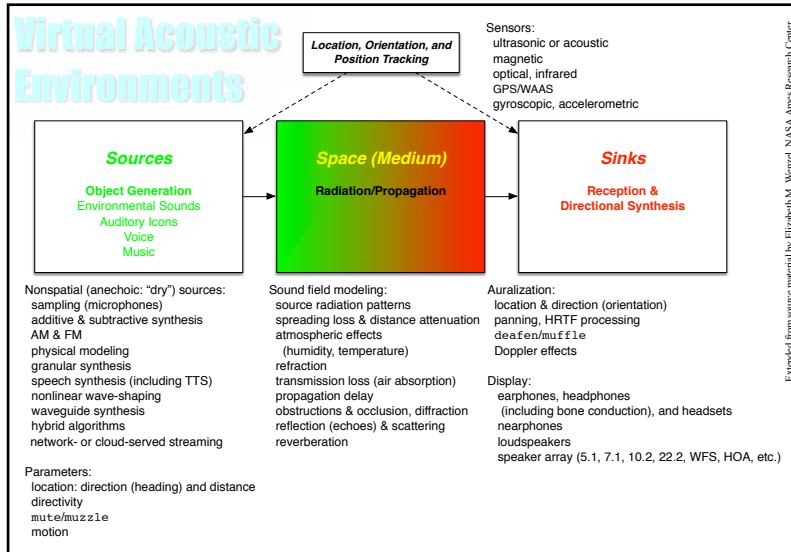
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Sound, Sensation, & Signal

	Stage	Domain	Realm	Practice	Considerations
Objective	Sound	Acoustics	Physics	<i>Transmission:</i> propagation, air mixing	Personal and public transducers, cross-fading, speaker arrays, smart speakers, mobile-ambient interfaces
	Transduction	Biophysics, biochemistry	Physiology	Bone conduction, cochlear implants	Critical bands & ERBs, auditory or loudness recruitment
Subjective	Sensation	Psychology, psychoacoustics	Perception, sensorineural process	<i>Apprehension:</i> Subjective composition, vection	Auditory objects, binaural imagery, multimodal stimulation
	Signals	Cognition: auditory event	Procedure, practicality, central auditory process	<i>Interpretation:</i> Logical convention, metaphorical mapping, culture & semiotics	Parameterized directionalization & spatialization, layering & audio windowing, narrowcasting, multipresence, mental models, practical interpretation

Michael Cohen & William L. Martens. "Spatial Soundscape Superposition and Multimodal Interaction". In: *The Technology of Binaural Understanding*. Ed. by Jens Blauert & Jonas Braasch. Modern Acoustics and Signal Processing. Berlin & Heidelberg: Springer, ASA Press, 2020. Chap. 13. ISBN: 978-3-030-00385-2, 3-030-00385-X, 978-3-030-00386-9. DOI: 10.1007/978-3-030-00386-9_13. URL: <https://www.springer.com/gp/book/9783030003852>.

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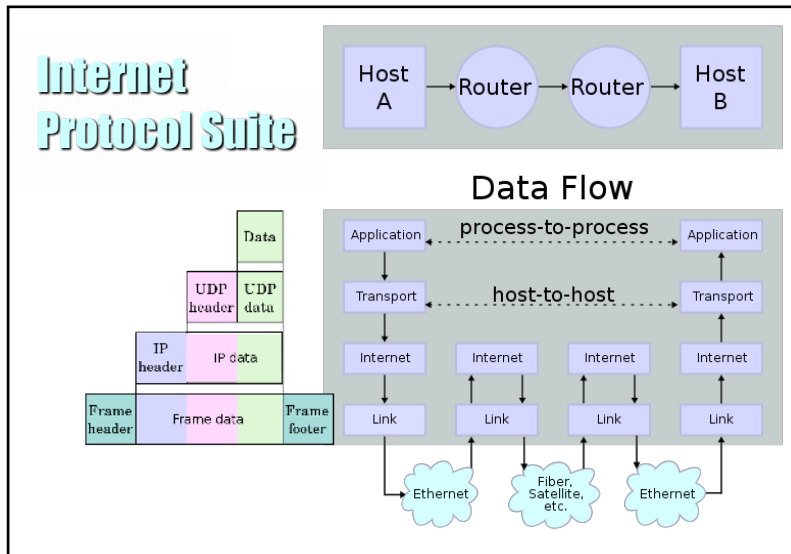


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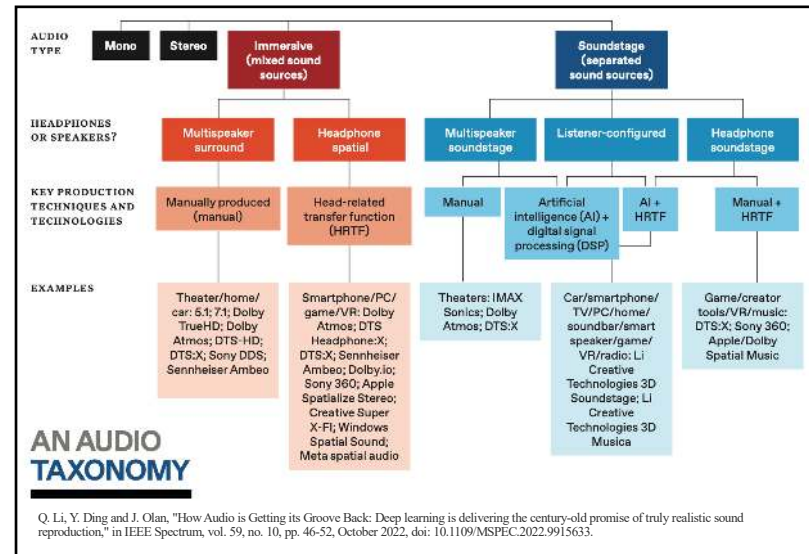
Acoustic diffusion; 音響拡散 [おんきょうかくさん]

