SUBJECT INDEX

2D flow visualization	constraints on navigation	correspondence problem,
techniques, 201,	metaphors and, 327	218–219
203–205	defined, 18	for diagram enrichment,
2D positioning and selection,	design using, 20	224–225
319–320	physical vs. graphical,	moving frames, 221
2-handed interaction, 321-322	19–20, 323–324	perception of animate
2-1/2D sketch processing, 22	surfaces and, 31	motion, 223-224
3D displays. See stereoscopic	visual representation of,	visual momentum in,
displays; task-based	18–19	311–312
space perception;	aliasing	wagon-wheel effect, 219
virtual-reality (VR)	antialiasing techniques,	antialiasing techniques
displays	64–65	overview, 64-65
1976 uniform chromaticity	Nyquist limit and, 63-64	temporal, 67
scale (UCS) diagram	temporal, 67	vernier acuity and, 65-66
(CIE), 109, 110	useful effects, 65	arbitrary representations
	ambient optical array	characteristics, 15-17
	computer graphics and,	defined, 10
"action system" of pattern	31–32	hybrids with sensory
perception, 22	defined, 31, 32	representations, 13
acuities. See visual acuities	dynamic flow patterns,	methodologies for
adaptation, lightness constancy	32–33	studying, 15, 16
and, 85	ambient shading, 36, 245-	Saussure's arbitrariness
advection trajectories, 204	246	principle, 6
aesthetic impression of 3D	amodal control memory, 353	sensory representations vs.,
space (presence),	analytic processing, separable	10, 27
293–294	dimensions and, 177	artifacts (cultural), 1-2, 17
affordance theory	angular disparity for	artifacts (graphical)
direct perception of	stereoscopic depth,	aliasing, 63-65
affordances, 18	271–272	visualization and
interface design and,	animated visual languages,	perception of, 3
18–20	312–315	artificial spatial cues, 279-280
top-down approach of,	animation. See also motion	atmospheric depth, 280
18	animated images vs.	attention
affordances	words, 305–306	as both low-level and high-
computer monitor	animated visual languages,	level property of
deficiencies, 68	312–315	vision, 146

as control for visual	beam-splitters, 43, 44	range of light levels and
working memory,	beat (hand gesture), 311	lightness constancy,
353	behaviorism, 401-402	85
eye movements and, 359	binocular depth cues. See also	shading information and,
fovea-center attentional	specific cues	37
field, 146	defined, 260	specialized regions and
inattentional blindness,	eye convergence, 270	neural pathways,
359	stereoscopic depth,	11–12
motion and attraction of,	271–279	tabula rasa view of,
360–362	binocular viewing, visual	10–11
as motor for cognition,	acuities and, 48	tuned receptive fields in,
352	bistable regions of transparency,	159–160
push and pull cues, 359	205, 207	visual field and processing
Resink's model, 362–363	bivariate color sequences,	power, 51
searchlight model of, 364	135–138	brain pixels
selectivity of, 359–360	bivariate maps, 254–255	defined, 52–53
supervisory control systems	black, specular vs. nonspecular	optimal screen and, 53–57
and, 364–365	reflection and, 88, 89	total number (TPB) for
time to change, 353	black-white channel. See	computer display, 54
visual monitoring	luminance channel	uniquely stimulated (USBP)
strategies, 365–366	blindness. See also color	by computer display,
visual working memory	blindness	54–55
and, 353, 359–362	to change, 357	visual efficiency (VE)
attentional blink, 228	inattentional, 359	equation, 55
attributes of entities or	stereo, 271	brightness. See also lightness;
relationships. See also	blink, attentional, 228	luminance;
entity-relationship	blink coding, 183	simultaneous
model	brain. See also neurons	brightness contrast
defined, 24, 212	architecture of primary	Cornsweet effect, 77
dimensions of, 25	visual areas, 159–	defined, 80, 83
levels of measurement,	160	edge enhancement, 77–79
24–25	as evolved for this physical	luminance vs., 80, 84
augmented-reality systems	world, 10, 11–12	Mach band effect, 74, 77,
applications, 43	Gabor function and	94
beam-splitters for, 43,	receptive field	magnitude estimation,
44	properties, 161–162	83–84
defined, 42	illusions and hard-wired	
optics and, 42–45	musions and nard-wired	monitor gamma, 84, 92
	processing in 14	as monotonic viewal
norcontual problems in	processing in, 14	as monotonic visual
perceptual problems in	organization of object	attribute, 181
HMDs, 43–44	organization of object information by,	attribute, 181 overview, 83–84
HMDs, 43–44 perceptual problems in	organization of object information by, 255–257	attribute, 181 overview, 83–84 power law, 83–84
HMDs, 43–44 perceptual problems in HUDs, 43	organization of object information by, 255–257 parallel processing by	attribute, 181 overview, 83–84 power law, 83–84 simultaneous brightness
HMDs, 43–44 perceptual problems in	organization of object information by, 255–257	attribute, 181 overview, 83–84 power law, 83–84

surface-shading methods and DOG model, 75–77	child studies, 401–402 choice reaction time, 318–319 chromatic aberration, 45–46,	CIElab uniform color space, 108, 132 CIEluv uniform color
Weber's law, 88-89	47	space, 89-90,
brown, 118	chromatic contrast, 117,	108–110, 132
brushing technique, 348, 376	124–125	color differences and
	chromatic spatial sensitivity, 62	uniform color spaces,
	chromaticity coordinates (CIE)	108–110
CAE FOHMD, 57, 58	chromaticity diagram	color measurement system
camera analogy for the eye,	properties, 105–107	overview, 389–391
38–40	complementary wavelength	color volume, 103, 104
canonical view	of a color, 107	converting between
image-based object	of equal-energy white, 106	tristimulus values and
recognition and, 230	excitation purity, 106–107	chromaticity
for silhouettes, 235, 236	generating colors defined	coordinates, 105
cast shadows	by CIE tristimulus	human spectral sensitivity
defined, 245	values, 107-108	function standard,
as depth cues, 266-268	overview, 104–105	81–82
guidelines for displaying	purple boundary, 105	illuminants, 106
surfaces, 252	spectrum locus, 105	luminance as Y tristimulus
layered data and, 268	standard illuminants, 106	value, 103
motion and, 268-269	transforming tristimulus	monitor gamut, 103
overview, 36	values to and from,	overview, 103-104
for scalar field	105	standard observer for, 103
representation,	for two sets of monitor	tristimulus values,
245–246	phosphors, 107	103–104, 389–391
categorical colors, 113	chromostereopsis, 46, 47	uniform gray-scale
categorical knowledge for	chunking	standard, 89-90
wayfinding, 331	in long-term memory, 367,	CIElab uniform color space,
category data, 25	368–369	108, 132
cathode ray tube displays. See	of subtasks, 322	CIEluv uniform color space
computer monitors	CIE standards. See also	applications, 108
causality, motion and	chromaticity	CIE 1976 uniform
perception of,	coordinates (CIE)	chromaticity scale
222–223	abstract primary lamps	(UCS) diagram, 109,
Cave Automatic Virtual	and, 103	110
Environment (CAVE),	chromaticity coordinates,	color sequences from, 132
55, 56	104–108	equations, 108–109
central executive in visual	chromaticity diagram	limitations, 109, 111
working memory, 353	properties, 105-107	uniform gray-scale
change blindness, 357	CIE 1976 uniform	standard, 89–90
change of basis, 387-388	chromaticity scale	classification tasks
Chernoff faces, 239-240	(UCS) diagram, 109,	restricted, glyphs for,
Chevreul illusion, 74, 77	110	177–178