Quality (Property)	Physical Process	Quantitative attribute
reflectivity	reflection	reflectance
absorptivity	absorption	absorbance
transmissivity	transmission	transmittance

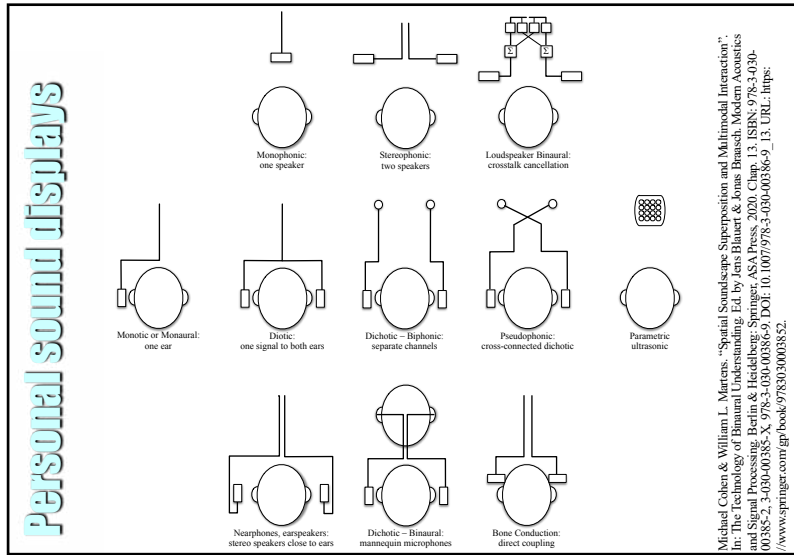
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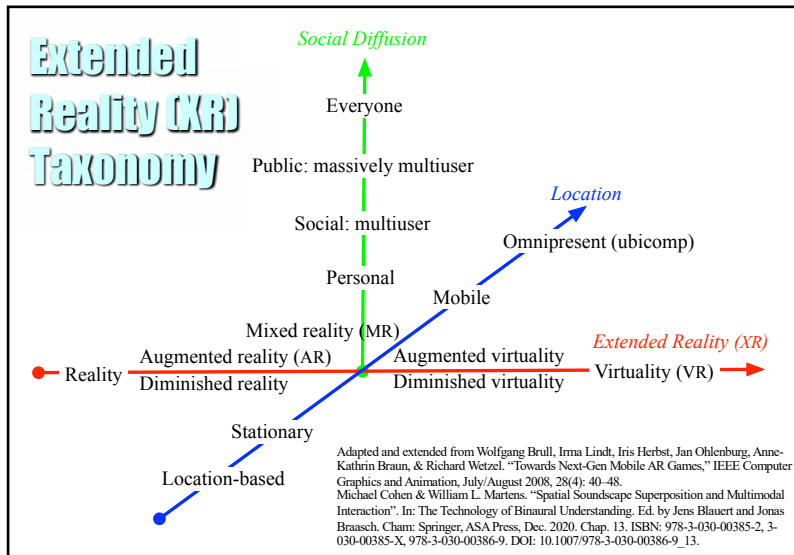


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Combining signals: $I_{1+2} \propto (x_1(t) + x_2(t))^2$

$1/\tau \int (x_1^2(t) + 2x_1(t)x_2(t) + x_2^2(t)) dt$	Energy in 1 st term		Energy in cross-product		Energy in 2 nd term		Superposition	$L_{1+2} - L_1 = 10 \log I_{1+2}/I_1$
1	2	1	Positively correlated, reinforcing				up to +6 dB, quadruple power with double amplitude	
1	0	1	Uncorrelated, incoherent				up to +3 dB, double power	
1	-2	1	Negatively correlated, cancelling				-∞ dB	

946



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Audio and visual displays along private→public continuum across spatial separation and social intimacy: 音声、画像再生方式と視聴対象者

Proxemic Context	Users	Architecture	Auditory Display	Visual Display
Intimate, Private	1	headset, wearable computer	<i>ear</i> top headphones, ear buds, nearphones, ear speakers, PSAPs	<i>eye</i> top HWD (head-worn display) HMD (head-mounted display) mobile phone
Individual, Personal	1	chair	mobile phone, smartphone, tablet "sound shower" isolation directional displays	laptop display, desktop monitor, smartphone, tablet
Interpersonal	few	couch or bench	multichannel crosstalk-cancelled speakers (ex.: stereo dipole)	HDTV, "fishtank VR," NEC VisionDome, workbench
Multipersonal, Familiar	10s	vehicle, spatially immersive display, home theater (e.g., Cave, Cabin)	surround sound (ex.: ITU 5.1, 7.1.4, NHK 22.2 etc.), soundbar	projection (ex.: Cave™ or Cabin™), 4K, 8K
Social	100s	club, theater, "reality centers" Asimov's "Prime Radiant"	speaker array (ex.: VBAP, DirAC, DBAP, WFS)	large-screen display (ex.: IMAX)
Public	1000s	stadium, concert arena	public address, sound reinforcement	(ex.: Jumbotron), multiple screens (to reach distant viewers)