closure (Gestalt law) figure and ground perception and, 196, 198	speeded, glyphs for,	Application 1: color	negative light and,
figure and ground perception and, 196, 198 overview, 194–196, 197 cluster analysis, 401 coding words and images dual coding theory, 297–299, 306 imagens and logogens, 297–298 images vs. words, 303–306 links between images and words, 306–311 nature of language, 299–301 text labels for images, 307–309 visual languages, 301–303 cognition. See also thinking with visualizations attention as motor for, 352 cognitive components of visual thinking, 370–371 frames of reference, 333–337 memory as framework for, 352 as process in systems, 1–2 spatial map for wayfinding, 330, 331, 332–333 visual thinking, 298–299 cognitive secience, 1 cognitive see also CIE standards; 332–333 color. See also CIE standards; 342–144 measurement, 100–103 110–116 preattentive processing of, 152, 124, 155 proximity luminance covariance, 279–280 relative unimportance of color vision, 97 saturation, 117–118 satransparency ecotors vs. lights, 104 three-stage model of there-stage model of there-stage model of satration and, 21, 1287, 188 transparency perception and, 205 trichromacy, 1287–280 relative unimportance of color vision, 97 saturation, 117–118 satration, 117–118 surface colors vs. lights, 104 three-stage model of there-stage model of secrolors, 113 tolor convexity and, 155 connectedness grouping conjunction of convexity and, 155 connectedness grouping conjunction of convexity and, 155 connectedness grouping conjunction of color vision, 97 saturation, 117–118 startarion, 117–118 there-stage model of three-stage model of secrolors, 113 tolor-on-matching setup, 108–101 tocolor-matching setup, 108–101 tocolor-matching set			101–102
perception and, 196, 198 123–127 152, 154, 155 proximity luminance covariance, 279–280 relative unimportance of the treative unimportance of covariance, 279–280 relative unimportance of covariance, 279–280 relative unimportance of the treative unimportance of covariance, 279–280 relative unimportance of covariance, 279–280 relative un		and color spaces,	opponent process theory,
198 overview, 194–196, 197 Application 3: data maps, cluster analysis, 401 127–138 Application 4: color relative unimportance of color vision, 97 297–299, 306 138–140 saturation, 117–118 surface colors vision, 97 297–298 data analysis, 297–298 data analysis, and words, 306–311 primary characteristic, anture of language, 299–301 categorical colors, 113 categorical colors, 113 conjunction of convexity and, 155 connectedness grouping with visualizations attention as motor for, 352 cognitive components of visual thinking, 370–371 correspondence problem and, 219 critical function of color vision, 97 saturation, 117–118 surface colors vs. lights, attraction, 117, 118 surface colors vs. lights, attraction, 117–118 surface color vision, 97–89 connectedness grouping primary characteristic, and three-stage model of perception and, 210 surface colors vs. lights, attraction, 117–118 surface colors vs. lights, attraction, 117–118 surface colors vs. lights, attraction, 117–118 surface color vision, 97–98 connectedness grouping primary characteristic, and, 155 color channels sea attraction and, 125 color bindness attention of color vision, 97–98 color, 191, 192 color bindness attention of color vision, 97–98 color, 191, 192 color sequen	* *		
cluster analysis, 401 coding words and images dual coding theory, 297–299, 306 imagens and logogens, 297–298 images vs. words, 303–306 links between images and words, 306–311 nature of language, 299–301 text labels for images, 307–309 visual languages, 301–303 cognition. See also thinking with visualizations attention as motor for, 352 cognitive components of visual thinking, 370–371 memory as framework for, 352 as process in systems, 1–2 spatial map for wayfinding, 330, 331, 332–333 visual thinking, 298–299 cognitive science, 1 conding words and images Application 3: data maps, 127–138 color see also CIE standards; Application 3: data maps, 127–138 color see also CIE standards; Application 4: color relative unimportance of relative unimportance	perception and, 196,	Application 2: labeling,	
cluster analysis, 401 coding words and images dual coding theory,			
coding words and images dual coding theory, 297–299, 306 138–140 saturation, 117–118 surface color vision, 97 297–298 data analysis, 104 three-stage model of links between images and words, 303–306 links between images and words, 306–311 primary characteristic, nature of language, 299–301 categorical colors, 113 categorical colors, 113 text labels for images, 307–309 visual languages, 301–303 cognition. See also thinking with visualizations attention as motor for, 352 cognitive components of visual thinking, 370–371 correspondence problem and, 219 critical function of color wayfinding, 330, 331, 332–333 visual thinking, 298–299 for cognitive psychology, 397 cognitive psychology, 397 cognitive spatial map for wayfinding, 330, 331, 332–333 visual thinking, 293–339 color. See also CIE standards; measurement, 100–103 hours attention as motor for, 352 connectedness grouping principle vs., 191, 192 color sequences for, 2010 in peripheral vision, 361 color channels. See also specific channels of equation describing, 100, 332–333 visual thinking, 298–299 for enhancement, 196 cognitive psychology, 397 cognitive science, 1 cognitive psychology, 397 cognitive spatial map for wayfinding, 330, 331, 332–333 rol color. See also CIE standards; measurement, 100–103 hours attraction of gamut and, 138 color rocressing, 116 color reproduction gamut and, 138 heuristic principles for, 138		Application 3: data maps,	
dual coding theory, 297–299, 306 138–140 saturation, 177–118 surface colors vision, 97 saturation, 117–118 surface colors vs. lights, data analysis, 104 three-stage model of perception and, 21, perception and, 21, 187, 188 transparency perception and, 205 trichromacy theory, 207–309 color-matching setup, visual languages, 301–303 cognition. See also thinking with visualizations attention as motor for, 352 cognitive components of visual thinking, 370–371 correspondence problem frames of reference, 333–337 critical function of color vision, 97–98 crognitive science, 1 cognitive special map for wayfinding, 330, 331, 32–333 visual thinking, 298–299 cognitive science, 1 color. See also CIE standards; measurement, 100–103 color reproduction of color vision, 97–98 color packets, 123 color principles for, 138 color. See also CIE standards; measurement, 100–103 surface color vision, 97 saturation, 117–118 saturation, 110 saturation and, 118 color channels of color vision, 97–98 color sequences for, 120 co			· · · · · · · · · · · · · · · · · · ·
297–299, 306 imagens and logogens, 297–298 data analysis, 104 images vs. words, 303–306 links between images and words, 306–311 nature of language, 299–301 text labels for images, 307–309 visual languages, 301–303 cognition. See also thinking with visualizations attention as motor for, 352 cognitive components of visual thinking, 370–371 frames of reference, 333–337 memory as framework for, 352 as process in systems, 1–2 spatial map for wayfinding, 330, 331, 332–333 visual thinking, 298–299 cognitive science, 1 cognitive spetchology, 397 cognitive spatial map for wayfinding, 330, 331, 332–333 color. See also CIE standards; Application 5: exploratory data analysis, 104 three-stage model of perception and, 21, 187, 188 transparency perception and, 205 trichromacy theory, 187, 198 transparency perception and, 205 trichromacy theory, 187, 188 transparency perception and, 205 trichromacy theory, 20lor blindness author's experience, 97 color labels and, 125 color color convexive, 99–100 in peripheral vision, 361 color channels. See also specific described, 110 illustrated, 111 information display and, 116 properties, 113–116 sattribute rather than primary characteristic, 187, 188 transparency perception and, 205 trichromacy theory, 20lor blindness author's experience, 97 color labels and, 125 color color color experience, 97 color labels and, 125 color labels and, 125 color color color color perception and, 214 three-stage model of three-stage model of perception and, 205 trichromacy t		Application 4: color	
imagens and logogens, 297–298 data analysis, 104 three-stage model of links between images and words, 303–306 links between images and words, 306–311 primary characteristic, 187, 188 transparency perception and, 21, 187, 188 transparency perception and, 205 trichomacy theory, 209–301 categorical colors, 113 categorical colors, 113 categorical colors, 113 categorical colors, 113 color-matching setup, visual languages, 301–303 cognition. See also thinking with visualizations attention as motor for, 352 cognitive components of visual thinking, 370–371 correspondence problem and, 219 color labels and, 125 color labels and, 125 color sequences for, 232 contrast, 117 correspondence problem and, 219 in peripheral vision, 361 color channels. See also specific wayfinding, 330, 331, 332–333 visual thinking, 298–299 for color diagram enhancement, 196 cognitive science, 1 cognitive spatial map for wayfinding, 330, 331, 332–333 row wayfinding, 330, 331, 330		reproduction,	color vision, 97
images vs. words, 303–306 links between images and words, 306–311 nature of language, 299–301 text labels for images, visual languages, 301–303 cognition. See also thinking with visualizations attention as motor for, 352 cognitive components of visual thinking, 370–371 frames of reference, 332–337 memory as framework for, 352 as process in systems, 1–2 spatial map for wayfinding, 330, 331, 332–333 rognitive specience, 1 cognitive spatial map for wayfinding, 330, 331, 332–333 color. See also CIE standards; data analysis, 140–143 three-stage model of transparency perception and, 205 trichromacy theory, 98–99 unique hues, 112 color blindness author's experience, 97 color labels and, 125 color sequences for, 134–135, 136 overview, 99–100 in peripheral vision, 361 color channels. See also specific color channels. See also specific color channels of col	297–299, 306	138–140	saturation, 117–118
images vs. words, 303–306 links between images and words, 306–311 nature of language, 299–301 text labels for images, 307–309 visual languages, 301–303 cognition. See also thinking with visualizations attention as motor for, 352 cognitive components of visual thinking, 370–371 frames of reference, 333–337 memory as framework for, 352 as process in systems, 1–2 spatial map for wayfinding, 330, 331, 332–333 visual thinking, 298–299 cognitive spechology, 397 cognitive spechology, 397 cognitive spechology, 397 cognitive spatial map for wayfinding, 330, 331, 332–333 color. See also CIE standards; 140–143 as attribute rather than perception and, 21, 71, 71, 71, 71, 71, 71, 71, 71, 71, 7	imagens and logogens,	Application 5: exploratory	surface colors vs. lights,
links between images and words, 306–311 primary characteristic, nature of language, 299–301 categorical colors, 113 categorical colors, 113 and, 205 trichomacy theory, color-matching setup, visual languages, 301–303 cognition. See also thinking with visualizations attention as motor for, 352 connectedness grouping visual thinking, 370–371 correspondence problem and, 219 correspondence problem and, 219 correspondence problem and, 210 trichomacy theory, 28–99 unique hues, 112 color blindness author's experience, 97 color labels and, 125 color sequences for, 233–333 visual thinking, 298–299 to Euler diagram enhancement, 196 cognitive spatial map for wayfinding, 330, 331, 332–333 color. See also CIE standards; measurement, 100–103 sa attribute rather than primary characteristic, 187, 188 transparency perception and, 215, 187, 188 transparency perception and, 205 trichomacy theory, 298–99 unique hues, 112 color blindness author's experience, 97 color labels and, 125 color sequences for, 298–99 unique hues, 112 color blindness author's experience, 97 color labels and, 125 color sequences for, 298–99 in principle vs., 191, 192 color channels. See also specific vision, 97–98 channels described, 110 illustrated, 111 information display and, 216 properties, 113–116 saturation and, 118 color constancy, 80 color palettes, 123 color properties, 113–116 saturation and, 118 color reproduction 332–333 color processing, 116 color creproduction 232–333 color processing, 116 color creproduction 232–333 color processing, 116 color creproduction 232–333 end 143–144 measurement, 100–103 herein and, 215 color properties of trichromacy theory, 205 trichomacy theory, 205 color blindness author's experience, 97 color blindness	297–298	data analysis,	104
mords, 306–311 nature of language, 299–301 categorical colors, 113 categorical colors, 113 categorical colors, 113 color. See also Other sequences for, 100–101 as process in systems, 1–2 spatial map for wayfinding, 330, 331, and 233 cognitive science, 1 color. See also CIE standards; nature of language, 98, 116 categorical colors, 113 coolor convexity and, 155 connectedness grouping color color sexperience, 97 color labels and, 125 color blindness author's experience, 97 color labels and, 125 color seperience, 97 color labels and, 125 color seperience, 97 color labels and, 125 color sequences for, 134–135, 136 overview, 99–100 in peripheral vision, 361 color cohannels. See also specific color channels. See also specific color channels. See also specific color cohannels color cohannels color channels color ch		140–143	three-stage model of
nature of language, 299–301 categorical colors, 113 and, 205 trichromacy theory, 307–309 color-matching setup, visual languages, 301–303 100–101 unique hues, 112 color blindness author's experience, 97 color labels and, 125 cognitive components of visual thinking, 370–371 correspondence problem frames of reference, 352 cross-cultural consistency, as process in systems, 1–2 spatial map for wayfinding, 330, 331, visual thinking, 298–299 cognitive psychology, 397 cognitive science, 1 cognitive spatial map for wayfinding, 330, 331, wayfinding, 330, 331, as color. See also CIE standards; measurement, 100–103 trichromacy transparency perception and, 205 trichromacy transparency perception and, 205 trichromacy transparency perception and, 205 trichromacy theory, and, 205 trichromacy theory, 205	links between images and	as attribute rather than	perception and, 21,
text labels for images, 307–309 color-matching setup, visual languages, 301–303 100–101 unique hues, 112 color blindness with visualizations attention as motor for, 352 connectedness grouping cognitive components of visual thinking, 370–371 correspondence problem amemory as framework for, 352 cross-cultural consistency, as process in systems, 1–2 spatial map for wayfinding, 330, 331, visual thinking, 298–299 for Euler diagram cognitive specific spatial map for wayfinding, 330, 331, cognitive specific spatial map for wayfinding, 330, 331, cognitive spatial map for wayfinding, 330, 331, as color. See also CIE standards; categorical colors, 113 and, 205 trichromacy theory, 298–99 trichestandards, 103–110 unique hues, 112 color blindness author's experience, 97 color blindness author's experience, 97 color labels and, 125 color sequences for, 134–135, 136 overview, 99–100 in peripheral vision, 361 color channels. See also specific described, 110 illustrated, 111 information display and, 116 properties, 113–116 saturation and, 118 color constancy, 80 color constancy, 80 color palettes, 123 color processing, 116 color principles for, 138 color. See also CIE standards; measurement, 100–103 heuristic principles for, 138	words, 306–311	primary characteristic,	187, 188
text labels for images, 307–309 color-matching setup, 98–99 visual languages, 301–303 100–101 unique hues, 112 color blindness with visualizations attention as motor for, 352 connectedness grouping color sequences for, visual thinking, 370–371 correspondence problem frames of reference, and, 219 in peripheral vision, 361 as process in systems, 1–2 as process in systems, 1–2 spatial map for wayfinding, 330, 331, visual thinking, 298–299 for Euler diagram cognitive psychology, 397 cognitive science, 1 cognitive spatial map for wayfinding, 330, 331, accolor. See also CIE standards; CIE standards, 103–110 trichromacy theory, 98–99 unique hues, 112 color blindness author's experience, 97 color blindness author's experience, 97 color blindness author's experience, 97 color sequences for, 125 color respondence problem overview, 99–100 in peripheral vision, 361 color channels. See also specific color channels. See also specific described, 110 illustrated, 111 information display and, 116 properties, 113–116 properties, 113–116 color constancy, 80 color constancy, 80 color constancy, 80 color constancy, 80 color processing, 116 color processing, 116 color reproduction gamut and, 138 heuristic principles for, 138 color. See also CIE standards; measurement, 100–103 heuristic principles for, 138	nature of language,	98, 116	transparency perception
visual languages, 301–303 cognition. See also thinking with visualizations attention as motor for, 352 cognitive components of visual thinking, 370–371 frames of reference, memory as framework for, as process in systems, 1–2 spatial map for wayfinding, 330, 331, visual thinking, 298–299 cognitive scopictive synthinking, 298–299 cognitive synthinking, 298–299 cognitive spatial map for wayfinding, 330, 331, againgt a gamut, 101 cognitive spatial map for wayfinding, 330, 331, wayfinding, 330, 331, againgt and, 183 color. See also CIE standards; conjunction of convexity and, 155 author's experience, 97 color blindness author's experience, 97 color paleties, 123 color color paleties, 123 color processing, 116 color reproduction gamut and, 138 heuristic principles for, 138	299-301	categorical colors, 113	
visual languages, 301–303 cognition. See also thinking with visualizations attention as motor for, 352 cognitive components of visual thinking, 370–371 frames of reference, memory as framework for, as process in systems, 1–2 spatial map for wayfinding, 330, 331, visual thinking, 298–299 cognitive systems, 1–2 sognitive psychology, 397 cognitive systial map for wayfinding, 330, 331, 332–333 color. See also thinking conjunction of convexity and, 155 connectedness grouping contrast, 117 134–135, 136 overview, 99–100 in peripheral vision, 361 color channels. See also specific color channels. color channels described, 110 illustrated, 111 information display and, 116 properties, 113–116 saturation and, 118 color constancy, 80 color palettes, 123 color processing, 116 color processing, 120 color processing, 12	text labels for images,	CIE standards, 103-110	trichromacy theory,
cognition. See also thinking with visualizations attention as motor for, 352 cognitive components of visual thinking, 370–371 correspondence problem frames of reference, memory as framework for, 352 as process in systems, 1–2 spatial map for wayfinding, 330, 331, visual thinking, 298–299 cognitive someone, and cognitive psychology, 397 cognitive someone, and glyph design and, 183 color. See also thinking and, 155 connectedness grouping coninction of convexity and, 155 connectedness grouping color labels and, 125 color sequences for, 134–135, 136 overview, 99–100 in peripheral vision, 361 color channels. See also specific color channels. See also specific described, 110 illustrated, 111 information display and, equation describing, 100, 116 properties, 113–116 saturation and, 118 color color constancy, 80 color processing, 116 color processing, 116 color reproduction gamut and, 138 heuristic principles for, 138	307–309	color-matching setup,	. 98–99
with visualizations and, 155 author's experience, 97 attention as motor for, 352 connectedness grouping color labels and, 125 cognitive components of visual thinking, 2012 correspondence problem frames of reference, and, 219 in peripheral vision, 361 color channels. See also specific memory as framework for, 352 cross-cultural consistency, as process in systems, 1–2 spatial map for cultural meanings for, 16 wayfinding, 330, 331, visual thinking, 298–299 for Euler diagram conjitive special map for wayfinding, 330, 331, and thinking, 330, 331, and thinking, 298–299 cognitive special map for wayfinding, 330, 331, and thinking, 330, 331, and thinking	visual languages, 301-303	100–101	unique hues, 112
attention as motor for, 352 cognitive components of visual thinking, 370–371 correspondence problem frames of reference, and, 219 as process in systems, 1–2 spatial map for wayfinding, 330, 331, visual thinking, 298–299 cognitive spatial map for wayfinding, 330, 331, cognitive spatial map for wayfinding, 330, 331, wayfinding, 330, 331, cognitive spatial map for wayfinding, 330, 331, and thinking and thinking and thinking and the spatial map for wayfinding, 330, 331, cognitive spatial map for wayfinding, 330, 331, and thinking and the spatial map for the spatial map fo	cognition. See also thinking		color blindness
cognitive components of visual thinking, contrast, 117 correspondence problem frames of reference, and, 219 in peripheral vision, 361 color channels. See also specific memory as framework for, 352 cross-cultural consistency, as process in systems, 1–2 spatial map for cultural meanings for, 16 wayfinding, 330, 331, cognitive psychology, 397 cognitive spatial map for wayfinding, 330, 331, acgonitive spatial map for glyph design and, 183 color. See also CIE standards; measurement, 100–103 color reproduction gamut and, 138 color. See also CIE standards; measurement, 100–103 color sequences for, 134–134 color sequences for, 135 color sequences for, 135 color sequences for, 136 color sequences for, 136 color sequences for, 136 color sequences for, 134–134 color sequences for, 135 color sequences for, 136 color sequences for, 136 color sequences for, 136 color sequences for, 136 color sequences for, 134–134 color sequences for seque	with visualizations	•	author's experience, 97
visual thinking, 370–371 correspondence problem frames of reference, and, 219 in peripheral vision, 361 color channels. See also specific memory as framework for, 352 cross-cultural consistency, as process in systems, 1–2 112 illustrated, 111 spatial map for cultural meanings for, 16 wayfinding, 330, 331, visual thinking, 298–299 for Euler diagram cognitive psychology, 397 enhancement, 196 cognitive science, 1 gamut, 101 color processing, 116 color constancy, 80 cognitive spatial map for wayfinding, 330, 331, lessons for visualization, 332–333 143–144 gamut and, 138 color. See also CIE standards; measurement, 100–103 heuristic principles for, 138	attention as motor for, 352		color labels and, 125
frames of reference, frames of reference, and, 219 in peripheral vision, 361 color channels. See also specific memory as framework for, as process in systems, 1–2 spatial map for wayfinding, 330, 331, visual thinking, 298–299 cognitive psychology, 397 cognitive science, 1 wayfinding, 330, 331, wayfinding, 330, 331, cognitive spatial map for wayfinding, 330, 331, cognitive spatial map for wayfinding, 330, 331, and the properties, 113–116 gamut, 101 cognitive spatial map for wayfinding, 330, 331, and the properties, 123 cognitive spatial map for wayfinding, 330, 331, and the properties, 123 color constancy, 80 color constancy, 80 color constancy, 80 color palettes, 123 color processing, 116 color reproduction spatial map for wayfinding, 330, 331, and the properties of the prope	cognitive components of	principle vs., 191, 192	
frames of reference, 333–337 critical function of color memory as framework for, 352 as process in systems, 1–2 spatial map for wayfinding, 330, 331, visual thinking, 298–299 cognitive psychology, 397 cognitive spatial map for wayfinding, 330, 331, and 101 cognitive spatial map for wayfinding, 330, 331, and 101 color palettes, 123 color processing, 116 color reproduction yayfinding, 330, 331, alessons for visualization, 332–333 color. See also CIE standards; measurement, 100–103 min peripheral vision, 361 color channels. See also specific color channels color chane	visual thinking,	contrast, 117	
memory as framework for, vision, 97–98 channels. See also specific vision, 97–98 channels 352 cross-cultural consistency, as process in systems, 1–2 112 illustrated, 111 information display and, wayfinding, 330, 331, equation describing, 100, 332–333 101 properties, 113–116 visual thinking, 298–299 for Euler diagram saturation and, 118 cognitive psychology, 397 enhancement, 196 cognitive special map for glyph design and, 183 color palettes, 123 color processing, 116 wayfinding, 330, 331, and glyph design and, 183 color reproduction gamut and, 138 color. See also CIE standards; measurement, 100–103 heuristic principles for, 138		correspondence problem	
memory as framework for, vision, 97–98 channels 352 cross-cultural consistency, described, 110 as process in systems, 1–2 112 illustrated, 111 spatial map for cultural meanings for, 16 information display and, wayfinding, 330, 331, equation describing, 100, 116 332–333 101 properties, 113–116 visual thinking, 298–299 for Euler diagram saturation and, 118 cognitive psychology, 397 enhancement, 196 color constancy, 80 cognitive spatial map for glyph design and, 183 color palettes, 123 cognitive spatial map for glyph design and, 183 color processing, 116 wayfinding, 330, 331, lessons for visualization, 332–333 143–144 gamut and, 138 color. See also CIE standards; measurement, 100–103 heuristic principles for, 138	frames of reference,	,	
352 cross-cultural consistency, as process in systems, 1–2 112 illustrated, 111 information display and, wayfinding, 330, 331, equation describing, 100, 332–333 101 properties, 113–116 yisual thinking, 298–299 for Euler diagram saturation and, 118 cognitive psychology, 397 enhancement, 196 color constancy, 80 cognitive science, 1 gamut, 101 color palettes, 123 cognitive spatial map for wayfinding, 330, 331, lessons for visualization, 332–333 143–144 gamut and, 138 color. See also CIE standards; measurement, 100–103 heuristic principles for, 138			color channels. See also specific
as process in systems, 1–2 spatial map for wayfinding, 330, 331, visual thinking, 298–299 cognitive psychology, 397 cognitive science, 1 wayfinding, 330, 331, spatial map for wayfinding, 398, 397 cognitive spatial map for wayfinding, 330, 331, 332–333 color. See also CIE standards; 112 illustrated, 111 information display and, 116 properties, 113–116 saturation and, 118 color color constancy, 80 color constancy, 80 color palettes, 123 color processing, 116 color reproduction gamut and, 138 heuristic principles for, 138	•		
spatial map for cultural meanings for, 16 information display and, wayfinding, 330, 331, equation describing, 100, 116 332–333 101 properties, 113–116 visual thinking, 298–299 for Euler diagram saturation and, 118 cognitive psychology, 397 enhancement, 196 cognitive science, 1 gamut, 101 color palettes, 123 cognitive spatial map for glyph design and, 183 color spatial map for wayfinding, 330, 331, lessons for visualization, 332–333 143–144 gamut and, 138 color. See also CIE standards; measurement, 100–103 heuristic principles for, 138		cross-cultural consistency,	· · · · · · · · · · · · · · · · · · ·
wayfinding, 330, 331, and an arrange of the sequence of the se			
332–333 101 properties, 113–116 visual thinking, 298–299 for Euler diagram saturation and, 118 cognitive psychology, 397 enhancement, 196 cognitive science, 1 gamut, 101 cognitive spatial map for glyph design and, 183 wayfinding, 330, 331, 332–333 lessons for visualization, 332–333 color. See also CIE standards; measurement, 100–103 properties, 113–116 color constancy, 80 color palettes, 123 color processing, 116 color reproduction gamut and, 138 heuristic principles for, 138	-		
visual thinking, 298–299 for Euler diagram saturation and, 118 cognitive psychology, 397 enhancement, 196 color constancy, 80 cognitive science, 1 gamut, 101 color palettes, 123 cognitive spatial map for glyph design and, 183 color processing, 116 wayfinding, 330, 331, lessons for visualization, 332–333 143–144 gamut and, 138 color. See also CIE standards; measurement, 100–103 heuristic principles for, 138	wayfinding, 330, 331,	equation describing, 100,	
cognitive psychology, 397 enhancement, 196 color constancy, 80 cognitive science, 1 gamut, 101 color palettes, 123 cognitive spatial map for glyph design and, 183 color processing, 116 wayfinding, 330, 331, lessons for visualization, 332–333 143–144 gamut and, 138 color. See also CIE standards; measurement, 100–103 heuristic principles for, 138			
cognitive science, 1 gamut, 101 color palettes, 123 color processing, 116 wayfinding, 330, 331, lessons for visualization, 332–333 143–144 gamut and, 138 color. See also CIE standards; measurement, 100–103 heuristic principles for, 138		for Euler diagram	
cognitive spatial map for glyph design and, 183 color processing, 116 wayfinding, 330, 331, lessons for visualization, 332–333 143–144 gamut and, 138 color. See also CIE standards; measurement, 100–103 heuristic principles for, 138		enhancement, 196	
wayfinding, 330, 331, lessons for visualization, color reproduction gamut and, 138 color. See also CIE standards; measurement, 100–103 heuristic principles for, 138	•	0 ,	
332–333 143–144 gamut and, 138 color. <i>See also</i> CIE standards; measurement, 100–103 heuristic principles for, 138			
color. See also CIE standards; measurement, 100-103 heuristic principles for, 138	wayfinding, 330, 331,	lessons for visualization,	color reproduction
color blindness multivariate surface display relationships vs. absolute			
ė i		- ·	relationships vs. absolute
appearance, 116–118 and, 254 values for, 138	appearance, 116-118	and, 254	values for, 138

smooth color changes and,	combinatorial explosion in user	strengths and deficiencies,
140	studies, 403–404	67–68
three-dimensional	Commission Internationale de	three-dimensional
transformations for	l'Éclairage (CIE). See	transformations for
gamut mapping,	CIE standards	gamut mapping,
138–140	complementary wavelength of a	138–140
color spaces. See also CIE	color, 107	visual angle and, 40
standards; specific	compound lens imaging	visual efficiency (VE)
color spaces	properties, 41	equation, 55
changing primaries,	computer animation. See	voltage transformation into
387–388	animation	lightness in, 92
CIElab uniform color	computer languages. See	computers as cognitive tools, 2
space, 108, 132	programming	concavity, 155
CIEluv uniform color	languages	concept maps or mind maps,
space, 89-90,	computer monitors	379–380
108–110, 132	acuity graph for, 54	cone cells
color differences and	brain pixels and the	cone response space, 99,
uniform color spaces,	optimal screen, 53-57	100
108-110	calibrating to CIE	foveal, 47
color sequences from, 132	coordinates, 104	overview, 47
color specification	chromatic aberration in,	sensitivity functions, 99
interfaces and,	45-46	trichromacy and, 98
119–121	chromaticity coordinates	conjunction search
cone response space, 99,	for two sets of	defined, 154-155
100	phosphors, 107	pattern learning study, 206
defined, 98	contrast illusions on CRT	preattentive processing
HSV, 119	displays, 87	and, 154-156
perceived color differences	contrast variations in, 60	with spatial dimensions,
and, 123	depth of focus and, 42	155–156
RGB, 101, 102, 119	gamma function, 84, 92	connectedness (Gestalt law),
trichromacy and, 98-99	gamut, 101, 103, 108	191, 192
color specification interfaces	generating colors defined	Constellation system, 380, 381
color palettes for, 123	by CIE tristimulus	continuity
color planes for, 120-121	values, 107-108	Gestalt law, 191-192, 193
color spaces and, 119-121	illumination and	good continuation
names for colors and,	surrounds, 90–93, 95	experiments,
121–123	matching colors to room	199–200, 201
separating luminance from	colors, 92–93	transparency perception
chromatic dimensions,	nonlinearity in, 84	and, 205, 206
119–120	optimal display, 62-67	contour. See also continuity
colorimetry, trichromacy as	refresh rate, 66–67	closure (Gestalt law),
basis for, 100	screen size and visual	194–196, 197, 198
column perception. See row and	efficiency, 54–57	contour maps, 249,
column perception	stereo displays, 272	251–252
column perception	stereo displays, 2/2	201 20 2