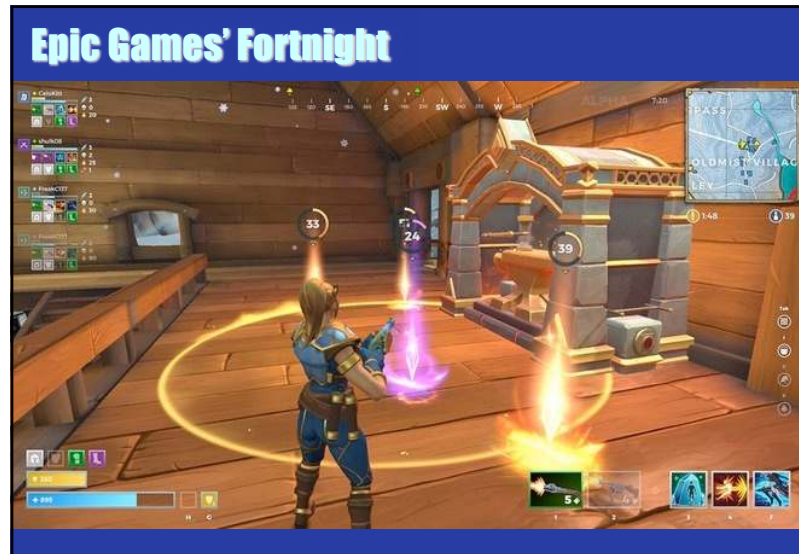
437

Ubicomp intimacy; ユビキタス 親密性

- smart spaces and aware environments (“everyware”)
- cooperative buildings
- roomware (software for rooms) and reactive rooms
- media spaces
- immoBots (immobile robots)
- spatially immersive displays
- information furniture
- networked appliances
- handheld/mobile/nomadic/portable/wireless/ambulatory
- wearable/intimate computing (“wearware”)
- computational clothing (smart fabrics & clothes)
- motes/smart dust
- MEMS (microelectromechanical systems)

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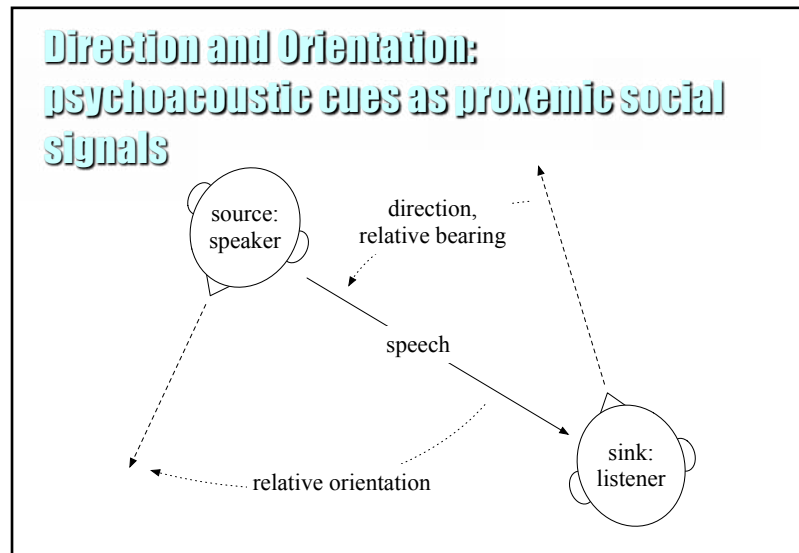
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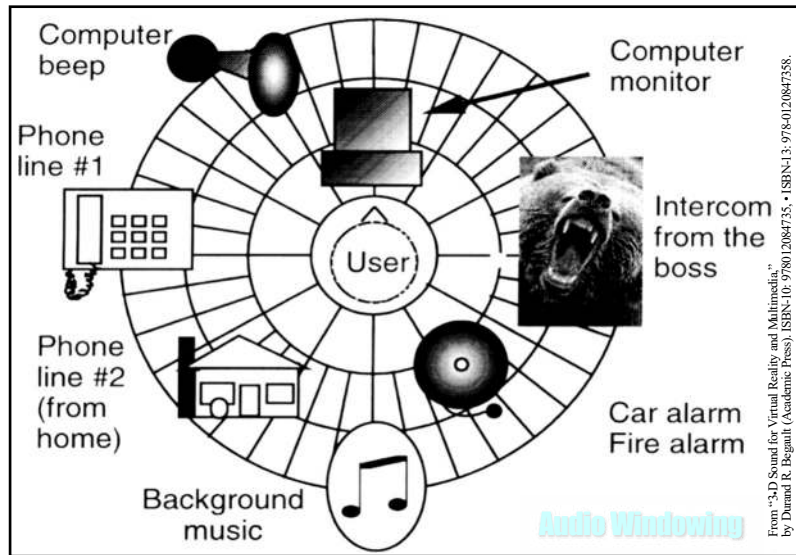
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	Source; 音源	Sink; 受聴者
Function, Role	Production, Radiation (effector) Emission & radiation Pitcher: “Throw” or “Cast” Push, Mutator, Fan-out	Reception (sensor) Consumption Catcher: “Catch” Pull, Accessor, Fan-in
Presence Locus	Nimbus (projection, exposure)	Focus (receptivity, sensitivity)
Modulation	Amplification & Attenuation (Gain)	Sensitization & Desensitization
Media Direction	OUTput (display), production	INput (control), reception
Instance	Speaker	Listener
Perspective	Object	Subject
Social Media; ソーシャルメディア (FEJ)	Followee; フォロー中、フォロワー、フォロイ	Follower; フォロワー
Transducer	Loudspeaker (motor, driver)	Microphone array or dummy-head (generator, drivee)
Organs	Mouth	Ears
Metaphorical Device	Megaphone, Loud-hailer, Bullhorn, Speaking-trumpet, Blowhorn (nozzle)	Ear horn or trumpet, Hearing aid (sound funnel)
Symbols	+, ♂	-, ♀
Selectively Include	select (solo) or cue 🗣️	attend: confide and harken (hearken)
Attenuate	muzzle	muffle
Exclude	mute (conceal) 🗣️	deafen (blind)