Cornsweet effect, 77	
defined, 198	
direction perception and,	
200–201, 202, 203	
edge enhancement, 77-79	
expressive power of lines,	
212 flow visualization	
techniques (2D), 201, 203–205	
illusory, 198–199	
motion and, 219–220	
neurophysiological	
mechanisms of	
perception, 199	
shading interaction,	
248–252, 253	cont
silhouettes, 233, 235–237	cont
surface shape perception	cont
and, 248–252	con
three-stage model of	con
perception and, 21,	COO
187, 188	COO
contour generator, 235	Cor
contour, maps, 249, 251–252	corr
contrast. See also simultaneous	cost
brightness contrast	crea
Chevreul illusion, 74, 77	
chromatic, 117, 124–125	cris
contrast threshold as	cros
function of temporal	cros
and spatial frequency,	
61–62	
Cornsweet effect, 77	CR
crispening, 90	
edge enhancement, 77-79	cult
Hermann grid illusion, 72,	cult
73	
illusions on CRT displays,	
87	
luminance contrast effects,	
94, 95	
Mach band effect, 74, 77,	
94	

paper reproductions of effects, 86-87 perceptually independent textures and, 169 as primary perceptual dimension of texture, 164 sharpening, 94 simultaneous brightness contrast, 72-73, 75-79 spatial contrast sensitivity function, 59-61 text contrast, 83 texture contrast effects, 170, 171 trol compatibility in interaction, 322-324 trols in user studies, 404 vergent eye movements, 363 vexity, 155 rdinate knowledge for wayfinding, 331 ensweet effect, 77 respondence problem, 218 t of knowledge, 351 ative problem solving, 383-385 pening, 90 ss-cultural studies, 401 ss-cultural validity of sensory vs. arbitrary representations, 14 T displays. See computer monitors tural relativism, 6, 8 ture arbitrary representations and, 16 color code meanings and, 16, 125 cross-cultural consistency for color, 112 cross-cultural studies, 401

embedded aspects of
visualization, 16
language structure as
cross-cultural, 299
order of color name
appearance in
languages, 112
sign language and, 299
cushion maps, 255, 256
cyclic visual attributes, 181–182
cyclopean scale for stereoscopic
displays, 276

data classification attributes of entities or relationships, 24-25 entities, 23 metadata, 26 operations as data, 25-26 overview, 23 relationships, 23-24 usefulness of, 23, 25 data glyphs. See glyphs data maps. See also exploration and navigation loop for interaction bivariate color sequences, 135-138 bivariate or multivariate maps, 254-255 color sequences for, 127-138 contour maps, 249, 251-252 cushion maps, 255, 256 generation of distinct textures using Gabor function, 166-167 interval pseudocolor sequences, 132–133 knowledge structure interfaces, 379-383

sequences (labeling regions), 128–129 lag between hand ordinal pseudocolor movement and visual sequences, 129–132 feedback in VR, 268–269 size gradient, 260–262 stereoscopic depth, 280 path tracing, 321 selection time for graphical interfaces, 319 selection time for graphical interfaces, 319 selection time for graphical pseudocoloring in, interfaces, 319 selection time for graphical pseudocolors, 133–134 sepect-accuracy tradeoff, and interfaces, 319 sequences for the color blind, 134–135 vigilance tasks, 324 declarative knowledge for contrast and reading errors, 75 spectrum color sequences, 128, 136 supporting visualization with, 338 dependent variables, 403 depth cues. See also task-based tactical map displays, 145, 157–158 treemaps, 216–217 visual grammar of elements, 215–217 elements, 215–217 atmospheric depth, 280 binocular cues, 260 clements, 215–217 atmospheric depth, 280 binocular cues, 260 cast shadows, 266–268 cast shadows, 266–268 cast shadows, 266–268 combinations of cues, 260 data selection and manipulation loop for interaction dependency graph, 283 depth of focus, 266 design. See also interface design affordance theory and, 2D positioning and depth of focus, 266
ordinal pseudocolor sequences, 129–132 feedback in VR, 268–269 orientation of maps, 319–320 size gradient, 260–262 337–338 learning, 322 stereoscopic depth, 271–279 128 selection time for graphical pseudocoloring in, 127–128 speed-accuracy tradeoff, 213–134 sequences for the color blind, 134–135 vigilance tasks, 324 stereoscopic depth augmented-reality systems contrast and reading errors, 75 dependency graph for depth with, 338 depth cues. See also task-based supporting visualization with, 338 treemaps, 216–217 artificial spatial cues, 263, 264, 369–370 tasks and depth of focus cues, 283 treemaps, 216–217 artificial spatial cues, 263, 264, 369–370 tasks and depth of focus, 266 defined, 259 design See also interface design affordance theory and, 20 positioning and depth of focus, 266
sequences, 129–132 feedback in VR, 319–320 size gradient, 260–262 337–338 learning, 322 stereoscopic depth, perceptual color sequences, 128 selection time for graphical pseudocoloring in, 127–128 speed-accuracy tradeoff, ratio pseudocolors, 133–134 two-handed interaction, blind, 134–135 vigilance tasks, 324 declarative knowledge for contrast and reading errors, 75 deixis, 309–310 deixis, 309–310 supporting visualization with, 338 depth cues. See also task-based tactical map displays, 145, 157–158 specific cues tactical map displays, 145, 157–158 specific cues tements, 215–217 data mining, 187 Data Mountain interface, 262, 263, 264, 369– 370 280–283 depth of focus, 266 design. See also interface design affordance theory and, depth of focus, 266 design. See also interface design affordance theory and, depth of focus, 266 design. See also interface design affordance theory and, depth of focus, 266 128, 136 combinations of cues, 260 design. See also interface design affordance theory and, depth of focus, 266 273–274 virtual-reality displays and, depth of focus, 266 280 size gradient, 260–262 stereoscopic depth, 271–279 structure-from-motion, 271–279 structure-from-motion, 268–269 texture gradient, 260–262 weighted-average model, 281 depth of focus. See also structure-from-motion, 281 texture gradient, 260–262 weighted-average model, 281 depth of focus. See also structure-from-motion, 281 depth of focus. See also structure-from-motion, 281 texture gradient, 260–262 weighted-average model, 281 depth of focus. See also structure-from-motion, 281 texture gradient, 260–262 weighted-average model, 281 depth of focus See also structure-from-motion, 281 computed office also structure-from-motion, 281 computed-reality systems depth of part at substructure-from-motion, 281 depth of focus See also structure-from-motion, 281 depth of focus See also structure-from-motion dept
orientation of maps, 337–338 learning, 322 stereoscopic depth, 260–262 stereoscopic depth, 271–279 learning, 321 selection time for graphical pseudocoloring in, 127–128 speed-accuracy tradeoff, 269–270 texture gradient, 260–262 weighted-average model, 281 depth of focus. See also stereoscopic depth, 271–279 structure-from-motion, 269–270 texture gradient, 260–262 weighted-average model, 281 depth of focus. See also texture gradient, 260–262 weighted-average model, 281 depth of focus. See also texture gradient, 260–262 weighted-average model, 281 depth of focus. See also texture gradient, 260–262 weighted-average model, 281 depth of focus. See also texture gradient, 260–262 weighted-average model, 281 depth of focus. See also texture gradient, 260–262 weighted-average model, 281 depth of focus. See also texture gradient, 260–262 weighted-average model, 281 depth of focus. See also texture gradient, 260–262 weighted-average model, 281 depth of focus. See also texture gradient, 260–262 weighted-average model, 281 depth of focus. See also texture gradient, 260–262 weighted-average model, 281 depth of focus. See also texture gradient, 260–262 weighted-average model, 281 depth of focus. See also augmented-reality systems and, 43–44 computer monitor deficiencies, 68 defined, 41 as depth cue, 266 of human eye, 41–42 range for various distances (table), 42 simulating with flat-screen displays, 35 vergence-focus problem, 279–280 displays, 35 vergence-focus problem, 273–274 virtual-reality displays and, 45, 46 derived data, 26 derived dat
perceptual color sequences, 128 path tracing, 321 stereoscopic depth, 271–279 128 selection time for graphical interfaces, 319 selection time for graphical pseudocoloring in, 127–128 speed-accuracy tradeoff, 269–270 texture gradient, 260–262 ratio pseudocolors, 318–319 two-handed interaction, 321–322 weighted-average model, 133–134 two-handed interaction, 321–322 depth of focus. See also simultaneous brightness contrast and reading errors, 75 deixis, 309–310 dependency graph for depth supporting visualization with, 338 dependent variables, 403 depth cues. See also task-based tactical map displays, 145, 157–158 specific cues attical map displays, 145, 157–158 treemaps, 216–217 visual grammar of elements, 215–217 atmospheric depth, 280 binocular cues, 260 cast shadows, 266–268 combinations of cues, 370 deta a selection and manipulation loop for interaction 2D positioning and depth of focus, 266 128 dear at tracing, 321 carring apphical structure-from-motion, 269–270 texture graphical structure-from-motion, 269–270 texture gradient, 269–270 texture gradient, 269–262 weighted-average model, 281 depth of focus. See also stereoscopic depth augmented-reality systems and, 43–44 computer monitor deficiencies, 68 defined, 41 as depth cue, 266 of human eye, 41–42 range for various distances (table), 42 simulating with flat-screen displays, 35 vergence-focus problem, 279–280 displays, 35 vergence-focus problem, 273–274 virtual-reality displays and, 45, 46 derived data, 26 design. See also interface design affordance theory and, 49–44 design. See also interface design affordance theory and, 49–44 computer monitor deficiencies, 68 defined, 41 as depth or computer monitor deficiencies, 68 defined, 41 as depth or computer monitor deficiencies, 68 defined, 41 as depth or computer monitor deficiencies, 68 defined, 41 as depth or computer monitor deficiencies, 68 defined, 41 as depth or computer monitor deficiencies, 68 defined, 41 as depth or computer monitor deficiencies, 68 defined, 41 as depth or computer monitor deficienci
perceptual color sequences, 128 selection time for graphical pseudocoloring in, 127–128 speed-accuracy tradeoff, action pseudocolors, 133–134 two-handed interaction, sequences for the color blind, 134–135 vigilance tasks, 324 simultaneous brightness contrast and reading errors, 75 deixis, 309–310 dependency graph for depth supporting visualization with, 338 dependent variables, 403 dependent, 215–217 specific cues telements, 215–217 atmospheric depth, 280 delata selection and manipulation loop for interaction 2D positioning and depth of focus, 266 twisting, 321 and tradeoff, structure-from-motion, 269–270 texture gradient, 260–262 weighted-average model, 281 depth of focus. See also texture gradient, 260–262 weighted-average model, 281 depth of focus. See also texture gradient, 260–262 weighted-average model, 281 depth of focus. See also texture gradient, 260–262 weighted-average model, 281 depth of focus. See also texture gradient, 260–262 weighted-average model, 281 depth of focus. See also texture gradient, 260–262 weighted-average model, 281 depth of focus. See also texture gradient, 260–262 weighted-average model, 281 depth of focus. See also texture gradient, 260–262 weighted-average model, 281 depth of focus. See also texture from-motion, 281 depth of focus. See also texture-from-motion, 281 depth of focus. See also interface, 262 design. See also interface design affordance theory and, 45–44 computer monitor deficiencies, 68 defined, 41 as depth or cues deficiencies, 68 defined,
selection time for graphical pseudocoloring in, 127–128 speed-accuracy tradeoff, 133–134 two-handed interaction, sequences for the color blind, 134–135 vigilance tasks, 324 stereoscopic depth augmented-reality systems contrast and reading errors, 75 deixis, 309–310 dependency graph for depth 128, 136 cues, 283 supporting visualization with, 338 depth cues. See also task-based tactical map displays, 145, 157–158 treemaps, 216–217 visual grammar of elements, 215–217 data mining, 187 Data Mountain interface, 262, 263, 264, 369–370 deata selection and manipulation loop for interaction 2D positioning and sequences interface design and depth of focus, 266 texture gradient, 260–262 texture from subject of texture gradient, 260–
pseudocoloring in, interfaces, 319 269–270 127–128 speed-accuracy tradeoff, ratio pseudocolors, 318–319 weighted-average model, 133–134 two-handed interaction, 281 sequences for the color blind, 134–135 vigilance tasks, 324 stereoscopic depth simultaneous brightness contrast and reading errors, 75 deixis, 309–310 computer monitor deficiencies, 68 128, 136 cues, 283 defined, 41 supporting visualization with, 338 dependent variables, 403 with, 338 depth cues. See also task-based tactical map displays, 145, space perception; visual grammar of elements, 215–217 artificial spatial cues, visual grammar of elements, 215–217 atmospheric depth, 280 elements, 215–217 atmospheric depth, 280 defined, 370 280–283 defined, 259 data selection and manipulation loop for interaction dependency graph, 283 affordance theory and, 2D positioning and depth of focus, 266 speed accuracy tradeoff, texture gradient, 260–262 weighted. 2810 texture gradient, 260–262 weighted. 281 texture gradient, 260–262 weighted-average model, 281 depth of focus. See also weighted-average model, 281 depth of focus. See also augmented-reality systems augmented-reality systems and, 43–44 computer monitor defined, 41 as depth of defined, 41 as depth cue, 266 of human eye, 41–42 range for various distances (table), 42 streemaps, 216–217 artificial spatial cues, simulating with flat-screen displays, 35 vergence-focus problem, 273–274 virtual-reality displays and, 263, 264, 369 combinations of cues, 370 280–283 derived data, 26 design. See also interface design affordance theory and, 2D positioning and depth of focus, 266 18–20
127–128 speed-accuracy tradeoff, ratio pseudocolors, 318–319 weighted-average model, 133–134 two-handed interaction, 281 depth of focus. See also blind, 134–135 vigilance tasks, 324 stereoscopic depth augmented-reality systems contrast and reading errors, 75 deixis, 309–310 dependency graph for depth supporting visualization with, 338 depth cues. See also task-based tactical map displays, 145, 157–158 specific cues visual grammar of elements, 215–217 atmospheric depth, 280 deta amining, 187 binocular cues, 260 combinations of cues, 263, 264, 369– 370 dependency graph, 283 depth of focus, 266 design. See also interface design affordance theory and, 2D positioning and depth of focus, 266 weighted-average model, weighted-average model, 281 depth of focus, 260 weighted-average model, 281 depth of focus, 261 weighted-average model, 281 depth of focus, 281 depth of focus, 281 depth of focus, 262 weighted-average model, 281 depth of focus, 281 depth of focus, 281 depth of focus, 281 depth of focus, 260 witghted-average model, 281 depth of focus, 281 depth of focus, 281 depth of focus, 260 weighted-average model, 281 depth of focus, 260 tepth augmented-reality systems augmented-reality augmented-r
ratio pseudocolors, 133–134 two-handed interaction, 281 depth of focus. See also blind, 134–135 vigilance tasks, 324 stereoscopic depth augmented-reality systems contrast and reading errors, 75 deixis, 309–310 computer monitor spectrum color sequences, dependency graph for depth supporting visualization with, 338 depth cues. See also depth dependent variables, 403 depth cues. See also task-based tactical map displays, 145, space perception; specific cues visual grammar of elements, 215–217 atmospheric depth, 280 delements, 215–217 data mining, 187 binocular cues, 260 cast shadows, 266–268 combinations of cues, 370 280–283 dependency graph, 280 dependency graph, 280 dependency graph, 280 dependency graph, 280 dependency graph, 283 defordance theory and, 2D positioning and depth of focus, 266
sequences for the color blind, 134–135 vigilance tasks, 324 stereoscopic depth augmented-reality systems contrast and reading errors, 75 deixis, 309–310 computer monitor spectrum color sequences, 128, 136 cues, 283 depth of cues, 283 defined, 41 as depth cues. See also stereoscopic depth deficiencies, 68 defined, 41 as depth cue, 266 depth cues. See also task-based tactical map displays, 145, 157–158 specific cues treemaps, 216–217 artificial spatial cues, 215–217 atmospheric depth, 280 dements, 215–217 atmospheric depth, 280 dements, 215–217 atmospheric depth, 280 dements, 263, 264, 369– cast shadows, 266–268 combinations of cues, 370 280–283 depth of focus, 266 design. See also interface design affordance theory and, 2D positioning and depth of focus, 266
sequences for the color blind, 134–135 vigilance tasks, 324 stereoscopic depth augmented-reality systems contrast and reading errors, 75 deixis, 309–310 computer monitor spectrum color sequences, 128, 136 cues, 283 depth of depth with, 338 depth cues. See also task-based tactical map displays, 145, 157–158 specific cues 157–158 specific cues visual grammar of elements, 216–217 artificial spatial cues, 260 clements, 215–217 atmospheric depth, 280 deta selection and manipulation loop for interaction 2D positioning and depth of focus, 266 deata selection and manipulation loop for interaction 2D positioning and depth of focus, 324 stereoscopic depth augmented-reality systems augmented rea
blind, 134–135 vigilance tasks, 324 stereoscopic depth declarative knowledge for augmented-reality systems wayfinding, 330, 331 and, 43–44 computer monitor dependency graph for depth deficiencies, 68 defined, 41 supporting visualization with, 338 depth cues. See also task-based tactical map displays, 145, space perception; specific cues visual grammar of elements, 215–217 data mining, 187 binocular cues, 260 cest shadows, 266–268 cest shadows, 266–268 data selection and manipulation loop for interaction 2D positioning and depth declarative knowledge for augmented-reality systems and, 43–44 computer monitor dependency graph for depth deficiencies, 68 defined, 41 as depth cue, 266 of human eye, 41–42 range for various distances (table), 42 simulating with flat-screen displays, 35 vergence-focus problem, 279–280 displays, 35 vergence-focus problem, 279–280 vergence-focus problem, 260 273–274 virtual-reality displays and, 280–283 defined, 259 design. See also interface design affordance theory and, 2D positioning and depth of focus, 266 18–20
simultaneous brightness contrast and reading errors, 75 deixis, 309–310 spectrum color sequences, 128, 136 supporting visualization with, 338 dependency graph for depth with, 338 dependency graph for depth with, 338 depth cues, 283 depth cues. See also task-based tactical map displays, 145, 157–158 space perception; specific cues visual grammar of elements, 215–217 data mining, 187 Data Mountain interface, 262, 263, 264, 369– 370 data selection and manipulation loop for interaction 2D positioning and deixis, 309–310 computer monitor deficiencies, 68 defined, 41 as depth cue, 266 of human eye, 41–42 range for various distances (table), 42 simulating with flat-screen displays, 35 vergence-focus problem, 273–274 virtual-reality displays and, 45, 46 derived data, 26 design. See also interface design affordance theory and, 18–20
contrast and reading errors, 75 deixis, 309–310 computer monitor spectrum color sequences, dependency graph for depth supporting visualization with, 338 dependent variables, 403 dependent variables, 403 as depth cue, 266 of human eye, 41–42 range for various distances specific cues artificial spatial cues, visual grammar of elements, 215–217 atmospheric depth, 280 detendent, 263, 264, 369–370 data selection and manipulation loop for interaction 2D positioning and dependency graph, 283 defined, 264 computer monitor deficiencies, 68 defined, 41 as depth cue, 266 deficiencies, 68 defined, 41 as depth cue, 266 of human eye, 41–42 range for various distances (table), 42 simulating with flat-screen displays, 35 vergence-focus problem, 273–274 virtual-reality displays and, 263, 264, 369–283 derived data, 26 design. See also interface design affordance theory and, depth of focus, 266 18–20
errors, 75 deixis, 309–310 computer monitor spectrum color sequences, dependency graph for depth 128, 136 cues, 283 defined, 41 supporting visualization dependent variables, 403 as depth cue, 266 with, 338 depth cues. See also task-based tactical map displays, 145, space perception; range for various distances 157–158 specific cues (table), 42 treemaps, 216–217 artificial spatial cues, visual grammar of 279–280 displays, 35 elements, 215–217 atmospheric depth, 280 vergence-focus problem, data mining, 187 binocular cues, 260 273–274 Data Mountain interface, 262, cast shadows, 266–268 virtual-reality displays and, 263, 264, 369– combinations of cues, 370 280–283 derived data, 26 data selection and manipulation loop for interaction dependency graph, 283 affordance theory and, 2D positioning and depth of focus, 266 18–20
spectrum color sequences, 128, 136 cues, 283 defined, 41 supporting visualization with, 338 depth cues. See also task-based tactical map displays, 145, 157–158 space perception; specific cues treemaps, 216–217 artificial spatial cues, visual grammar of elements, 215–217 atmospheric depth, 280 elements, 215–217 data mining, 187 binocular cues, 260 cast shadows, 266–268 cast shadows, 266–268 data selection and manipulation loop for interaction 2D positioning and depth of focus, 266 design. See also defined, 259 defined, 41 as defined, 266 design. See also interface design affordance theory and, 250 atmospheric depth, 280 defined, 259 affordance theory and, 2D positioning and depth of focus, 266 18–20
128, 136 cues, 283 defined, 41 supporting visualization dependent variables, 403 as depth cue, 266 with, 338 depth cues. See also task-based of human eye, 41–42 tactical map displays, 145, space perception; range for various distances 157–158 specific cues (table), 42 treemaps, 216–217 artificial spatial cues, visual grammar of 279–280 displays, 35 elements, 215–217 atmospheric depth, 280 vergence-focus problem, data mining, 187 binocular cues, 260 273–274 Data Mountain interface, 262, cast shadows, 266–268 virtual-reality displays and, 263, 264, 369– combinations of cues, 370 280–283 derived data, 26 data selection and manipulation loop for interaction dependency graph, 283 affordance theory and, 2D positioning and depth of focus, 266 18–20
supporting visualization with, 338 depth cues. See also task-based tactical map displays, 145, space perception; range for various distances 157–158 specific cues (table), 42 treemaps, 216–217 artificial spatial cues, visual grammar of 279–280 displays, 35 elements, 215–217 atmospheric depth, 280 vergence-focus problem, data mining, 187 binocular cues, 260 273–274 Data Mountain interface, 262, cast shadows, 266–268 virtual-reality displays and, 263, 264, 369– combinations of cues, 370 280–283 derived data, 26 design. See also interface design loop for interaction depth of focus, 266 18–20
with, 338 depth cues. See also task-based tactical map displays, 145, space perception; range for various distances 157–158 specific cues (table), 42 treemaps, 216–217 artificial spatial cues, visual grammar of elements, 215–217 atmospheric depth, 280 vergence-focus problem, data mining, 187 binocular cues, 260 273–274 virtual-reality displays and, 263, 264, 369– combinations of cues, 370 280–283 derived data, 26 derived data, 26 design. See also interface design loop for interaction depth of focus, 266 18–20
tactical map displays, 145, space perception; range for various distances 157–158 specific cues (table), 42 treemaps, 216–217 artificial spatial cues, visual grammar of 279–280 displays, 35 elements, 215–217 atmospheric depth, 280 vergence-focus problem, data mining, 187 binocular cues, 260 273–274 Data Mountain interface, 262, cast shadows, 266–268 virtual-reality displays and, 263, 264, 369– combinations of cues, 370 280–283 derived data, 26 derived data, 26 design. See also interface design loop for interaction dependency graph, 283 affordance theory and, 2D positioning and depth of focus, 266 18–20
treemaps, 216–217 artificial spatial cues, simulating with flat-screen visual grammar of 279–280 displays, 35 elements, 215–217 atmospheric depth, 280 vergence-focus problem, data mining, 187 binocular cues, 260 273–274 Data Mountain interface, 262, cast shadows, 266–268 virtual-reality displays and, 263, 264, 369– combinations of cues, 370 280–283 derived data, 26 data selection and manipulation loop for interaction dependency graph, 283 affordance theory and, 2D positioning and depth of focus, 266 18–20
visual grammar of 279–280 displays, 35 elements, 215–217 atmospheric depth, 280 vergence-focus problem, data mining, 187 binocular cues, 260 273–274 Data Mountain interface, 262, cast shadows, 266–268 virtual-reality displays and, 263, 264, 369– combinations of cues, 370 280–283 derived data, 26 data selection and manipulation defined, 259 design. See also interface design loop for interaction dependency graph, 283 affordance theory and, 2D positioning and depth of focus, 266 18–20
visual grammar of 279–280 displays, 35 elements, 215–217 atmospheric depth, 280 vergence-focus problem, data mining, 187 binocular cues, 260 273–274 Data Mountain interface, 262, cast shadows, 266–268 virtual-reality displays and, 263, 264, 369– combinations of cues, 370 280–283 derived data, 26 data selection and manipulation defined, 259 design. See also interface design loop for interaction dependency graph, 283 affordance theory and, 2D positioning and depth of focus, 266 18–20
elements, 215–217 atmospheric depth, 280 vergence-focus problem, data mining, 187 binocular cues, 260 273–274 Data Mountain interface, 262, cast shadows, 266–268 virtual-reality displays and, 263, 264, 369– combinations of cues, 370 280–283 derived data, 26 design and manipulation defined, 259 design. See also interface design loop for interaction dependency graph, 283 affordance theory and, 2D positioning and depth of focus, 266 18–20
Data Mountain interface, 262, cast shadows, 266–268 virtual-reality displays and, 263, 264, 369– combinations of cues, 45, 46 370 280–283 derived data, 26 data selection and manipulation defined, 259 design. See also interface design loop for interaction dependency graph, 283 affordance theory and, 2D positioning and depth of focus, 266 18–20
263, 264, 369— combinations of cues, 45, 46 370 280–283 derived data, 26 data selection and manipulation defined, 259 design. See also interface design loop for interaction dependency graph, 283 affordance theory and, 2D positioning and depth of focus, 266 18–20
370 280–283 derived data, 26 data selection and manipulation loop for interaction dependency graph, 283 affordance theory and, 2D positioning and depth of focus, 266 18–20
data selection and manipulation defined, 259 design. See also interface design loop for interaction dependency graph, 283 affordance theory and, 2D positioning and depth of focus, 266 18–20
loop for interaction dependency graph, 283 affordance theory and, 2D positioning and depth of focus, 266 18–20
2D positioning and depth of focus, 266 18–20
selection, 319–320 eye accommodation, 269 contour perception and,
choice reaction time, eye convergence, 270 199–200, 201
318–319 monocular dynamic cues, Gestalt laws as principles
control compatibility, 260, 269–271 for, 190, 191, 192,
322–324 monocular static cues, 194, 196, 197, 225
described, 317 260 glyph, 176–177, 182–183,
Fitts' law, 319–320, 321 navigation and, 326 355–356
Hick-Hyman law, 318 occlusion, 265–266 implications from visual
hover queries, 320–321, perspective cues, 260– problem solving
376 262 model, 374–379