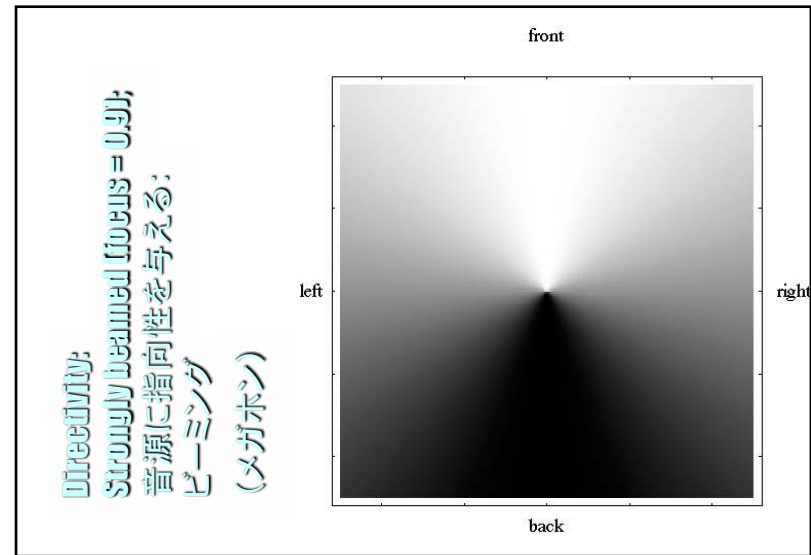
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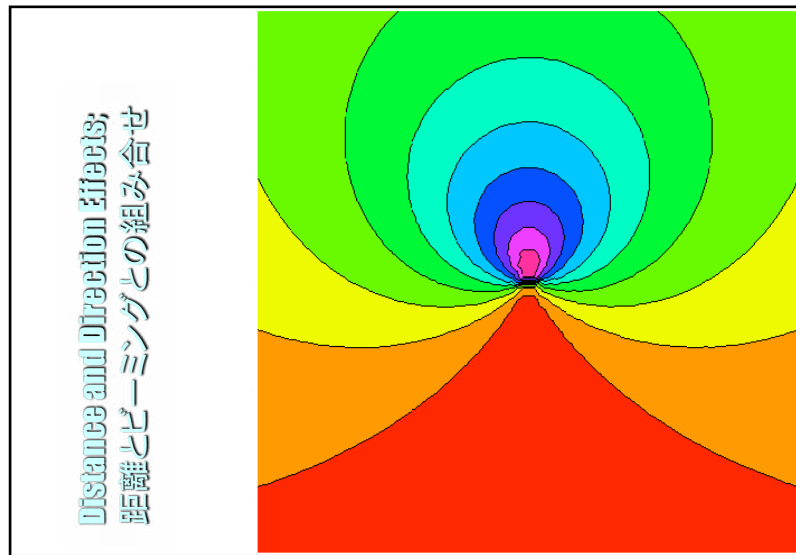
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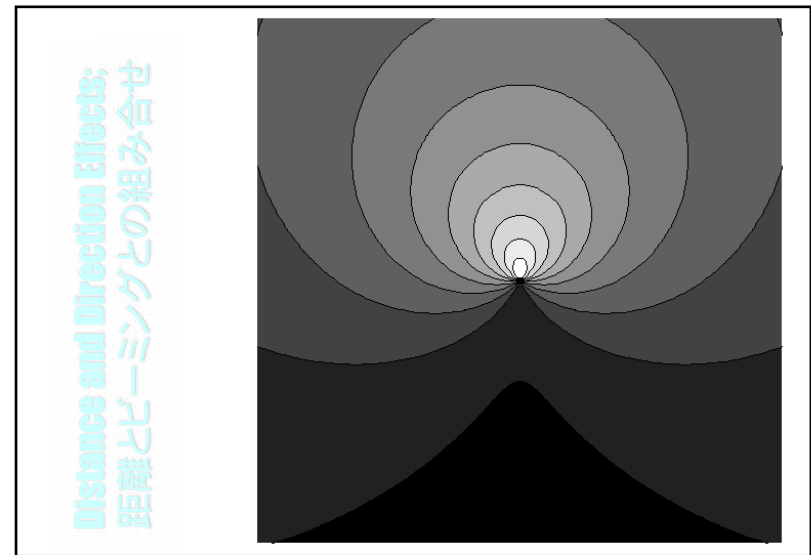
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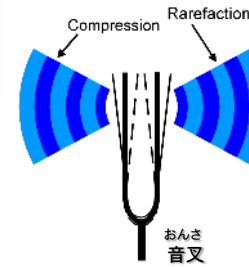
Cappuccino cardioid



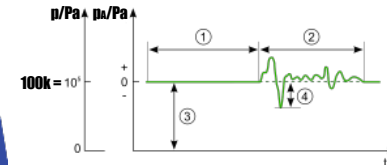
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Sound Propagation

- Air particles move over a very small distance
 - ◆ $7.68 \cdot 10^{-8}$ m
 - ◆ $\approx 1/300$ diameter of a hydrogen molecule
- Alternate regions of compression ("push": increased density) and rarefaction ("pull": decreased density, increased vacuuum)
- That disturbance is propagated through the medium.



Charles E. Spinks, Intro. to Sound (3rd Ed.), Fig. 1-4, p. 13.

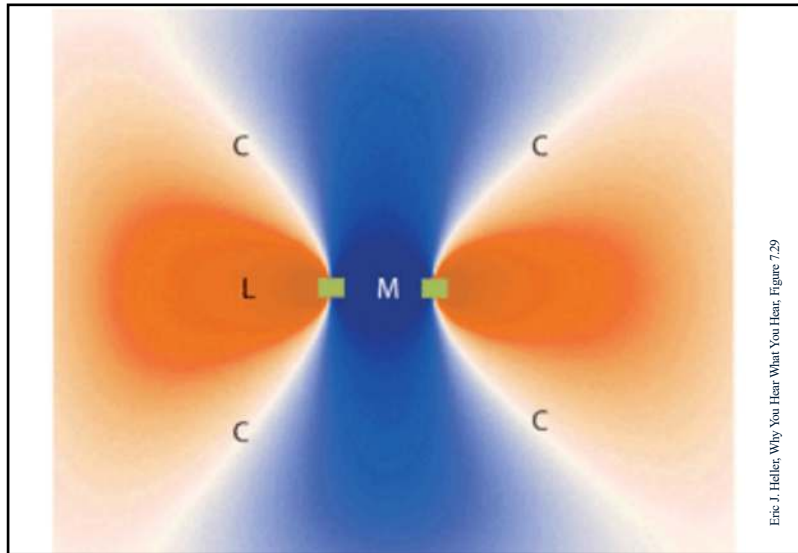


1. Silence
2. Audible sound
3. Atmospheric pressure
4. Sound pressure



https://en.wikipedia.org/wiki/Sound_pressure

304

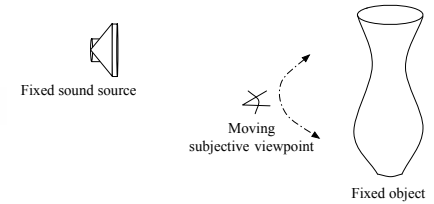


Eric J. Heller, Why You Hear What You Hear, Figure 7.29

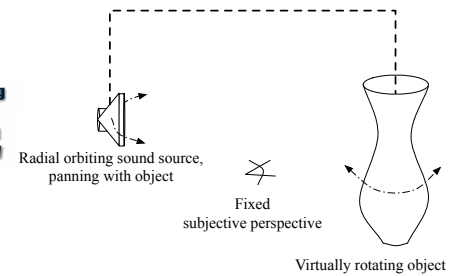
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Rotation as revolution

Egocentric "spin-around" gesture featuring orbit around object of regard and subjectively panning audio



Exocentric rotation expressed as revolution: spatial sound source following egocentric rotating object, as if carried by long strut projecting from object of regard to periphery



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Position						
Static (Posture, Pose)			Dynamic (Gesture): 動作 Spatial Degrees-of-Freedom			
Location (displacement)		Scalar	Translation: 移動 Camera Motion	Directionality (Force)	Along axis	Perpendicular to plane
lateral, horizontal (transverse breadth or width)		abscissa x	sway; 左右 track ("crab")	left ↔ right <side-to-side>	x	median (sagittal)
frontal, longitudinal (depth)		ordinate y	surge; 前後 dolly	out, back (aft): retreat (drag) ↔ <forwards & backwards> in, forth (fore): advance (thrust)	y	frontal (coronal)
vertical (height)		altitude z	heave; 上下 boom ("crane")	up: ascend (lift) ↓ down: descend (weight)	z	horizontal (transverse)
Orientation, Direction, Attitude			Rotation: 回転		About axis	In plane
elevation, inclination		ϕ (Φ)	nitch (tumble, flip); 縦方向 tilt	climb/dive	x	median (sagittal)
(barrel roll)		ψ	roll (tilt, bank, flop); 横方向 (roll)	left/right	y	frontal (coronal)
azimuth		θ	yaw (whirl, twist); 偏方向 pan	CCW/CW	z	horizontal (transverse)
Location and Orientation			Revolution: 回転 & Rotation: 回転			
focal pivot "inspection posture"		x, y, θ	orbit with phase-locked altitude: "spin-around"	CCW/CW	z	horizontal (transverse)

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Ubicomp (ubiquitous computing) ユビキタスコンピューティング

- ✦ Instead of VR which puts users inside of computer-generated world, ubicomp forces the computer out into the world with people.
- ✦ XR: Extended (Augmented, Enhanced, Hybrid, Mediated, Mixed) Reality/Virtuality (AR, MR, VR)
- ✦ Calm computing; 静かな
- ✦ Pervasive computing
- ✦ Ambient control/display: networked physical objects
- ✦ Saturated
 - distributed & pervasive
 - continuous & networked
 - transparent or invisible ("disappearing computer"); 透明
- ✦ IoT; モノのインターネット

802

Fixed-mobile Convergence (FMC) & Mobile-ambient interfaces

- ✦ Personal (individual): mobile telephony, smartphones, PSAPs (personal sound amplification devices), hearables, hearing aids, nearphones
- ✦ Social: smart speakers, robots, roomware
- ✦ Public: IoT, ubicomp, location-based resources