multidimensional discrete data and, 182–183 occlusion and, 266 pattern perception and, 188 preattentive processing	tracing data paths in 3D graphs, 284–287 Difference of Gaussians (DOG) model Chevreul illusion and, 74,	ecological optics ambient optical array, 31–32 surfaces vs. classical geometry, 30–31
and, 152, 157-158	equation for, 71	edge enhancement. See also
symbol, 152, 157–158	Hermann grid illusion and,	contour
transparency applications,	72, 73	artists' techniques, 78
205–206	Mach band effect and, 74,	Cornsweet effect, 77
visual working memory	77	for flow pattern
capacity and,	pattern perception and,	enhancement,
355–356	71–72	78–79
detail	simultaneous brightness	egocentric frames of reference,
establishing shot and, 312	contrast and, 72-	333–335, 336
tradeoff with texture, 175	73	electromagnetic spectrum, 30,
visual working memory	surface-shading methods	31
limitations and, 357	and, 75–77	elision techniques, 344
detection methods in	diplopia	End of Science, The (Horgan),
psychophysics,	cyclopean scale and, 276	entity-relationship model
395–396	defined, 271	attributes of entities or
deuteranopia (color blindness),	as stereoscopic display	
99–100	problem, 274–275	relationships, 24–25, 212
diagrams	direct perception defined, 18	entities defined, 23
animation for enriching, 224–225	problems for visualization	modeling entities defined,
chromaticity diagram	theory development,	212
	19–20	for node-link diagrams,
properties, 105–107 Euler, 195–196	visual mechanisms and, 19,	212–213
flowcharts, 302	20	relationships defined,
geon diagrams, 241–243,	direction as monotonic visual	23–24, 212
244	attribute, 181	environment. See visual
map grammar, 215–217	display. See information display	environment
node-link diagrams,	distant objects, stereoscopic	EPIC (executive process
210–215, 284–287,	depth cue and, 274	interactive control),
379–380	distortion techniques, 340-	353, 354
perceptual syntax of,	342	episodic memory, 367
210–217	DOG. See Difference of	equiluminous patterns, 114
role of convention and,	Gaussians (DOG)	error perception, 3
10	model	establishing shot
sketchy, 384–385	dots per inch, 63, 65	(cinematography),
structure diagrams,	dual coding theory, 297–299,	312
302–303	306, 330	Euler diagrams, 195–196
text labels, 307–309	dynamic queries, 346, 348, 376	excitation purity, 106–107
ical labels, 307-307	a, marine queries, 5 10, 5 10, 570	execution purity, 100 107