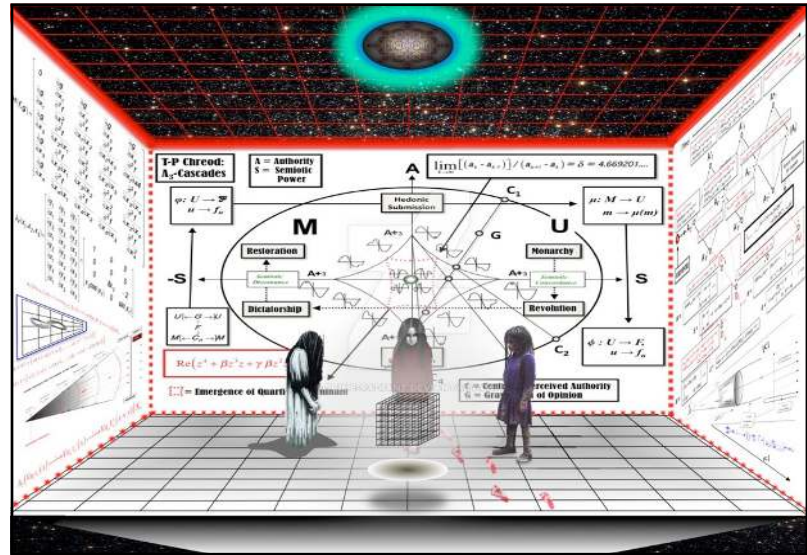
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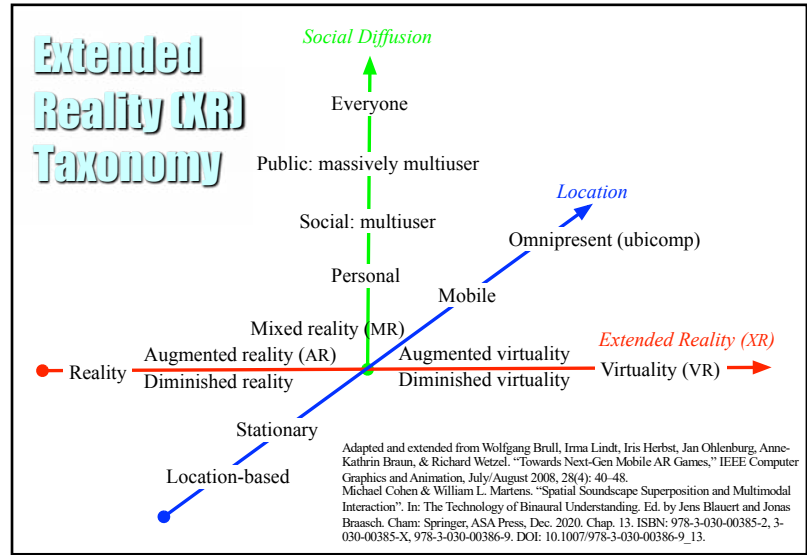
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797



798



757

Microsoft HoloLens 2



www.microsoft.com/ja-jp/hololens

772

Meta Quest 3



<https://www.meta.com/jp/en/quest/quest-3/>

771

Magic Leap 2



<https://www.magicleap.com/device>

773

Apple Vision Pro




<https://www.apple.com/apple-vision-pro>





774



2486

Smart speakers



-  **Amazon Alexa**
-  **Apple Siri**
-  **Google Assistant**
-  **Microsoft Cortana**

2485

Mobile-ambient interfaces

	Mobile	Ambient
Intimacy	Personal	Public
Vector	Input	Output
Role	Source	Sink
Mode	Control, Display	Display, Control
Granularity	Individual	Group
Rank	Primary	Secondary
Spatial Information	Information as space	Space as information

438

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Public	1000s	stadium, concert arena	public address, sound reinforcement	(ex.: Jumbotron), multiple screens (to reach distant viewers)

437

Mt. Bandai; 磐梯山 &
Lake Inawashiro; 猪苗代湖



180

Mixer "S & M"



1345

Musical joke

- "Can you play solo?"
ソロはできますか?
- "How do you mean?"
そういう意味ですか?
- "So low we can't hear you!"
小さくて聞き取れません!

1346



1350

Predicate Calculus Notation for Include/Exclude
 Narrowing and Selection Functions

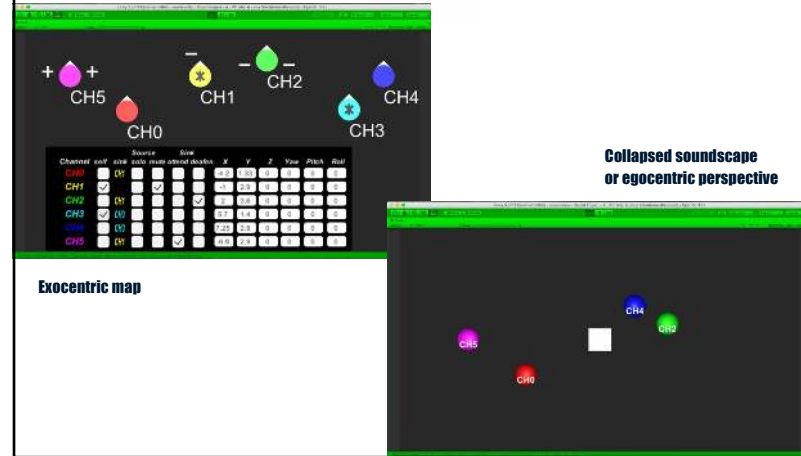
$$\text{active}(x) = \neg \text{exclude}(x) \wedge ((\exists y (\text{include}(y) \wedge (\text{self}(x) \Leftrightarrow \text{self}(y)))) \Rightarrow \text{include}(x))$$

$$\text{active}(\text{source}_x) = \neg \text{mute}(x) \wedge ((\exists y (\text{select}(y) \wedge (\text{self}(x) \Leftrightarrow \text{self}(y)))) \Rightarrow \text{select}(x))$$

$$\text{active}(\text{sink}_x) = \neg \text{deafen}(x) \wedge ((\exists y (\text{attend}(y) \wedge (\text{self}(x) \Leftrightarrow \text{self}(y)))) \Rightarrow \text{attend}(x))$$

1430

Unity Mixels Interface



1445

Visual Representation of Audio Exclude Functions; 声Exclude機能の視覚表現

		Source mute	Sink deafen
icon			
Figurative representation	own; 自身 (reflexive)		
	others; 他人 (transitive)		

1576

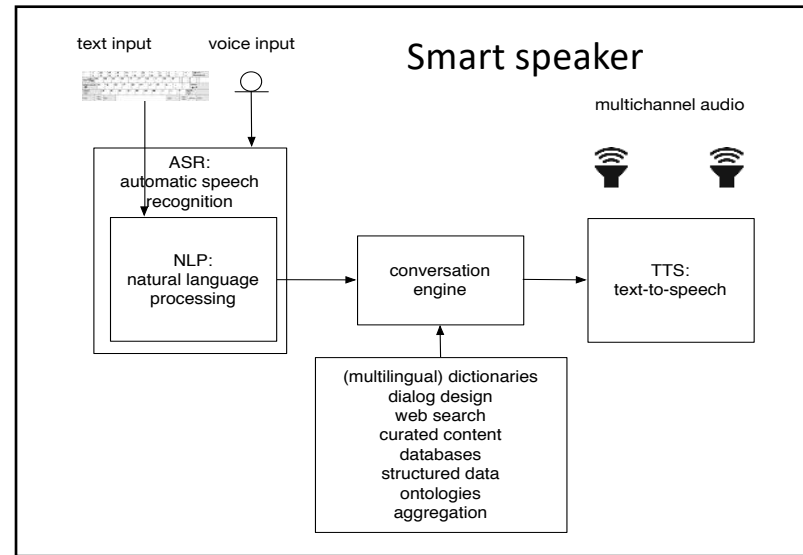
Visual Representation of Audio Include Functions; 音声Include機能の視覚表現

		Source select	Sink attend
icon			
Figurative representation	target (explicit)		
	others (implicit)		

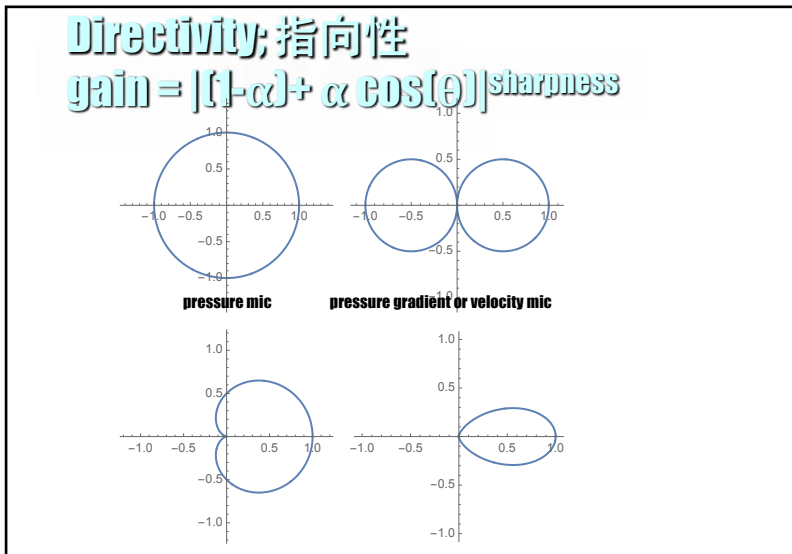
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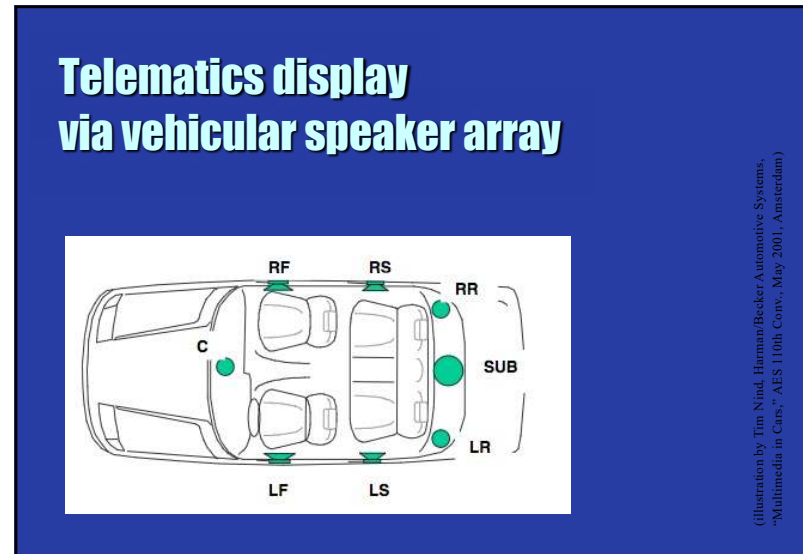
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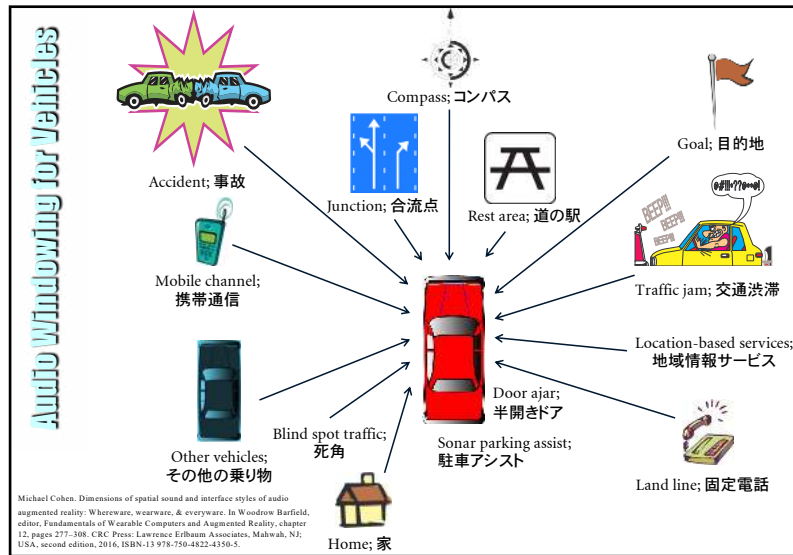
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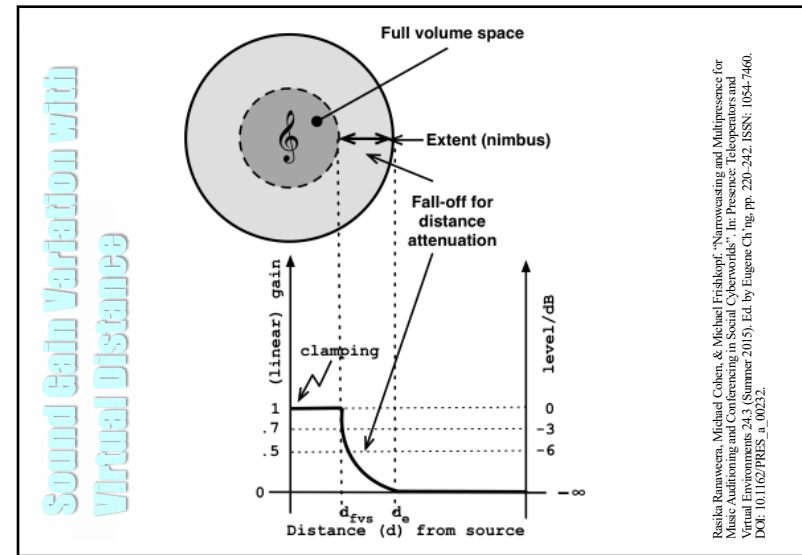
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Idiomatic Auralization: figurative or metaphorical mappings