exocentric frames of reference, and prive experimenter bias, 402 exploration and navigation loop for interaction basic navigation, and scales and processing in, and processing in, and frames of reference, and frame of reference, and processing in, and frame at a 326–327 spatial navigation metaphors, 327–330 exploratory data analysis, color for, 140–143 expressive motion, 221–222 Exvis data glyphs, 172, 184 expe movements attention and, 359 exploratory date amalysis, 59, 90 experimenter for changing, 320–333 exportangle for control, 325–327 eye movements attention and, 359 exploratory date analysis, color experimenter for changing scales, and acuity, distribution and the control and frame at 21, 52 eye convergence depth cues, and an exportangle for changing scales and the optimal screen, 53–57 camera analogy for, 38–40 chromatic aberration, and control and frame rate, 326–327 spatial navigation acuity distribution and the optimal such acuity distribution and the optimal screen, 53–57 camera analogy for, 38–40 chromatic aberration, and frame rate, 326–327 spatial navigation acuity distribution and the optimal screen, 53–57 camera analogy for, 38–40 chromatic aberration, and frame rate, 326–327 spatial navigation metaphors, 327–330 wayfinding, 330–333 exploratory data analysis, color for, 140–143 expressive motion, 221–222 Exvis data glyphs, 172, 184 eye accommodation, 269, 364 eye chart demonstrating visual acuity, 51, 52 eye convergence depth cues, 270 eye movements attention and, 359	executive process interactive control (EPIC), 353,	eye accommodation, 269,	visual angle, 40 visual stress, 62, 63
exocentric frames of reference, 335–336. See also map view experimenter bias, 402 exploration and navigation loop for interaction basic navigation, 235 costs of navigation, 376–379 described, 317 focus-context problem for changing scales, 338–345 frames of reference, 333–337 locomotion and viewpoint control, 325–333 map orientation, 337–338 overview, 325 perception for navigation, 325–327 rapid interaction with data, 345–349 self-motion perception and frame rate, 326–327 spatial navigation metaphors, 327–330 exploratory data analysis, color for, 140–143 expressive gestures, 311 expressive gestures, 311 expressive motion, 221–222 Exvis data glyphs, 172, 184 eye accommodation, 269, 364 expressive gestures, 270 eye movements from the data, 370 context problem of convergence depth cues, 270 exponents on the data of the data of the data of the data and the company that is the data and the company that the data and th		·	
intrasaccadic scanning loop, 374 saccadic, 363–364, 376 saccadic suppression, 361, 364 saccadic suppression, 364 saccadic suppression, 365–366 saccadic sup			
experimenter bias, 402 exploration and navigation loop for interaction basic navigation control loop, 325 costs of navigation, 376–379 described, 317 focus-context problem for changing scales, 338–345 locomotion and viewpoint control, 325–333 map orientation, 337–338 overview, 325 perception for navigation, 325–327 rapid interaction with data, 345–349 self-motion perception and frame rate, 326–327 spatial navigation metaphors, 327–330 wayfinding, 330–333 exploratory data analysis, color for, 140–143 expressive gestures, 311 expressive motion, 221–222 Exvis data glyphs, 172, 184 eye accommodation, 269, 364 eye movements loop, 324 saccadic, 363–364, 361 saccadic, 363–364, 361 saccadic suppression, 361, 364 strategies, 365–366 eve, the. See also specific parts accommodation, 269, 364 eve, the. See also specific parts accommodation, 269, 364 eve, the. See also specific parts accommodation, 269, 364 eve, the. See also specific parts accommodation, 269, 364 eve, the. See also specific parts accommodation, 269, 364 eve, the. See also specific parts accommodation, 269, 364 eve, the. See also specific parts accommodation, 269, 364 eve, the. See also specific parts accommodation, 269, 364 eve, the. See also specific parts accommodation, 269, 364 eve, the. See also specific parts accommodation, 269, 364 eve, the. See also specific parts accommodation, 269, 364 loops in visualization, advertion trajectories, 204 background luminance adjustment for, 78–79 overview, 32–33 sliver plots for, 175 tasks for flow visualization techniques, 78–79, 201, 203–205 floying navigation metaphor, 328, 329–330, 377 focal distances, 43–44 focus. See also specific parts acciuty distribution and the orientation, 269, 364 eve, the. See also specific parts acciuty distributio			metaphon, 520, 525
experimenter bias, 402 exploration and navigation loop for interaction basic navigation control loop, 325 costs of navigation, 376-379 described, 317 focus-context problem for changing scales, 338-345 frames of reference, 333-337 locomotion and viewpoint control, 325-333 map orientation, 337-338 overview, 325 perception for navigation, 325-327 rapid interaction with data, 345-349 self-motion perception and frame rate, 326-327 spatial navigation metaphors, 327-330 wayfinding, 330-333 exploratory data analysis, color for, 140-143 expressive gestures, 311 expressive motion, 221-222 Exvis data glyphs, 172, 184 eye acommodation, 269, 364 experimenter bias, 402 exploration and navigation loop supervisory control systems and, 364-365 types of, 363 and, 364-365 types of, 363 and, 364-365 types of, 363 in any display, 365-366 eve, the See also specific parts accommodation, 269, 364 eve, the See also sp			
exploration and navigation loop for interaction basic navigation control basic navigation control supervisory control systems loop, 325 costs of navigation, 376–379 visual monitoring described, 317 strategies, 365–366 eye, the. See also specific parts accommodation, 269, 364 acuity distribution and the visual field, 50–53 brain pixels and the optimal screen, 53–57 camera analogy for, 38–40 chromatic aberration, 325–327 rapid interaction with data, 345–349 self-motion perception and frame rate, 326–327 spatial navigation metaphors, 327–330 wayfinding, 330–333 exploratory data analysis, color for, 140–143 expressive motion, 221–222 Exvis data glyphs, 172, 184 eye accommodation, 269, 364 eye movements from the data acuity, 51, 52 eye convergence depth cues, 270 every converse acceptance of the data supplements on	*		faces
for interaction basic navigation control loop, 325 costs of navigation, 376–379 described, 317 focus-context problem for changing scales, 338–345 frames of reference, 333–337 locomotion and viewpoint control, 325–333 map orientation, 337–338 overview, 325 perception for navigation, 325–327 rapid interaction with data, 345–349 self-motion perception and frame rate, 326–327 spatial navigation metaphors, 327–330 exploratory data analysis, color for, 140–143 expressive motion, 221–222 Exvis data glyphs, 172, 184 eye accommodation, 269, 364 eye chart demonstrating visual acuity, 51, 52 eye convergence depth cues, 270 eye movements adia, 364–365 supervisory control systems spacial action coding system (FACS), 238 families of colors, 127 feedback loops in visualization, 4–5 figure and ground, 197–199 fish-eye technique, generalized, 516 supervisory (pto display for, 38–40 cpet, the. See also specific parts service parts accommodation, 269, 364 sacuity distribution and the visual field, 50–53 patial native size, 53–57 camera analogy for, 38–40 specie portion of, 29, 364 sacuity distribution and the visual field, 50–53 space portion of, 269, 364 sacuity distribution and the visual field, 50–53 space portion of, 269, 364 sacuity distribution and the visual field, 50–53 space portion of, 269, 364 specie portion of, 36–36 specie portion of, 267, 369 specie portio			
basic navigation control loop, 325 costs of navigation, 376–379 described, 317 focus-context problem for changing scales, 338–345 frames of reference, 333–337 locomotion and viewpoint control, 325–333 map orientation, 337–338 overview, 325 perception for navigation, 325–327 rapid interaction with data, 345–349 self-motion perception and frame rate, 326–327 spatial navigation metaphors, 327–330 wayfinding, 330–333 exploratory data analysis, color for, 140–143 expressive gestures, 311 expressive gestures, 311 expressive gestures, 112 eye movements supervisory control systems and, 364–365 and, 364–365 types of, 363 (FACS), 238 familae of colors, 127 feedback loops in visualization, 4–5 figure and ground, 197–199 fish-eye technique, generalized, 51 figure and ground, 197–199 fish-eye technique, generalized, 51 figure and ground, 197–199 fish-eye technique, generalized, 51 for, 39 camera analogy for, 38–40 chromatic aberration, 349 diplopia, 271 diplopia, 271 diplopia, 271 diplopia, 271 diplopia, 271 solving advection trajectories, 204 background luminance adjustment for, 78–79 overview, 32–33 sliver plots for, 175 tasks for flow visualization 204 visualization techniques, 78–79, 201, 203–205 flowcharts, 302 flying navigation metaphor, 328, 329–330, 377 focal distances, 43–44 focus. See also depth of focus eye accommodation, 269, 364 eye convergence depth cues, 270 eye movements function, 57–62 families of colors, 127 feedback loops in visualization, 4–5 families of colors, 127 feedback loops in visualization, 4–5 families of colors, 127 feedback loops in visualization, 4–5 families of colors, 127 feedback loops in visualization, 4–5 figure and ground, 197–199 fish-eye technique, generalized, 34–4 fitts' law, 319–320, 321 flow patterns. See also vector adjustment for, 78–79 overview, 32–37 focation rate generalized, 34–4 fitts' law, 319–320, 321 flow patterns. See also vector adjustment for, 78–79 overview, 32–30 figure and ground, 197–199 fish-eye technique, generalized, 4–5 figure and ground, 197–199 fish-eye tec	-		
loop, 325 costs of navigation, 376–379 described, 317 focus-context problem for changing scales, 338–345 locomotion and viewpoint control, 325–333 map orientation, 337–338 overview, 325 perception for navigation, 325–327 rapid interaction with data, 345–349 self-motion perception and frame rate, 326–327 spatial navigation metaphors, 327–330 wayfinding, 330–333 exploratory data analysis, color for, 140–143 expressive gestures, 311 expressive gestures, 311 expressive gestures, 311 expressive gestures, 270 eye movements loon and viging in types of, 363 (types families of colors, 127 feedback loops in visualization, 4-5 figure and ground, 197–199 figure and ground and ighe visual arcuity after the background luminance abovection trajectories, 204 background luminance adjustrent for, 7		= = :	
costs of navigation, 376–379 visual monitoring fedescribed, 317 strategies, 365–366 focus-context problem for changing scales, 338–345 accommodation, 269, 364 acuity distribution and the visual field, 50–53 brain pixels and the optimal screen, 53–57 camera analogy for, 38–40 chromatic aberration, 325–333 map orientation, 337–338 overview, 325 perception for navigation, 325–327 rapid interaction with data, 345–349 self-motion perception and frame rate, 326–327 spatial navigation metaphors, 327–330 wayfinding, 330–333 exploratory data analysis, color for, 140–143 expressive gestures, 311 expressive motion, 269, 364 eye chart demonstrating visual acuity, 51, 52 eye convergence depth cues, 270 eye movements of the discontange of the discontang			
described, 317 focus-context problem for changing scales, 338–345 frames of reference, 333–337 locomotion and viewpoint control, 325–333 map orientation, 337–338 overview, 325 perception for navigation, 325–327 rapid interaction with data, 345–349 self-motion perception and frame rate, 326–327 spatial navigation metaphors, 327–330 wayfinding, 330–333 exploratory data analysis, color for, 140–143 expressive gestures, 311 expressive gestures, 311 expressive gestures, 311 expressive gestures, 312 experence depth cues, 270 eye movements visual monitoring strategies, 365–366 eye, the. See also specific parts accommodation, 269, 364 eye, the. See also specific parts accommodation, 269, 364 eye, the. See also specific parts accommodation, 269, 364 eye, the. See also specific parts accommodation, 269, 364 eye, the. See also specific parts accommodation, 269, 364 eye, the. See also specific parts accommodation, 269, 364 eye, the. See also specific parts accommodation, 269, 364 eye, the. See also specific parts accommodation, 269, 364 eye, the. See also specific parts accommodation, 269, 364 eye, the. See also specific parts accommodation, 269, 364 eye, the. See also specific parts accommodation, 269, 364 eye, the. See also specific parts accommodation, 269, 364 eye in wisualization and the visual field, 50–53 brain pixels and the 16w patterns. See also vector fields advection trajectories, 204 background luminance adjustment for, 78–79 overview, 32–33 sliver plots for, 175 tasks for flow visualization, 204 visualization, 204 visualization, 204 visualization, 204 poverview, 32–33 sliver plots for, 175 tasks for flow visualization techniques, 78–79, 201, 203–205 flowcharts, 302 flowcharts, 3		·	
described, 317 focus-context problem for changing scales, 338–345 frames of reference, 333–337 locomotion and viewpoint control, 325–333 map orientation, 337–338 overview, 325 perception for navigation, 325–327 rapid interaction with data, 345–349 self-motion perception and frame rate, 326–327 spatial navigation metaphors, 327–330 wayfinding, 330–333 exploratory data analysis, color for, 140–143 expressive gestures, 311 expressive gestures, 311 expressive motion, 269, 364 eye, the. See also specific parts accommodation, 269, 364 eye, the. See also specific parts accommodation, 269, 364 eye, the. See also specific parts accommodation, 269, 364 eye, the. See also specific parts accommodation, 269, 364 eye, the. See also specific parts accommodation, 269, 364 eye, the. See also specific parts accommodation, 269, 364 eye, the. See also specific parts accommodation, 269, 364 eye, the. See also specific parts accommodation, 269, 364 eye, the. See also specific parts accommodation, 269, 364 eye, the see also specific parts accommodation, 269, 364 eye, chart demonstrating visual acuity, 51, 52 eye convergence depth cues, 270 eye movements strategies, 365–366 eye, the. See also specific parts accommodation, 269, 364 eye, the see also specific parts accommodation, 269, 364 eye, the see also specific parts accommodation, 269, 364 eye, the see also specific parts accommodation, 269, 364 eye, the see also specific parts accommodation, 269, 364 eye, the see also specific parts accommodation, 269, 364 eye, the see also specific parts accommodation, 269, 364 eye, the see also specific parts accommodation, 269, 364 eye, the see also ovector fields advection trajectories, 204 background luminance advection trajectories, 204 fields advection trajectories, 204 background luminance advection trajectories, 204 focus and avection trajectories, 204 focus accommodation, 269, 364 eye fields		• •	
focus-context problem for changing scales, 338–345 accommodation, 269, 364 acuity distribution and the frames of reference, 333–337 brain pixels and the control, 325–333 camera analogy for, 38–40 chromatic aberration, 325–327 for, 39 rapid interaction with data, 345–349 self-motion perception and frame rate, 326–327 spatial navigation metaphors, 327–330 wayfinding, 330–333 exploratory data analysis, color for, 140–143 expressive gestures, 311 expressive motion, 221–222 Exvis data glyphs, 172, 184 eye accommodation, 269, 364 eye chart demonstrating visual acuity, 51, 52 eye convergence depth cues, 270 eye movements for reisual accommodation, 269, 364 even movements for function, 57–62 figure and ground, 197–199 fish-eye technique, generalized, 504–54 figure and ground, 197–199 fish-eye technique, generalized, 544 figure and ground, 197–199 fish-eye technique, generalized, 544 figure and ground, 197–199 fish-eye technique, generalized, 544 figure and ground, 197–199 fish-eye technique, 544 figure a			
changing scales, 338–345 acuity distribution and the visual field, 50–53 prain pixels and the optimal screen, 53–57 camera analogy for, 38–40 fields advection trajectories, 204 background luminance adjustment for, 78–79 overview, 32–537 rapid interaction with data, 345–349 self-motion perception and frame rate, 326–327 spatial navigation metaphors, 327–330 wayfinding, 330–333 rexploratory data analysis, color for, 140–143 cxpressive gestures, 311 expressive gestures, 311 expressive gestures, 311 expressive gestures, 311 expressive motion, 221–222 Exvis data glyphs, 172, 184 eye convergence depth cues, 270 emover importance visual field, 50–53 fights date in the visual field, 50–53 prain pixels and the visual field, 50–57 pra			
frames of reference, 333–337 brain pixels and the visual field, 50–53 brain pixels and the control, 325–333 camera analogy for, 38–40 overview, 325 perception for navigation, 325–327 rapid interaction with data, 345–349 self-motion perception and frame rate, 326–327 spatial navigation metaphors, 327–330 exploratory data analysis, color for, 140–143 expressive gestures, 311 expressive motion, 221–222 Exvis data glyphs, 172, 184 eye accommodation, 269, 364 eye convergence depth cues, 270 exploratory dense and evition, single acuities, 47–49 eye movements brain pixels and the visual field, 50–53 344 Fitts' law, 319–320, 321 flow patterns. See also vector fields advection trajectories, 204 background luminance adjustment for, 78–79 overview, 32–33 sliver plots for, 175 tasks for flow visualization, 204 visualization, 204 visualization techniques, 78–79, 201, 203–205 flowcharts, 302 flow patterns. See also depth of focus advection trajectories, 204 background luminance adjustment for, 78–79 overview, 32–33 sliver plots for, 175 tasks for flow visualization, 204 visualization techniques, 78–79, 201, 203–205 flowcharts, 302 flying navigation metaphor, for, 140–143 focus. See also depth of focus eye accommodation, 269, 364 eye accommodation, 269, 364 eye convergence depth cues, 270 spatial contrast sensitivity function, 57–62 fields advection trajectories, 204 background luminance adjustment for, 78–79 overview, 32–33 sliver plots for, 175 tasks for flow visualization techniques, 78–79 overview, 32–33 sliver plots for, 175 tasks for flow visualization techniques, 78–79, 201, 203–205 flowcharts, 302 flying navigation metaphor, focal distances, 43–44 focus. See also depth of focus eye accommodation, 269, 344 focus-context problem for camera analogy for, 38–40 fields advection trajectories, 204 background luminance adjustment for, 78–79 overview, 32–33 sliver plots for, 175 tasks for flow visualization techniques, 78–79, 201, 203–205 flowcharts, 302 flying navigation focus. See also depth of focus charging factories, 43–			
frames of reference, 333–337 brain pixels and the control, 325–333 map orientation, 337–338 overview, 32.5 perception for navigation, 325–327 rapid interaction with data, 345–349 self-motion perception and frame rate, 326–327 spatial navigation metaphors, 327–330 exploratory data analysis, color for, 140–143 expressive gestures, 311 expressive motion, 221–222 Exvis data glyphs, 172, 184 eye accommodation, 269, 364 eye chart demonstrating visual acuity, 51, 52 eve convergence depth cues, 270 everview, 32–33 brain pixels and the optimal screen, 53–57 coptimal screen, 53–57 coptimal screen, 53–57 coptimal screen, 53–57 camera analogy for, 38–40 chromatic aberration, optimal screen, 53–57 camera analogy for, 38–40 filow patterns. See also vector ficuts, 19–30 filow patterns. See also vector filos patterns. See also filods advection trajectories, 204 background luminance adjustrent for, 78–79 overview, 32–33 sliver pl			
locomotion and viewpoint control, 325–333 camera analogy for, 38–40 fields advection trajectories, 204 background luminance adjustment for, 78–79 overview, 325 perception for navigation, 325–327 for, 39 overview, 325–327 for, 39 overview, 325–327 for, 39 overview, 325–327 for, 39 overview, 325–329 illustrated, 39 self-motion perception and frame rate, 326–327 neural processing in, spatial navigation perception and frame rate, 327–330 optics and augmented wayfinding, 330–333 exploratory data analysis, color for, 140–143 displays, 45, 46 expressive gestures, 311 Panum's fusional area, expressive motion, 221–222 analysis despressive motion, 269, 364 eye accommodation, 269, 364 eye convergence depth cues, 270 eye movements function in an optimal screen, 53–57 camera analogy for, 38–40 fields advection trajectories, 204 background intrajectories, 204 flow patterns. See also vector fields advection trajectories, 204 flow patterns. See also vector fields advection trajectories, 204 salvestion, 325–327 for, 39–40 verview, 32–33 aveverview, 32–33 soverview, 32–33 silver plots for, 78–79 overview, 32–33 sliver plots for, 175 tasks for flow visualization, 204 visualization, 204 visualization techniques, 78–79, 201, 203–205 flowcharts, 302 flying navigation metaphor, 328, 329–330, 377 focal distances, 43–44 focus. See also depth of focus eye accommodation, 269, 364 lightness constancy, eye accommodation, 269, 364 eye accommodation, 269, 364 eye accommodation, 269, 364 eye convergence depth cues, simple acuities, 47–49 spatial contrast sensitivity eye movements function, 57–62 vergence-focus problem,			
locomotion and viewpoint control, 325–333 camera analogy for, 38–40 fields advection trajectories, 204 overview, 325 for, 39 substituting the formation perception for navigation, 325–327 for, 39 overview, 32–33 silver plots for, 175 tasks for flow patterns. See also vector fields advection trajectories, 204 background luminance adjustment for, 78–79 overview, 32–327 for, 39 overview, 32–33 silver plots for, 175 tasks for flow frame rate, 326–327 neural processing in, spatial navigation perception and frame rate, 326–327 neural processing in, spatial navigation perception and for, 140–143 for, 140–143 displays, 45, 46 expressive gestures, 311 expressive gestures, 311 Panum's fusional area, expressive motion, 221–222 panum's fusional area, expressive motion, 269, 364 eye accommodation, 269, 364 eye chart demonstrating visual expressive depth cues, acuity, 51, 52 receptors, 46–47 acuity, 51, 52 receptors, 46–47 spatial contrast sensitivity eye movements fusions for function, 57–62 flow patterns. See also vector fields advection trajectories, 204 fields advection trajectories, 204 advection trajectories, 204 advection trajectories, 204 background luminance adjustment for, 78–79 overview, 32–33 silver plots for, 78–79 overview, 32–33 silver plots for, 175 tasks for flow visualization, 204 visualization, 204 visualization, 204 visualization, 204 visualization techniques, 78–79, 201, 203–205 flowcharts, 302 flying navigation metaphor, 328, 329–330, 377 focal distances, 43–44 focus. See also depth of focus eye accommodation, 269, 364 eye accommodation, 269, 364 eye accommodation, 269, 364 eye convergence depth cues, simple acuities, 47–49 heads-up display problems, 338–345 heads-up display problems, spatial contrast sensitivity 44 vergence-focus problem,			Fitts' law, 319-320, 321
control, 325–333 map orientation, 337–338 overview, 325 perception for navigation, 325–327 rapid interaction with data, 345–349 self-motion perception and frame rate, 326–327 spatial navigation metaphors, 327–330 overjoin and frame rate, 326–327 spatial navigation metaphors, 327–330 overjoin and for, 140–143 expressive gestures, 311 expressive motion, 221–222 Exvis data glyphs, 172, 184 eye accommodation, 269, 364 eye accommodation, 269, 364 eye movements computational perspective adjustment for, 78–79 overview, 32–33 sliver plots for, 175 tasks for flow visualization, 204 visualization, 204 visualization techniques, 70–71 78–79, 201, 203–205 flowcharts, 302 flying navigation metaphor, 328, 329–330, 377 focal distances, 43–44 focus. See also depth of focus eye accommodation, 269, 364 lightness constancy, eye chart demonstrating visual acuity, 51, 52 eye convergence depth cues, 270 spatial contrast sensitivity function, 57–62 fields advection trajectories, 204 background luminance adjustment for, 78–79 overview, 32–33 sliver plots for, 175 tasks for flow visualization, 204 visualization techniques, 78–79, 201, 203–205 flowcharts, 302 flying navigation metaphor, 328, 329–330, 377 focal distances, 43–44 focus. See also depth of focus eye accommodation, 269, 364 focus-context problem for changing scales, 338–345 heads-up display problems, 44 vergence-focus problem,			
map orientation, 337–338 overview, 325 perception for navigation, 325–327 rapid interaction with diplopia, 271 data, 345–349 self-motion perception and frame rate, 326–327 metaphors, 327–330 exploratory data analysis, color for, 140–143 expressive gestures, 311 expressive gestures, 311 expressive motion, 221–222 Exvis data glyphs, 172, 184 eye accommodation, 269, 364 eye convergence depth cues, 270 emparation for, 39 overview, 32–33 sliver plots for, 175 tasks for flow visualization, 204 visualization, 204 visualization techniques, 70–71 78–79, 201, 203–205 flowcharts, 302 flowcharts, 302 flowcharts, 302 flying navigation metaphor, focal distances, 43–44 focal distances, 43–44 focus. See also depth of focus eye accommodation, 269, 364 eye accommodation, 269, 364 eye convergence depth cues, 270 spatial contrast sensitivity eye movements chromatic aberration, advection trajectories, 204 background luminance adjustment for, 78–79 overview, 32–33 squistment for, 78–79 overview, 32–33 sliver plots for, 175 tasks for flow visualization, 204 visualization, 204 visualization, 204 visualization, 204 visualization, 204 visualization techniques, visualization, 204 visualization techniques, visualization t			•
overview, 32.5 perception for navigation, 325–327 rapid interaction with diplopia, 271 data, 345–349 self-motion perception and frame rate, 326–327 metaphors, 327–330 exploratory data analysis, color for, 140–143 expressive gestures, 311 expressive motion, 221–222 Exvis data glyphs, 172, 184 eve accommodation, 269, 364 eve convergence depth cues, 270 everyiew, 32–33 for, 39 overview, 32–33 sliver plots for, 175 tasks for flow visualization, 204 visualization, 204 visualization techniques, 70–71 78–79, 201, 203–205 flowcharts, 302 flying navigation metaphor, focal distances, 43–44 focus. See also depth of focus eye accommodation, 269, 364 eye accommodation, 269, 364 eye convergence depth cues, 270 spatial contrast sensitivity for, 39 overview, 32–33 spatial contrast sensitivity adjustment for, 78–79 overview, 32–33 sliver plots for, 175 tasks for flow visualization techniques, visualization techniques, 78–79, 201, 203–205 flowcharts, 302 flying navigation metaphor, focal distances, 43–44 focus. See also depth of focus eye accommodation, 269, 364 eye accommodation, 269, 60 eye accommodation, 269, 364 eye convergence depth cues, simple acuities, 47–49 eye movements function, 57–62 evergence-focus problem,			advection trajectories, 204
perception for navigation, 325–327 for, 39 overview, 32–33 rapid interaction with diplopia, 271 sliver plots for, 175 tasks for flow self-motion perception and frame rate, 326–327 neural processing in, spatial navigation 70–71 rate processing in, spatial navigation 70–71 rate processing in, and processing in	~		
rapid interaction with diplopia, 271 sliver plots for, 175 tasks for flow self-motion perception and frame rate, 326–327 neural processing in, spatial navigation 70–71 78–79, 201, 203–205 metaphors, 327–330 optics and augmented-wayfinding, 330–333 reality systems, 42–45 flowcharts, 302 flying navigation metaphor, optics in virtual-reality 328, 329–330, 377 for, 140–143 displays, 45, 46 focal distances, 43–44 expressive gestures, 311 Panum's fusional area, expressive motion, 221–222 271–273 eye accommodation, 269, 364 eye accommodation, 269, 364 eye chart demonstrating visual acuity, 51, 52 receptors, 46–47 acuity, 51, 52 receptors, 46–47 acuity, 51, 52 eye convergence depth cues, 270 spatial contrast sensitivity eye movements function, 57–62 vergence-focus problem,		computational perspective	
rapid interaction with data, 345–349 illustrated, 39 tasks for flow self-motion perception and frame rate, 326–327 neural processing in, spatial navigation 70–71 78–79, 201, 203–205 metaphors, 327–330 optics and augmentedwayfinding, 330–333 reality systems, 42–45 flying navigation metaphor, optics in virtual-reality 328, 329–330, 377 for, 140–143 displays, 45, 46 focal distances, 43–44 expressive gestures, 311 Panum's fusional area, expressive motion, 221–222 271–273 eye accommodation, 269, 364 eye accommodation, 269, 364 eye chart demonstrating visual acuity, 51, 52 receptors, 46–47 spatial contrast sensitivity eye movements function, 57–62 spatial contrast sensitivity function, 57–62 visualization tasks for flow visualstacks for flow visualization, 204 visualiza			· · · · · · · · · · · · · · · · · · ·
data, 345–349 illustrated, 39 tasks for flow self-motion perception and frame rate, 326–327 neural processing in, spatial navigation 70–71 78–79, 201, 203–205 metaphors, 327–330 optics and augmented-wayfinding, 330–333 reality systems, 42–45 flying navigation metaphor, optics in virtual-reality 328, 329–330, 377 for, 140–143 displays, 45, 46 focal distances, 43–44 expressive gestures, 311 Panum's fusional area, expressive motion, 221–222 271–273 eye accommodation, 269, 364 eye accommodation, 269, 364 eye chart demonstrating visual acuity, 51, 52 receptors, 46–47 338–345 eye convergence depth cues, 270 spatial contrast sensitivity eye movements function, 57–62 versus data glaps and function, 57–62 versus data glaps and function, 57–62 versus despite and function, 269, spatial contrast sensitivity function, 57–62 versus despite and function, 57–62 versus despite and function, 269, spatial contrast sensitivity function, 57–62 versus despite and function, 269, spatial contrast sensitivity function, 57–62 versus problem,			
self-motion perception and frame rate, 326–327 neural processing in, spatial navigation 70–71 78–79, 201, 203–205 metaphors, 327–330 optics and augmented-wayfinding, 330–333 reality systems, 42–45 flowcharts, 302 flying navigation metaphor, optics in virtual-reality 328, 329–330, 377 for, 140–143 displays, 45, 46 focal distances, 43–44 expressive gestures, 311 Panum's fusional area, expressive motion, 221–222 271–273 eye accommodation, 269, 364 eye accommodation, 269, 364 elightness constancy, eye chart demonstrating visual acuity, 51, 52 receptors, 46–47 338–345 eye convergence depth cues, 270 spatial contrast sensitivity eye movements function, 57–62 versus problem,			- · · · · · · · · · · · · · · · · · · ·
frame rate, 326–327 spatial navigation metaphors, 327–330 wayfinding, 330–333 exploratory data analysis, color for, 140–143 expressive gestures, 311 expressive motion, 221–222 Exvis data glyphs, 172, 184 eye accommodation, 269, 364 eye accommodation, 269, 364 eye chart demonstrating visual acuity, 51, 52 eye convergence depth cues, 270 eye movements neural processing in, 70–71 78–79, 201, 203–205 flowcharts, 302 flying navigation metaphor, flying navigation metaphor, 328, 329–330, 377 focal distances, 43–44 focus. See also depth of focus eye accommodation, 269, focus. See also depth of focus eye accommodation, 269, focus-context problem for changing scales, 338–345 heads-up display problems, 44 eye movements function, 57–62 receptors problem,			visualization, 204
spatial navigation 70–71 78–79, 201, 203–205 metaphors, 327–330 optics and augmented- wayfinding, 330–333 reality systems, 42–45 flying navigation metaphor, exploratory data analysis, color for, 140–143 optics in virtual-reality 328, 329–330, 377 for, 140–143 displays, 45, 46 focal distances, 43–44 expressive gestures, 311 Panum's fusional area, expressive motion, 221–222 271–273 eye accommodation, 269, Exvis data glyphs, 172, 184 range of light levels and eye accommodation, 269, 364 lightness constancy, eye chart demonstrating visual acuity, 51, 52 receptors, 46–47 338–345 eye convergence depth cues, 270 spatial contrast sensitivity eye movements function, 57–62 vergence-focus problem,		neural processing in,	visualization techniques,
metaphors, 327–330 optics and augmented- wayfinding, 330–333 reality systems, 42–45 flying navigation metaphor, exploratory data analysis, color for, 140–143 optics in virtual-reality 328, 329–330, 377 for, 140–143 displays, 45, 46 focal distances, 43–44 expressive gestures, 311 Panum's fusional area, expressive motion, 221–222 271–273 eye accommodation, 269, Exvis data glyphs, 172, 184 range of light levels and eye accommodation, 269, 364 lightness constancy, eye chart demonstrating visual acuity, 51, 52 receptors, 46–47 338–345 eye convergence depth cues, 270 spatial contrast sensitivity eye movements function, 57–62 vergence-focus problem,		70–71	78–79, 201, 203–205
wayfinding, 330–333 reality systems, 42–45 flying navigation metaphor, optics in virtual-reality 328, 329–330, 377 for, 140–143 displays, 45, 46 focal distances, 43–44 expressive gestures, 311 Panum's fusional area, expressive motion, 221–222 271–273 eye accommodation, 269, Exvis data glyphs, 172, 184 range of light levels and eye accommodation, 269, 364 lightness constancy, eye chart demonstrating visual acuity, 51, 52 receptors, 46–47 338–345 eye convergence depth cues, 270 spatial contrast sensitivity eye movements function, 57–62 flying navigation metaphor, flying navigation metaphor, apriled flow focal distances, 43–44 focal distances, 43–44 focult distances, 43–44 focult distances, 43–44 focult distances, 45–44 eye accommodation, 269, apriled flying navigation metaphor, apriled flying navigation metaphor, apriled flying navigation metaphor, apriled flying navigation metaphor, apriled flying navigation flow focult flying navigation flow focult flying navigation flying navigation flying navigation flow focult flying navigation flying navigation flow focult flying navigation flow flying navigation flow flying navigation flow flow flying navigation flow flow flow flow flow flow flow flow		optics and augmented-	flowcharts, 302
for, 140–143 expressive gestures, 311 expressive motion, 221–222 Exvis data glyphs, 172, 184 eye accommodation, 269, 364 eye accommodation, 269, 364 eye chart demonstrating visual acuity, 51, 52 eye convergence depth cues, 270 eye movements displays, 45, 46 focal distances, 43–44 focus. See also depth of focus eye accommodation, 269, eye accommodation, 269, focus-context problem for changing scales, 338–345 heads-up display problems, 47–49 eye movements function, 57–62 vergence-focus problem,		reality systems, 42-45	flying navigation metaphor,
expressive gestures, 311 Panum's fusional area, expressive motion, 221–222 271–273 Exvis data glyphs, 172, 184 eye accommodation, 269, 364 eye accommodation, 269, 364 eye chart demonstrating visual acuity, 51, 52 eye convergence depth cues, 270 eye movements Panum's fusional area, focus. See also depth of focus eye accommodation, 269, 364 range of light levels and 364 focus-context problem for changing scales, 338–345 eye convergence depth cues, simple acuities, 47–49 eye movements function, 57–62 vergence-focus problem,		optics in virtual-reality	
expressive motion, 221–222 271–273 eye accommodation, 269, Exvis data glyphs, 172, 184 eye accommodation, 269, 364 eye accommodation, 269, 364 eye chart demonstrating visual	for, 140–143	displays, 45, 46	
Exvis data glyphs, 172, 184 eye accommodation, 269, 364 eye chart demonstrating visual acuity, 51, 52 eye convergence depth cues, 270 eye movements range of light levels and lightness constancy, 85 receptors, 46–47 338–345 heads-up display problems, 44 eye movements function, 57–62 vergence-focus problem,	expressive gestures, 311	Panum's fusional area,	focus. See also depth of focus
eye accommodation, 269, 364 lightness constancy, eye chart demonstrating visual acuity, 51, 52 receptors, 46–47 a338–345 eye convergence depth cues, simple acuities, 47–49 heads-up display problems, 270 spatial contrast sensitivity eye movements function, 57–62 vergence-focus problem,	expressive motion, 221-222	271–273	eye accommodation, 269,
eye chart demonstrating visual acuity, 51, 52 receptors, 46–47 338–345 eye convergence depth cues, simple acuities, 47–49 heads-up display problems, 270 spatial contrast sensitivity 44 eye movements function, 57–62 vergence-focus problem,	Exvis data glyphs, 172, 184		
acuity, 51, 52 receptors, 46–47 338–345 eye convergence depth cues, simple acuities, 47–49 heads-up display problems, 270 spatial contrast sensitivity 44 eye movements function, 57–62 vergence-focus problem,	eye accommodation, 269, 364	lightness constancy,	
eye convergence depth cues, simple acuities, 47–49 heads-up display problems, 270 spatial contrast sensitivity 44 eye movements function, 57–62 vergence-focus problem,	eye chart demonstrating visual	85	changing scales,
270 spatial contrast sensitivity 44 eye movements function, 57–62 vergence-focus problem,	acuity, 51, 52		
eye movements function, 57–62 vergence-focus problem,	eye convergence depth cues,	simple acuities, 47-49	heads-up display problems,
· · · · · · · · · · · · · · · · · · ·	270		
attention and, 359 vergence angle, 270 273–274	•		
	attention and, 359	vergence angle, 270	273–274

focus-context problem for changing scales principle for distortion techniques for, 340–342 elision techniques for, 344-345 Barlow's second dogma overview, 338–339 and, 163 rapid zooming techniques for, 342–344 fundamental uncertainty spatial scale and, 339 structural scale and, 339 temporal scale and, 339 form perception color channels and, 115 features preattentively processed, 149–152 motion and, 219–220, 224 fovea acuity and distance from, 199–200 forested into transformations for transformations for gamut mapping, 138–140 ganglion cells, retinal. See also Difference of Gaussians (DOG) and transformation for distinct part of transformations for gamut mapping, 138–140 ganglion cells, retinal. See also Difference of Gaussians (DOG) model illustrated, 53 illustrated, 53 lateral geniculate nucleus and, 70, 71 on-center receptive field, and, 70, 71 on-center receptive field, receptive field defined, seperation of distinct sequences of textures using, generalized fish-eye technique, geographic information systems (GISs), 205 geons
distortion techniques for, 340–342 elision techniques for, 344 multiple windows for, Gabor function 344–345 overview, 338–339 rapid zooming techniques for, 342–344 spatial scale and, 339 structural scale and, 339 form perception color channels and, 115 features preattentively processed, 149–152 motion and, 219–220, 224 fovea distortion perception, 164 gamut mapping, 138–140 ganglion cells, retinal. See also point function Difference of Gaussians (DOG) model illustrated, 53 illustrated, 53 illustrated, 53 illustrated, 53 on-center receptive fields, and, 70, 71 on-center receptive fields, 70–71, 72 receptive field defined, separation of distinct 52–53, 70 generalized fish-eye technique, 344 geographic information systems fovea
elision techniques for, 344 multiple windows for, 344–345 overview, 338–339 rapid zooming techniques for, 342–344 spatial scale and, 339 structural scale and, 339 form perception color channels and, 115 features preattentively processed, 149–152 motion and, 219–220, 224 fovea
multiple windows for, 344–345
344–345 overview, 338–339 rapid zooming techniques for, 342–344 spatial scale and, 339 structural scale and, 339 form perception color channels and, 115 features preattentively processed, 149–152 motion and, 219–220, 224 fovea Barlow's second dogma and, 163 model illustrated, 53 illustrated, 53 illustrated, 53 industrated, 53 industrated, 53 illustrated, 53 on-center receptive fields, and, 70, 71 on-center receptive field, receptive field, receptive field defined, generation of distinct 52–53, 70 generalized fish-eye technique, geographic information systems experiments, (GISs), 205
overview, 338–339 and, 163 model rapid zooming techniques for, 342–344 fundamental uncertainty spatial scale and, 339 principle and, 164, and, 70, 71 structural scale and, 339 form perception color channels and, 115 features preattentively processed, 149–152 motion and, 219–220, 224 fovea and, 163 model illustrated, 53 illustrated, 53 illustrated, 53 illustrated, 53 illustrated, 53 on-center application of lateral geniculate nucleus and, 70, 71 on-center receptive field, receptive field, receptive field defined, generation of distinct 52–53, 70 generalized fish-eye technique, geographic information systems fovea (GISs), 205
overview, 338–339 and, 163 model rapid zooming techniques for, 342–344 fundamental uncertainty spatial scale and, 339 principle and, 164, and, 70, 71 structural scale and, 339 form perception color channels and, 115 features preattentively processed, 149–152 motion and, 219–220, 224 fovea and, 163 model illustrated, 53 illustrated, 53 illustrated, 53 illustrated, 53 illustrated, 53 on-center application of lateral geniculate nucleus and, 70, 71 on-center receptive field, receptive field, receptive field defined, generation of distinct 52–53, 70 generalized fish-eye technique, geographic information systems fovea (GISs), 205
rapid zooming techniques for, 342–344 fundamental uncertainty spatial scale and, 339 structural scale and, 339 temporal scale and, 339 form perception color channels and, 115 features preattentively processed, 149–152 motion and, 219–220, 224 fovea equation for, 163 illustrated, 53 fundamental uncertainty lateral geniculate nucleus and, 70, 71 on-center receptive field, 70–71, 72 receptive field defined, receptive field defined, generation of distinct 52–53, 70 generalized fish-eye technique, 344 geood continuation geographic information systems fovea (GISs), 205
for, 342–344 fundamental uncertainty spatial scale and, 339 principle and, 164, and, 70, 71 on-center receptive field, temporal scale and, 339 Gabor receptive fields, T0–71, 72 form perception 162, 164, 166 receptive field defined, color channels and, 115 generation of distinct 52–53, 70 features preattentively textures using, processed, 149–152 processed, 149–152 processed, 149–220, 224 good continuation geographic information systems fovea
spatial scale and, 339 principle and, 164, and, 70, 71 structural scale and, 339 165 on-center receptive field, temporal scale and, 339 Gabor receptive fields, 70–71, 72 form perception 162, 164, 166 receptive field defined, color channels and, 115 generation of distinct 52–53, 70 features preattentively textures using, generalized fish-eye technique, processed, 149–152 166–167 344 motion and, 219–220, 224 good continuation geographic information systems fovea experiments, (GISs), 205
structural scale and, 339 temporal scale and, 339 form perception color channels and, 115 features preattentively processed, 149–152 motion and, 219–220, 224 fovea 165 Gabor receptive fields, Gabor receptive fields, T0–71, 72 receptive field defined, receptive field defined, receptive field defined, generation of distinct 52–53, 70 generalized fish-eye technique, generalized fish-eye technique, geographic information systems fovea (GISs), 205
temporal scale and, 339 Gabor receptive fields, form perception color channels and, 115 features preattentively processed, 149–152 motion and, 219–220, 224 fovea Gabor receptive fields, 162, 164, 166 generation of distinct features using, generalized fish-eye technique, generalized fish-eye technique, geographic information systems fovea GISs), 205
form perception 162, 164, 166 receptive field defined, color channels and, 115 generation of distinct 52–53, 70 features preattentively textures using, processed, 149–152 166–167 344 motion and, 219–220, 224 good continuation geographic information systems fovea experiments, (GISs), 205
color channels and, 115 generation of distinct 52–53, 70 features preattentively textures using, processed, 149–152 166–167 344 motion and, 219–220, 224 good continuation geographic information systems fovea experiments, (GISs), 205
features preattentively textures using, generalized fish-eye technique, processed, 149–152 166–167 344 motion and, 219–220, 224 good continuation geographic information systems fovea experiments, (GISs), 205
processed, 149–152 166–167 344 motion and, 219–220, 224 good continuation geographic information systems experiments, (GISs), 205
motion and, 219–220, 224 good continuation geographic information systems fovea experiments, (GISs), 205
fovea experiments, (GISs), 205
51 illustrated, 162 defined, 233
cone cell packing in, 47 overview, 161–162 geon diagrams, 241–243,
defined, 47 primary perceptual 244
fovea-center attentional dimensions of texture illustrated, 235
field, 146 and, 164 neural-network model and,
Panum's fusional area, resolvable size for Gabor 233
271-273 pattern, 169-170 theory, 233
parafovea, 56, 361 spatial tuning curve, 168 UML diagrams vs. geon
receptor mosaic in, 48 texture segmentation and, diagrams, 241, 242
frame cancellation, 273 162, 163 Gestalt laws
frame rate, self-motion gamma closure, 194–196, 197
perception and, gamma function, 84 connectedness, 191, 192
326–327 voltage steps and continuity, 191–192, 193
frames perceptual steps, 92 design principles from,
moving frames and gamut 190, 191, 192, 194,
perception of motion, color reproduction and, 196, 197, 225
220–221 138 development of, 189
vection and, 290-291 defined, 101 figure and ground and,
frames of reference discriminable colors for 197–199
defined, 333 color monitors, 108 linking text and graphics
egocentric, 333–335, 336 monitor gamut (CIE), and, 307
exocentric, 335–336 103 proximity, 189
multiple simultaneous primaries and, 101 relative size, 196, 197
views and, 336–337 saturation contours, 118 similarity, 190–191

spatial concentration	for speeded classification	heads-up displays (HUDs), 44
principle, 189–190	tasks, 178-179	Hermann grid illusion, 72, 73
symmetry, 192–194	star plots, 184	Hick-Hyman law for choice
gestures	visual working memory	reaction time, 318
deixis, 309-310	capacity and,	hierarchical clustering, 401
expressive, 311	355–356	highlighting
overview, 309	whisker plots, 184	adding vs. taking away,
symbolic, 310–311	God's-eye view, 335–336	153–154
GISs (geographic information	Go-Go Gadget technique, 323,	semantic depth of field,
systems), 205	324	156–157
gist	Gouraud shading, 75–77	visually complex
defined, 356	graphemes, 160–161	environments and,
time for activation, 353	graphical interface design. See	156
visual working memory	interface design	HMDs. See head-mounted
capacity and,	graphs. See node-link diagrams	displays (HMDs)
356–357	grating acuity, 49	hover queries, 320-321, 376
glyphs	gray scales. See also luminance	HSV color space, 119
camouflaged by texture,	Chevreul illusion, 74, 77	HUDs (heads-up displays), 44
176	CIE standard, 89-90	hue
defined, 145	deficiencies for encoding	families of colors, 127
design, 176-177, 182-183,	data, 75, 93–94	in HSV color space, 119
355–356	dots per inch and, 65	unique hues, 112, 124
Exvis data glyphs, 172,	fundamental questions for	human spectral sensitivity
184	applying, 69	function, 81–82
integral and separable	Mach band effect, 74, 77,	hyperbolic tree browser, 340,
dimensions theory	94	342
and, 177–178	optimal display and, 65	hyperlink text, 376
integral-separable	simultaneous brightness	hypothesis formation,
dimension pairs and,	contrast, 72–73	visualization as aid in,
180–181	green, unique hues of, 112	4
integrated, 355-356	group perception. See Gestalt	
key lessons, 185–186	laws; pattern	
low-level graphical	perception	iconic memory, 148-149, 352
attributes in design of,		icons
182, 183		image-based object
multidimensional discrete	head-mounted displays (HMDs)	recognition and, 230,
data and, 182–183	CAE fiber-optic display	232
multidimensional mapping,	(FOHMD), 57, 58	user interrupts using,
184–185	depth of focus and, 42	361
multivariate discrete data	optical and perceptual	illusory contours, 198–199
and, 176–182	problems, 44–45	image-based object recognition
for restricted classification	perspective coupled to	attentional blink, 228
tasks, 177–178	head movement for,	canonical view, 230
in scatter plots, 145	265	defined, 227
in scatter proto, 115	203	defined, 22/

neurophysiological data,	instructional bias, 14	interface design. See also data
230, 231	integer data, 25	selection and
priming effects, 229–230	integral and separable	manipulation loop for
rapid serial visual	dimensions	interaction;
presentation (RSVP),	glyphs and, 177–178,	exploration and
228, 232	180–181	navigation loop for
recall ability for images,	pairs of, 180-181	interaction; virtual-
228	separating row and column	reality (VR) displays
recognition vs. recall, 228	information and, 191	2D positioning and
size and, 228-229	intelligent zooming, 340	selection, 319-320
user interface applications,	interaction metaphors, 327. See	affordance theory and,
230, 232	also spatial navigation	18-20
view direction and, 228	metaphors	choice reaction time,
imagens, 297-298	interactive data display	318-319
images vs. words	brushing technique, 348,	closure (Gestalt law) and,
animated images vs.	376	196, 197
words, 305–306	costs of navigation,	control compatibility,
overview, 303-304,	376–379	322–324
315–316	dynamic queries, 346, 348,	costs of navigation,
static images vs. words,	376	376–379
304	interactive data mapping,	depth cues and, 282-283
inattentional blindness, 359	345–346	FACS and avatar creation,
independent variables, 403	parallel coordinates	238
information density, 164	technique, 348-349	frames of reference,
information display. See also	visual query patterns,	333–337
computer monitors;	375–376	hover queries, 320-321, 376
design	interactive visualization. See	icons, 230, 232
abilities of the eye and, 29	also thinking with	image-based object
color channels and, 116	visualizations; specific	recognition
computer compared to	loops	applications, 230, 232
world, 29	data selection and	kinematic chain theory,
costs of navigation,	manipulation loop,	321
376–379	317, 318–324	knowledge structure
depth of focus and, 42	exploration and	interfaces, 379–383
guidelines for displaying	navigation loop, 317,	magic lens, 322
surfaces, 252, 254	325–349	path tracing, 321
optimal display, 62–67	implications from visual	problems with direct
perspective and total	problem solving	perception for, 19–20
information, 262,	model, 374–379	RSVP for image database
263, 264	overview, 317–318	search, 232
power law and, 84	problem-solving loop,	selection time for graphical
visual query patterns,	317–318	interfaces, 319
375–376	transparency principle,	spatial navigation
information psychophysics, 395	345, 349–350	metaphors, 327–330
miormation psychophysics, 373	J 10, JT/-330	metaphors, 327-330