- Separation of visual and auditory perspectives
 - Egocentric by not endocentric
 - Hyperacuity: HRTFs captured at fixed interaural baseline, but virtual environment can scale not subject but object
- Extreme compression or range-indifference
 - Google Cardboard, Oculus (Meta) Quest
- Rotation as revolution
 - Tuning fork
- Audio windowing, narrowcasting & multipresence (source & sink)

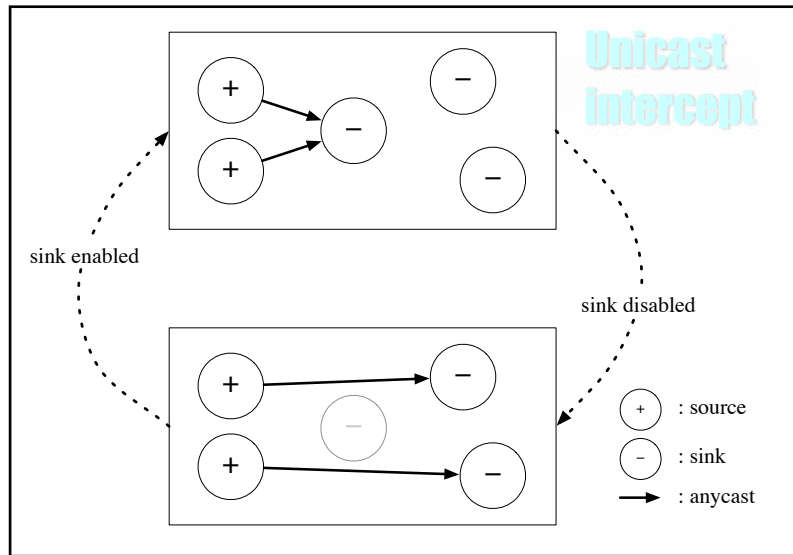
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Head motion ("cocking")

Euler Rotation	Plane	Disambiguating	Typical Designation	Rotation	Interpretation
yaw	median	Left-right	rotate	turn, shake	denial, contradiction: "no"
pitch	horizontal	Front-back	tip	nod	affirmation, concurrence: "yes"
roll	frontal	Above-below	pivot	roll, rock, bobble, tilt, wag, waggle	uncertainty, question: "maybe"

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674



1601

Nuanced multimedia narrowcasting; ナローキャスティング

	Source; 音源, ♂		Sink; 受聴者, ♀	
	Auditory	Visual	Auditory	Visual
	Selective audibility	Selective exposure 🧐	Selective audition	Selective vision
Disable	Mute (Solo)	Hide, invisibility	Deafen (Confide, Harken)	Blind (blindfold)
Enable	Solo/select ("talking stick")	Isolate, hide others	Attend	
Partial disable	Muzzle (stifle)	Fade, opacity, transparency	Muffle	Blinkers, blinders, tinted eyewear
Partial enable	Attenuate others	Fade others (spotlight)		

1581

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<https://play.google.com/store/apps/details?id=jp.ac.u.aizu.twirleds>
<https://apps.apple.com/app/twirleds/id962674836>

<https://u-aizu.ac.jp/~mcohen/spatial-media/Twirleds/>

1648