toolglasses, 322	labeling. See also	dual coding theory, 297-299, 306
transparency for, 205-	pseudocoloring	•
206	color blindness and, 125	as dynamic and distributed
transparency principle,	color conventions and, 125	over time, 301
345, 349–350	contrast with background	images vs. words, 303–306
two-handed interaction,	and, 124–125	links between images and
321–322	distinctness for color	words, 306–311
user interrupts, 360–361	labels, 123–124	logogens, 297–298
vigilance tasks, 324	families of colors for,	natural, 299, 301
interference effects, 256–257	127	sign language, 299-300
interval data	field size and, 125	visual languages, 301-303
defined, 24	gray scale deficiencies for	lateral geniculate nucleus
pseudocolor sequences,	encoding, 75, 93–94	(LGN), 70, 71, 159
132–133	as nominal information	lateral inhibition, 77, 85
real-number data and, 25	coding, 123	launching effect, 222
intrasaccadic scanning loop,	number of colors for,	layered data
374	125	cast shadows and, 268,
ISO standard for pointing	recommended colors,	269
device use, 320	125	transparency perception
isoluminant patterns, 114	text labels for images,	and, 205-206
	307–309	learning. See training or
	unique hues for, 124	learning
JND (just noticeable difference),	laciness effect, 205, 207	lens of the eye
109	Lambertian shading	camera analogy, 38-39
joystick. See pointing devices	defined, 245	depth of focus and, 41-42
just noticeable difference (JND),	examples, 36	equation for imaging
109	guidelines for displaying	properties, 41
	surfaces, 252	illustrated, 39
	overview, 35	nodal point, 41
KidSim animated visual	for scalar field	letter acuity, 49
language, 312-315	representation,	levels of measurement, 24-25
kinematic chain theory, 321	245–246	LGN (lateral geniculate
kinetic depth effect, 269–270	surface shape perception	nucleus), 70, 71, 159
K-means clustering, 401	and, 247-248, 250	lightness. See also brightness;
knowledge structure interfaces	landmarks for wayfinding,	luminance; reflected
concept maps or mind	331–332	light
maps, 379–380	language	defined, 80
Constellation system, 380,	animated visual languages,	luminance vs., 80, 84
381	312–315	preattentive processing of,
linking computer-based	computer languages, 299,	149, 150
analysis with	301–302	lightness constancy
visualization,	deep structures of, 299	adaptation mechanism, 85
380–383	development in children,	contrast mechanisms and,
trajectory mapping, 383	299	86
trajectory mapping, 505	2//	• • • • • • • • • • • • • • • • • • • •

defined, 80	visual working memory	in opponent process
direction of illumination	and, 367-368	theory, 110, 111
and, 87, 88	luminance. See also brightness;	properties, 113–116
factors aiding perception,	gray scales; lightness;	
85–86, 87–88	simultaneous	
lateral inhibition	brightness contrast	Macaque monkey visual
mechanism, 85	background luminance	pathways, 11, 12
paper reproductions of	adjustment for flow	Mach band effect, 74, 77, 94
effects, 86–87	fields, 78–79	magic lens, 322
range of light levels and,	as basic to vision, 69	magnifying windows vs.
85	brightness vs., 80, 84	zooming, 377–379
reference white used by	CIE Y tristimulus value as,	magnitude estimation, 83-84
brain, 87	103	map reading errors for scaling,
specular vs. nonspecular	color specification	332–333
reflection and, 88,	interfaces and,	map view
89	119–120	defined, 336
Likert scale, 399-400	defined, 80, 81	map orientation, 337-338
limited-capacity working	equation for, 81	maps, data. See data maps
memory, 307	gamma function, 84	masking technique for priming,
linear perspective, 260-262	human spectral sensitivity	230
lines. See contour	function or $V(\lambda)$,	MDS (multidimensional
links between images and	81–82	scaling), 381-382,
words	lightness vs., 80, 84	400
deixis, 309-310	luminance contrast effects,	memory. See also long-term
expressive gestures, 311	94, 95	memory; visual
gestures as linking devices,	multivariate surface display	working memory
309–311	and, 254	extension by visualizations,
overview, 306–307	overview, 81–83	352
static links, 307-309	power law, 83-84	as framework for
symbolic gestures,	proximity luminance	cognition, 352
310–311	covariance, 279-	iconic, 148-149, 352
logogens, 297-298	280	icons and, 230, 232
long-term memory. See also	receptor information and,	imagens and logogens in,
memory	69	297–298
capacity, 367	of sine wave grating,	limited-capacity working
chunking, 367, 368-369	58–59	memory, 307
concepts and, 369	text contrast, 83	long-term, 352, 366-
defined, 352	unique hues and, 112	370
episodic, 367	Weber's law, 88–89	navigation control loop
as network of linked	luminance channel	and, 325
concepts, 367, 368	described, 110	recall ability for images,
as verbal-propositional	human spectral sensitivity	228
memory, 366	function and, 81–82	recognition vs. recall,
visual, 369–370	illustrated, 111	228
	*	

aanaamu va ambituamu	color channels and	mouse spinal column, 174, 175
sensory vs. arbitrary representations and,	sensitivity, 115	Muller-Lyer illusion, 14
16	correspondence problem,	multidimensional discrete data
visual working memory,	218–219	color for displaying,
352–363	for diagram enrichment,	140–143
metadata, 26	224–225	glyph design and, 182-
method of adjustment, 397	expressive, 221–222	183
methodologies, 15. See also	flow patterns, 32–33	key lessons, 185–186
visualization	form and contour in,	motion for displaying,
techniques and	219–220	176
systems	glyph design and, 183	resolvable steps per
mind maps or concept maps,	judging relative movement	dimension and,
379–380	of self in	182–183
Mona Lisa illusion, 228-229	environment,	stereoscopic depth for
monitor gamut (CIE), 103	290–291	displaying, 176
monitors. See computer	monocular dynamic depth	multidimensional scaling
monitors	cues, 260, 269–271	(MDS), 381–382, 400
monocular dynamic depth cues,	moving frames and	multimedia, claims for,
260, 269–271	perception of,	306–307
monocular static depth cues.	220–221	multiple regression, 401
See also specific cues	for multidimensional data	multiple windows, 344-345
cast shadows, 266-268	display, 176	multiple-window technique,
defined, 260	pattern perception and, 22,	344–345
depth of focus, 266	217–225	multivariate discrete data,
eye accommodation, 269	perception of animate	glyphs and, 176–182
list of, 260	motion, 223-224	multivariate maps, 254-255
occlusion, 265-266	preattentive processing of,	Munsell system, 122-123
perspective cues, 260-262	152, 156	
pictures seen from the	sensitivity in the periphery,	
wrong viewpoint,	50	names for colors
262–265	structure-from-motion	brown, 118
shape-from-shading, 260,	depth cues, 269–270	categorical colors, 113
268, 269	surface shape perception	color specification
size gradient, 260–262	and, 247	interfaces and,
texture gradient, 260-262	target shape and, 156	121–123
monotonicity of visual	three-stage model of	combinations never used,
attributes, 181–182	perception and, 21,	110, 112
motion. See also animation	187, 188	cross-cultural consistency,
attention attraction and,	UFOV and, 147	112
360–362	wagon-wheel effect, 219	disagreement about, 121
cast shadows and depth	motion blur, 67	Munsell system, 122-
perception, 266–268	motion parallax, 269	123
causality perception and,	mouse (computer). See pointing	Natural Color System
222–223	devices	(NCS), 122–123

order of appearance in	1976 uniform chromaticity	realism vs. abstraction
languages, 112	scale (UCS) diagram	tradeoff, 258
Pantone system, 122-	(CIE), 109, 110	relationship to data
123	nodal point, 41	presented, 240-241
nanometers, 30	node-link diagrams	object file concept, 255–257,
Natural Color System (NCS),	concept maps or mind	356, 371
122–123	maps, 379–380	object recognition. See image-
natural language, 299, 301	entity-relationship model	based object
navigation interface. See	for, 212–213	recognition; structure-
exploration and	examples, 210	based object
navigation loop for	graph drawing algorithms,	recognition
interaction	210	objects
navigation metaphors. See	interdependencies and	cushion maps, 255, 256
spatial navigation	understanding of, 211	defined, 227
metaphors	links defined, 211	faces, 237-238
NCS (Natural Color System),	nodes defined, 211	image-based object
122–123	as perceptual, 211-212	recognition, 228–232
negative light, 101-102	in software engineering,	information organization
network model for long-term	211	by the brain, 255-257
memory, 367, 368	tracing data paths in 3D	judging relative positions
neural pathways for visual	graphs, 284–287	in space, 289–290
processing, 11	treemaps vs., 216-217	object display and object-
neural-network model of	visual grammar of	based diagrams,
structural object	elements, 213–215	239–243
recognition, 233,	nominal data	object file concept,
234	category data and, 25	255–257, 356, 371
neurons. See also brain	defined, 24	overview, 257–258
Gabor function and	pseudocolor sequences,	perceiving surface shapes
receptive field	128–129	of, 243–255
properties, 161–162	nominal information coding.	pervasiveness of metaphor,
neural pathways and visual	See labeling	227
processing, 11–12	nominalism, 8–9	proto-object flux, 22,
overview, 70	north-up map orientation,	362–363
parallel processing by	337–338	reaching for objects,
neuron arrays, 20–21,	numerosity, preattentive	291–292
188	processing of, 151,	structure-based object
neurophysiology. See also brain;	153–154	recognition, 233–
neurons	Nyquist limit, 63–64	237
of canonical view, 230,	z vy quist mins, so s v	occlusion. See also transparency
231		3D visualization of graphs
mechanisms of perception,	object display	and, 286
199	advantages of, 239, 241	closure (Gestalt law) and,
opponent process theory	Chernoff faces, 239–240	194–195
studies, 113	defined, 239	design and, 266
,	,	

	1 11	11.1
as most basic depth cue,	correspondence problem	parallel processing by neuron
283	and, 219	arrays, 20–21, 188
overview, 265–266	as cyclic visual attribute,	Passamoquoddy Bay
symmetry (Gestalt law)	181–182	visualization, 2–4
and, 192, 193	fundamental uncertainty	path tracing
operations, 25–26	principle and, 164,	in 3D graphs, 284–287
opponent process theory	165	in interactive visualization,
categorical colors, 113	glyph design and, 183	321
cross-cultural validity, 112	of maps, 337–338	pattern perception. See also
luminance channel, 110,	oriented sliver textures,	space perception
111	172–176	"action system" vs.
naming and, 110, 112	perceptually independent	"what" system, 22
neurophysiological studies,	textures and, 168–169	aliasing and, 64
113	as primary perceptual	contours and, 198-205
overview, 110	dimension of texture,	data mining and, 187
properties of color	164	DOG model and, 71-72
channels, 113-116	texture contrast illusions,	Gestalt laws, 189–198
psychological basis, 110	170, 171	Hermann grid illusion, 72,
red-green channel, 110,	tradeoffs using, 176	73
111	oriented sliver textures,	integral and separable
unique hues, 112	172–176	dimensions and, 191
yellow-blue channel, 111	over-the-shoulder-view, 335	learning in, 188, 206-
opportunity cost of knowledge,		209
351		motion and, 22, 217-225
optical flow, 32-33	paint model of surfaces	multivariate surface display
optimal display	ambient shading, 36	and, 254
acuity information and, 62	cast shadows, 36	parafovea and, 56
aliasing and, 63-65	Lambertian shading, 35	perceptual syntax of
brain pixels and, 53-57	overview, 35	diagrams, 210–217
gray levels, 65	specular shading, 36	priming, 188, 209
number of dots, 63, 65	Pantone system, 122–123	spatial concentration
spatial contrast sensitivity	Panum's fusional area, 271-273	principle, 189–190
function and, 62-63	paper	three-stage model of
superacuities and, 65-66	computer monitor vs., 92	perception and,
temporal requirements,	lightness constancy effects	21–22, 187–188
66–67	and, 86-87	transparency and
ordinal data	standard lamp for colors	overlapping data,
defined, 24	on, 116	205–206
integer data and, 25	parafovea	in visual processing model,
pseudocolor sequences,	attracting attention	21–22
129–132	outside, 361	visualization and, 3
orientation	pattern perception and, 56	pattern-induced epilepsy, 62
in Barlow's second dogma,	parallel coordinates technique,	Perception of Causality, The
163	348–349	(Michotte), 222–223

perceptual color sequences, 128	conjunction search and,	masking technique, 230
perceptual processing. See	154-156	object file concept and,
visual processing	defined, 149	256
perceptually independent	illustrated, 152	in pattern perception, 188,
textures, 167–169	of lightness, 149, 150	209
personal image memory banks,	list of features	principal components analysis,
232	preattentively	400
perspective depth cues	processed, 149-152	printers (dots per inch), 63, 65
overview, 260–262	neurological evidence for,	problem solving with
pictures seen from the	159–161	visualizations
wrong viewpoint,	processing rate for, 151	cognitive components of
262–265	rapid area judgments and,	visual thinking,
total information and,	154	370–371
262, 263, 264	symbol design and, 152,	costs of navigation,
phase angle, as cyclic visual	157–158	376–379
attribute, 181–182	typical experiments and	eye movement control
phobia desensitization, VR	results, 149–151	loop, 374
techniques for,	variety of distractors and,	implications for interactive
293	152–153	visualization design,
Phong shading, 75–77	preparation stage of creative	374–379
point acuity, 49	problem solving, 384	intrasaccadic scanning
point of interest navigation,	presence (aesthetic impression	loop, 374
343	of 3D space),	key features of visual
pointing devices	293–294	thinking, 371
control compatibility,	primary colors	pattern-finding loop,
322–323	changing sets, 102–103,	373–374
hover queries, 320–321, 376	387–388	problem-solving strategy,
ISO standard for	CIE standards, 103–110	372
	cross-cultural consistency,	process overview, 371–372
performance and comfort, 320	112 defined, 99	visual query construction, 372–373
selection time for graphical		
interfaces, 319	gamut and, 101 negative light and,	visual query patterns, 375–376
time for hyperlink jumps,	101–102	problem-solving loop for
376	RGB color space, 101, 102	interaction, 317–318
two-handed interaction,	trichromacy theory,	procedural knowledge for
321–322	98–99	wayfinding, 330, 331
position. See spatial position	tristimulus values (CIE),	production stage of creative
power law	103–104	problem solving, 384
of practice, 208, 322	priming	programming languages
for sensations, 83–84	defined, 188, 209, 229	animated visual languages,
preattentive processing	image-based object	312–315
combinations of features	recognition and,	Chomsky's analysis and,
and, 154	229–230	299
u, 10 1		

easy-to-learn, 316 flowcharts, 302 natural language and, 299, 301–302	ratio data defined, 24 pseudocolor sequences, 133–134	equation for, 36–37 Lambertian model, 35 specular light, 36, 38 relationships. <i>See</i> entity- relationship model
protanopia (color blindness), 99–100	real-number data and, 25 reaction time, choice, 318–319	relative size (Gestalt law), 196,
proto-object flux, 22, 362-363	realistic representation, 8-9	197
proximity (Gestalt law)	real-number data, 25	research methods. See
connectedness vs., 191,	receptive fields. See also	visualization
192	Difference of	techniques and
overview, 189	Gaussians (DOG)	systems
proximity luminance	model	Resink's model for attention,
covariance, 279–280	in the brain, 159–160	362–363
pseudocoloring	defined, 52–53, 70	resolution
bivariate color sequences, 135–138	Gabor receptive fields, 162, 164, 166	for stereoscopic displays, 274–275
for the color blind,	of ganglion cells, 52-53,	of texture, 169–170
134–135, 136	70–71, 72	visual acuities and, 48
interval sequences,	graphemes and, 161	resource cost of knowledge,
132–133	on-center, 70–71, 72	351
nominal sequences	tuned, 159-160	restricted classification tasks,
(labeling regions),	receptors	glyphs for, 177-178
128–129	adaptation mechanism, 85	retina. See also fovea
ordinal sequences,	foveal, 47, 48	camera analogy vs. human
129–132	luminance information	perception, 39–40
overview, 127–128	and, 69	ganglion cells, 52–53,
physical spectrum for, 128,	recognition of objects. See	70–71
136	image-based object	illustrated, 39
ratio pseudocolors,	recognition;	Panum's fusional area,
133–134	structure-based object	271–273
Psychology of Everyday Things,	recognition	photoreceptor cells in, 46–47
The (Norman), 20 psychophysics, 394–396	recognition vs. recall, 228 red-green channel	RGB color space
purple boundary, 105	color sequence, 136	overview, 101, 102
push and pull cues for	described, 110	transformation to HSV
attention, 359	illustrated, 111	color space, 119
attention, 337	properties, 113–116	robustness of linear perspective,
	saturation and, 118	262
rapid area judgments, 154	reference white, 87, 89	rod cells, 46–47, 98
rapid serial visual presentation	reflected light. See also	row and column perception
(RSVP), 228, 232	lightness; specular	integral and separable
rapid zooming techniques,	shading	dimensions and, 191
342–344	ambient light, 36	proximity and, 189
rating scales, 399–400	cast shadows, 36	similarity and, 190
<i>G</i> ···· <i>y</i> ········	,	• •

RSVP (rapid serial visual	selection in interactive	sensory immediacy, 14, 15
presentation), 228,	visualizations. See	sensory representations
232	data selection and	arbitrary representations
Rubin's Vase, 197, 198	manipulation loop for	vs., 10, 27
	interaction	brain regions and neural
	selection time for graphical	pathways and, 11-12
saccadic eye movements,	interfaces, 319	defined, 10
363–364, 376	selectivity of attention, 359-360	hybrids with arbitrary
saccadic suppression, 361, 364	self-movement sensation	representations, 13
sampling, 366	(vection), 290-291,	methodologies for
saturation	326–327	studying, 15
color sequence, 136	semantic depth of field,	properties, 13–15
in HSV color space, 119	156–157	shading
overview, 117–118	Semiology of Graphics (Bertin),	ambient, 36, 245
scaling for gamut mapping,	6, 297	brain and shading
140	semiotics	information, 37
scalar fields or univariate maps	arbitrary conventional	cast shadows, 36, 245
defined, 244	representations,	contour interaction,
shading models, 245-246	15–17	248–252, 253
spatial cues for	cultural relativism and, 6,	DOG model and surface-
representing, 244–247	8	shading methods,
surface texture, 246–247	defined, 6	74–77
scalar quantities, 25	Gibson's affordance theory,	Gouraud, 75-77
scale. See size or scale	18–20	guidelines for displaying
scatter plots	of graphics, 6–8	surfaces, 252
3D patterns of points,	nominalist critique of, 8-9	Lambertian, 35, 36, 245
288–289	origins of, 6	models for scalar field
artificial spatial cues for,	pictures as sensory	representation,
279–280	languages, 8-10	245–246
color for extending to	properties of sensory	multivariate surface display
multiple dimensions,	representations,	and, 254
141–143	13–15	paint model of surfaces
glyphs in, 145	sensory vs. arbitrary	and, 35-36
science, end foreseen for, 1	representations,	Phong, 75–77
searching the visual field. See	10–13	shape-from-shading depth
visual search	studies contradicting the	cues, 260, 268, 269
searchlight model of attention,	nominalist view, 9	specular, 36, 245
364	studying arbitrary	surface shape perception
segmentation model for texture	conventional symbols,	and, 247–252
figure and ground	17–20	uniform, 75–77
perception and, 196	testing claims about	shape
illustrated, 162	sensory	connectedness grouping
overview, 163	representations, 15	principle vs., 191, 192
texture resolution and,	semistructured interviews,	correspondence problem
169	399	and, 219

shape-from-shading depth	defined, 57	size constancy, 269, 290
cues, 260, 268–269	illustrated, 58, 59	vection and, 290-291
sharpening, 94	luminance, 58–59	sketchy diagrams, 384-385
sign language, 299-300	variations, 57–58	sliver plots, 172–176
signal detection theory, 396	size or scale. See also spatial	smooth-pursuit eye movements,
silhouettes	frequency	363
canonical, 235, 236	in Barlow's second dogma,	space perception. See also depth
contour generator, 235	163	cues; task-based space
rules for interpreting,	connectedness grouping	perception
235–237	principle vs., 191,	3D design and, 259
simple line drawings and,	192	as advanced pattern
233	cyclopean scale for	perception, 188
structure-based object	stereoscopic displays,	depth cue theory, 259–283
recognition and, 233,	276	task-based, 283-294
235–237	figure and ground	unifying theory lacking for,
similarity	perception and, 197	281
Gestalt law, 190–191	focus-context problem for	weighted-average model,
of pictures to objects, 8–9	changing scales,	281
symmetry and perception	338–345	spatial concentration principle,
of, 192, 194	fundamental uncertainty	189–190
simple lens imaging properties,	principle and, 164,	spatial conjunction, preattentive
41	165	processing and,
simulator sickness, 291	gradient as depth cue,	155–156
simultaneous brightness	260–262	spatial contrast sensitivity
contrast. See also	ground plane and	function
Difference of	estimation of, 279	defined, 59
	image-based object	optimal display and, 62–63
Gaussians (DOG) model	recognition and,	spatial frequency and,
Chevreul illusion, 74, 77	228–229	60–61
Cornsweet effect, 77	intelligent zooming, 340	spatial frequency
	as monotonic visual	Barlow's second dogma
edge enhancement, 77–79		and, 163
Mach band effect, 74, 77,	attribute, 181 multidimensional scaling,	channels, 168
94		contrast threshold as
map reading errors and, 75	381–382, 400	function of, 61–62
overview, 72–73	as primary perceptual	Nyquist limit, 63–64
surface-shading methods	dimension of texture,	
and DOG model,	164	optimal display and,
75–77	rapid zooming techniques,	62–66
sine wave grating	342-344	perceptually independent
for contrast sensitivity	relative (Gestalt law), 196,	textures and, 169
measuring, 59–60	197	spatial contrast sensitivity
contrast threshold as	resolvable size for Gabor	function, 59–61
function of temporal	pattern, 169–170	spatial contrast sensitivity
and spatial frequency,	scaling error in map	function and, 60-61
61–62	reading, 332-333	visual stress and, 62, 63

spatial information in visual	overview, 36	guidelines for displaying
working memory,	for scalar field	surfaces, 252
357–358	representation,	for judging relative
spatial modulation sensitivity	245-246	positions of objects in
function. See spatial	surface shape perception	space, 289-290
contrast sensitivity	and, 247-248, 250	for multidimensional data
function	speed-accuracy tradeoff,	display, 176
spatial navigation metaphors	318–319	other depth cues vs.,
cognitive constraints, 327	speeded classification tasks,	271–274, 276
eyeball-in-hand, 328,	glyphs for, 178–179	Panum's fusional area for,
329	S–R (stimulus-response)	271–273
flying, 328, 329–330, 377	compatibility,	perception as superacuity,
illustrated, 328	322–324	273
interaction metaphors	stages of visual processing	preattentive processing and
defined, 327	Stage 1: extracting low-	conjunction search,
physical constraints, 327	level properties,	155
spatial navigation	20–21	for real-world imagery
metaphors, 327–330	Stage 2: pattern	enhancement, 288
viewpoint control interface	perception, 21–22,	simple stereo display,
examples, 327	187–188	271–272
walking, 328, 329, 330,	Stage 3: sequential goal-	stereo-blindness, 271
377	directed processing,	surface shape perception
world-in-hand, 328, 329	22	and, 247, 288
spatial position	stages of visualization, 4–5	vection and, 290–291
fundamental uncertainty	staircase procedure, 396	vergence-focus problem,
principle and, 164,	standardization, 386	273–274
165	star plots, 184	stereoscopic displays. See also
glyph design and, 183	static images vs. words, 304	task-based space
preattentive processing of,	static links between images and	perception
152	words, 307–309	3D visualization of graphs
spatial sensitivity, color	statistical exploration, 400–401	and, 286–287
channels and,	stereo acuity, 47, 49	cyclopean scale for,
114–115	stereo-blindness, 271	276
spatial-scale focus-context	stereopsis superacuity, 273	diplopia and, 274–276
problem, 339	stereoscopic depth. See also	distance judgment
spectrum color sequences, 128,	depth of focus;	problems, 275
136	stereoscopic displays	distant objects and, 274
spectrum locus, 105	"true" 3D and, 271	enlarging the fusional area,
specular shading	angular disparity for,	275
defined, 245	angulai disparity loi.	2/3
		f
· · · · · · · · · · · · · · · · · · ·	271–272	frame cancellation and, 273
guidelines for displaying	271–272 basis of, 271	making effective displays,
guidelines for displaying surfaces, 252	271–272 basis of, 271 color channels and, 115	making effective displays, 274–279
guidelines for displaying	271–272 basis of, 271	making effective displays,

problems with, 273–274 resolution required for, 274–275	stereoscopic depth perception, 271–273 supervisory control systems,	figure and ground perception and, 196, 198
surface shape perception	364–366	overview, 192–194
and, 288	surface shape perception	
vergence-focus problem,	bivariate or multivariate	. 11 1 240 242
273–274	maps, 254–255	table lens, 340, 342
viewer-to-screen distance, 275	continuous surfaces, 243–244	tabula rasa view of the brain, 10–11
virtual eye separation for, 276–279	guidelines for displaying surfaces, 252, 254	tactical map displays, 145, 157-158
stimulus-response (S–R)	integration of cues for,	task identification in user
compatibility,	247–248, 249, 250	studies, 404
322–324	shading and contour	task-based space perception. See
stress	interaction, 248-252,	also depth cues
tunnel vision and, 147	253	aesthetic impression of 3D
visual, 62	spatial cues for scalar	space (presence),
Stroop effect, 257	fields, 244–247	293–294
structural analysis, 398-400	surfaces	identifying tasks, 283–284
structural-scale focus-context	classical geometry vs.,	judging relative movement
problem, 339	30	of self in
structure diagrams, 302-303	judging the morphology	environment,
structure-based object	of, 287–288	290–291
recognition	light colors vs. surface	judging relative positions
defined, 227	colors, 104	of objects in space,
effectiveness of simplified	paint model of, 35-38	289–290
views, 237	perceiving surface shapes	judging the morphology of
geon theory, 233, 234, 235	of objects, 243–255	surfaces and surface
neural-network model,	as primary human	target detection,
233, 234	interface with objects,	287–288
silhouettes and, 233,	30–31	judging the up direction,
235–237	surface target detection,	292–293
view direction and, 233	288	patterns of points in 3D
structured interviews, 399	texture as fundamental	space, 288-289
structure-from-motion depth	property of, 33–34	reaching for objects,
cues	symbol design	291–292
importance of, 270	glyph design and	tracing data paths in 3D
kinetic depth effect,	multidimensional	graphs, 284–287
269–270	discrete data,	TBP (total brain pixels), 54
motion parallax, 269	182–183	teleostereoscope, 276–277
superacuities	preattentive processing	temporal aliasing, 67
optimal display and,	and, 152, 157–158	temporal frequency
65–66	symbolic gestures, 310–311	contrast threshold as
overview, 47–48	symmetry (Gestalt law)	function of, 61–62

optimal display and,	163, 169, 196	lag between hand
66–67	surface shape perception	movement and visual
visual stress from, 62	and, 247–248, 249,	feedback in VR,
temporal-scale focus-context	250, 253	319–320
problem, 339	surface texture, 33–34,	language as distributed
tensor quantities, 25	246–247	over, 301
text contrast, 83	three-stage model of	for navigation in
text labels for images, 307-309	perception and, 21,	information spaces,
texture	187, 188	377
computerized visualizations	tradeoffs using, 175-	saccadic eye movement
lacking, 33-34	176	dwell period, 363
in contour maps, 252	ThemeScape visualization,	selection time for graphical
contrast effects, 170, 171	382–383	interfaces, 319
as critical to perception,	thinking. See cognition	for semantic meaning to be
33, 34	thinking with visualizations. See	activated, 353
dimensionality of visual	also problem solving	temporal aliasing, 67
texture, 170–171	with visualizations	temporal frequency, 61-62,
for Euler diagram	cost of knowledge	66–67
enhancement, 196	approach, 351	temporal-scale focus-
Exvis data glyphs, 172	creative problem solving,	context problem, 339
field displays, 172-176	383–385	toolglasses, 322
as fundamental property of	eye movements, 363–366	ToonTalk animated visual
surfaces, 33	long-term memory,	language, 312
fundamental uncertainty	366–370	total brain pixels (TBP), 54
principle and, 164,	memory extension and,	trackball. See pointing devices
165	352	track-up maps, 337
generation of distinct	memory systems, 352-	training or learning
textures, 166–167	363	chunking of subtasks, 322
glyph design and, 183	problem solving with	in interactive visualization,
glyphs camouflaged by,	visualizations,	322
176	370–383	for pattern perception,
gradient as depth cue,	visual queries and, 352,	188, 206–209
260–262, 288	356, 372–373	power law of practice,
guidelines for displaying	3D displays. See stereoscopic	208, 322
surfaces, 252	displays; task-based	sensory vs. arbitrary
multivariate surface display	space perception;	representations and,
and, 255	virtual-reality (VR)	13, 15–16
oriented sliver textures,	displays	transparency and, 349-350
172–176	time	trajectory mapping, 383
perceptually independent	for attention to change,	transparency
textures, 167–169	353	bistable regions, 205, 207
primary perceptual	choice reaction time,	good continuity and
dimensions, 164	318–319	perception of, 205,
resolution of, 169–170	Fitts' law, 319-320, 321	206
segmentation model, 162,	Hick-Hyman law, 318	interface design and, 205

laciness effect, 205, 207	UFOV. See useful field of view	controls, 404
overlapping data and,	(UFOV)	dependent variables, 403
205–206	UML (Unified Modeling	experimenter bias, 402
toolglasses, 322	Language), 241, 242	getting help, 404
transparency principle for	uncertainty principle for	independent variables, 403
interaction, 345,	perception, 164	number of subjects to use,
349–350	uniform chromaticity scale	403
tree structures	(UCS) diagram (CIE),	task identification, 404
3D visualization and,	109, 110	·
284–286	uniform color spaces	
cone tree, 284, 286	applications, 108	value, in HSV color space,
cushion maps, 255, 256	CIElab uniform color	119
hyperbolic tree browser,	space, 108, 132	VE (visual efficiency) equation,
340, 342	CIEluv uniform color	55
treemaps, 216–217	space, 89–90,	vection (self-motion) effects,
	108–110, 132	290–291, 326–327
treemaps conventional tree views vs.,	color sequences from,	vector fields. See also flow
216–217	132	patterns
	limitations, 109, 111	advection trajectories,
cushion maps, 255, 256	perceived color differences	204
trichromacy theory, 98–99	and, 123	
triggering effect, 222		direction perception and,
tristimulus values (CIE)	uniform shading, 75-77	200–201, 202, 203
generating colors on	unique hues	flow visualization
monitors, 107–108	labeling and, 124	techniques (2D), 201,
overview, 103–104,	in opponent process	203–205
389–391	theory, 112	good continuation and,
transforming chromaticity	uniquely stimulated brain pixels	200, 201
coordinates to and	(USBP), 54–55	tasks for flow
from, 105	univariate maps. See scalar	visualization, 204
trompe l'oeil art, 9	fields or univariate	vector quantities, 25
tuned receptive fields, 159-160	maps	verbal-propositional memory.
tunnel vision, 147	USBP (uniquely stimulated	See long-term memory
2-1/2D sketch processing, 22	brain pixels), 54–55	verbal-propositional processing,
2D flow visualization	useful field of view (UFOV)	353–354
techniques, 201,	cognitive load and, 147	vergence angle, 270
203–205	motion and, 147	vergence eye movements, 363
2D positioning and selection,	overview, 147	vergence-focus problem,
319–320	target density and, 147	273–274
two-handed interaction,	tunnel vision and, 147	vernier acuity
321–322	user interfaces. See interface	antialiasing and, 65-66
	design	defined, 49
	user interrupts, 360–361	optimal display and,
UCS (uniform chromaticity	user studies	65–66
scale) diagram (CIE),	combinatorial explosion,	as superacuity, 47-48
109, 110	403-404	useful aliasing and, 65
102, 110	.00 .01	actual annuality array oc

view direction	binocular viewing and, 48	structure diagrams,
canonical silhouettes, 235,	chromatic spatial	302–303
236	sensitivity, 62	visual momentum in
canonical view, 230	defined, 47	animation, 311–312
depth in pictures seen from	distance from fovea and,	visual long-term memory,
the wrong viewpoint,	51	369–370
262–265	distribution and the visual	visual momentum, 311–312
frames of reference,	field, 49–53	visual monitoring strategies,
333–337	eye chart demonstrating,	365–366
image-based object	51, 52	visual processing
recognition and, 228	higher-than-device	interfaces with other
judging the up direction,	resolution and, 48	cognitive processes,
292–293	illustrated, 49	22
landmark creation and,	low-frequency contrast	low-level, relative nature
331–332	sensitivity, 60–61	of, 94
map orientation, 337–338	optimal display and, 62	model of, 20–22
structure-based object	simple, 47–49	neural pathways involved
recognition and, 233	superacuities, 47–48,	in, 11
vigilance tasks, 324	65–66, 273	of objects, 257
virtual eye separation, 276–279	temporal frequency, 61–62	retina image and, 39–40
virtual-reality (VR) displays	visual angle, 40	Stage 1: extracting low-
augmented-reality systems	visual buffer. See iconic memory	level properties,
vs., 45	visual clusters, preattentive	20–21
Go-Go Gadget technique,	processing and, 155	Stage 2: pattern
323, 324	visual efficiency (VE) equation,	perception, 21–22
lag between hand	55	Stage 3: sequential goal-
movement and visual	visual environment	directed processing,
feedback, 319-320	ecological optics, 30-32	22
lightness constancy and,	figure and ground	value of color processing,
87	perception, 196–198	116
optics in, 45, 46	optical flow, 32-33	verbal-propositional
overview, 68	paint model of surfaces,	processing vs.,
perspective coupled to	35–38	353–354
head movement for	surrounds of monitors,	visual processing channel,
HMDs, 265	90–93, 95	167–168
for phobia desensitization,	texture, 33-34	visual queries. See also problem
293	visible light, 30	solving with
self-motion perception and	visual field of view, 50-51	visualizations
frame rate, 326-327	visual languages	constructing, 372–373
virtual hand/physical hand	animated, 312–315	patterns, 375-376
mismatches, 323	development of, 301	perception as sequence of,
visible light spectrum, 30, 31	examples of differing	356
visual acuities. See also specific	arbitrariness, 6, 7	visualizations' support for
acuities	flowcharts, 302	thinking and, 352

visual search. See also	nonvisual memory systems	visualization techniques and
interactive	and, 353-354	systems
visualization;	object file concept,	child studies, 401–402
preattentive	255–257, 356, 371	cognitive psychology, 397
processing	overview, 352-354	cross-cultural studies, 401
as benefit of visualization,	properties, 352–353	practical problems in
145–146	spatial information in,	conducting user
fovea-center attentional	357–358	studies, 402–404
field and, 146	as system of components,	psychophysics, 394–397
iconic memory and,	353	research goals, 393-394
148–149	visualization. See also	statistical exploration,
image-based object	interactive	400–401
recognition and, 232	visualization; thinking	structural analysis,
"mantra" for behavior and	with visualizations	398–400
interfaces, 317	advantages of, 2–4	V(λ). See human spectral
parsing rate for, 145	arguments against treating	sensitivity function
preattentive processing	as science, 5–6	voltage, in gamma function, 84,
and, 149–158	color lessons important to,	92
of tactical map displays,	143–144	VR. See virtual-reality (VR)
145, 157–158	continuous surfaces in,	displays
three-stage model of	243–244	
perception and, 188	culturally embedded	
tunnel vision and, 147	aspects, 16	wagon-wheel effect, 219
UFOV for, 147	defined, 2	walking navigation metaphor,
visual stress, 62, 63	direct perception and	328, 329, 330, 377
visual thinking. See problem	problems for theory	wayfinding
solving with	development, 19–20	categorical knowledge for,
visualizations;	goal for science of, 23	331
thinking with	linking computer-based	cognitive spatial map for,
visualizations	analysis with,	330, 331, 332–333
visual working memory	380–383	coordinate knowledge for,
amodal control memory,	maps for enhancing,	331
353	338	declarative knowledge for,
attention and, 353,	of operations, 26	330, 331
359–363	perceptual evaluation of	defined, 330
capacity, 352, 355-356	techniques and	dual coding theory and,
central executive in, 353	systems, 393-404	330
change blindness and, 357	role in cognitive systems, 2	landmarks and, 331-332
defined, 352	stages of, 4-5	procedural knowledge for,
disruption of, 353-354	standardization and, 386	330, 331
gist stored in, 356-357	tasks for flow	stages of, 330
glyph design and, 355-356	visualization, 204	terminology diversity for,
long-term memory and,	visual search as benefit of,	330
367–368	145–146	Weber's law, 88-89

"what" system of pattern
perception, 22
whisker plots, 184
white
chromaticity coordinates of
equal-energy white,
106
CIE standard illuminants,
106
reference white in CIE
standard, 89
reference white used by

brain, 87

reflection and, 88, 89
Wingman's view, 336
words. See images vs. words;
links between images and words
world-in-hand navigation
metaphor, 328, 329

specular vs. nonspecular

yellow-blue channel described, 110

illustrated, 111 properties, 113–116 saturation and, 118

zooming
intelligent, 340
magnifying windows vs.,
377–379
multiple-window technique
for, 344–345
rapid zooming techniques,
342–344