

Index

- abductive logic 10
 - discourse interpretation 51–52
 - interpretation of syntax 52–53
 - SHRUTI structured connectionist model 55–59
- Aboitiz–García Hypothesis (AGH) 138–139, 142–146
 - synthesis with MSH 148, 149–152, 163–167
- abstract language
 - development of 39–41
 - roots in action and experience 39–41
- Aché people (Paraguay) 105–106
- action
 - as goal-directed movement 17
 - communicative 21
 - complex action analysis 22–23
 - grammar of 42–43
 - integration with attention and scene description 309–310, 319–322
 - praxic 21
 - roots of abstract language 39–41
 - shared understanding of 469
- action and gesture, leading to language 491–493
- action-based representations of linguistic input 317–319
- action-grammar analogy hypothesis 429, 430–431
- action initiation, cortical site activation 121
- action-language model, computational framework 448, 457–464
- action-language re-use hypothesis 460–462
- action-oriented attention 306, 308
- action-oriented neurolinguistics 150, 163–167
- action-oriented perception 296–297, 298
- action patterns, analysis 38
- action planning
 - action constructions 38–39
 - activities involved 33, 37–38
- action production, underlying neural mechanisms 116–121
- action recognition 9
 - and mirror neurons 17–19
 - and MSH 199–200
 - as communication 23–24
 - based on movement generation mechanisms 199–201
 - DMP approach 199–200
 - underlying neural mechanisms 123–127
- action recognition and generation 177, 178, 337–338
 - and language 338–341
 - in the mirror system, 501
 - mirror system in dorsal streams 261
- action recognition parity 23–24
- action schema assemblage, tuning effects 38–39
- action sentences 42–43
- action sound recognition 150, 164–165
- action systems, link with language production 116
- action verbs 348–349
 - causal complexity 348
 - cross-linguistic diversity of meaning 349
 - diversity of subcategories (English) 352, 365
 - neuroanatomical substrates 347–348, 356, 358–362
 - processing 164, 165–166
 - representation in frontal regions 358–360
 - representation in parietal regions 358, 360–361
 - representation in temporal regions 358, 361–362
 - semantic classes 348–349
 - semantic properties 347–348
 - specialized manner verbs 349
 - support in Broca's area 365
 - transitive and intransitive 348
- adjectives, diversity of subcategories (English) 352
- affordance learning/emergence model (GAEM) 401–402, 408–410
- affordances
 - learning by infants 469–473
 - recognition of 6
- African/non-African languages, comparison of features 83–84
- agents understanding, folk theory of 65
- AGH *see* Aboitiz–García Hypothesis
- agrammatism 164, 165–166
- AI *see* artificial intelligence; robotics
- AIP (anterior region of intra-parietal sulcus)
 - relations with F5 and PF 12–13, 15–17

Cambridge University Press

978-0-521-84755-1 - Action to Language via the Mirror Neuron System

Edited by Michael A. Arbib

Index

[More information](#)

Index

535

- role in grasping 10–14
- American Sign Language *see* ASL; sign language
- anchored subscene
 - definition 291, 292
 - interface between vision and language 334–337
 - SVSS model of development 308–311, 311–315
 - see also* minimal subscene
- anterior cingulate cortex, roles in vocalization
 - and speech 160–163
- ape communication study
 - expression of intended actions and goals 525–526, 527
 - intentional action, language and mirror neurons 526
 - intentionality and the phylogeny of language 525–528
 - lexigram communication 525–526, 527
 - monkey mirror neuron capabilities 526–527
 - participants and background 525
 - species differences between monkeys, apes and humans 526–527
 - use of lexigrams to represent prior intent 527–528
 - use of symbolic combinations 525–526, 527
 - use (or not) of symbols to encode intended action 526–527
- apes
 - observation and imitation skills 512–513
 - protolanguage 66–67
 - role of conversational repetition 519–520
 - see also* individual species and great apes
- argument structure constructions 350–356
 - assembly in Broca's area 365
 - body-part possessor alternation 353–355
 - causative constructions 355–356
 - cross-linguistic diversity 355–356
 - ditransitive construction 351–352
 - division between constructional and verb meanings 362–364
 - Grammatically Relevant Semantic Subsystem Hypothesis 351–355
 - in early language development 365–367
 - locative alternation 352–353
 - meanings associated with 350, 351
 - morphosyntax 351, 352
 - neuroanatomical substrates 347–348, 362–365
 - range of types 350, 351
 - relation between verbs and constructions 350, 351
 - resemblance to minimal scenes 350, 351
 - reversative *un-* prefixation 355
 - semantic properties 347–348
- articulatory gestures (goal-directed vocal tract actions) 216–218
 - coherence of 220, 224–228
 - coupling relations 220, 226–228
 - multi-gestural segments 234–236
 - organ hypothesis for particularity 221–224
 - point attractor system 218
- role in phonological evolution 243–244
- articulatory phonology framework 216–218
- artificial intelligence (AI)
 - event recognition in dynamically changing scenes 327–328
 - HEARSAY-II model 302–303
- artificial systems model for human-like cognition 424
 - computational modeling 426–427
 - concepts from the Mirror System Hypothesis 426
 - embodiment of artificial systems 425
 - methodology 425–427
 - role of development in skills acquisition 425–426
 - role of imitation 426
 - see also* computational framework for action-language model
- ASL (American Sign Language)
 - classifier verbs 118–120
 - determinants of hand configuration 112, 118
 - lexical signs derived from non-lexical gestures 127–128
 - minimal pairs 111, 112
 - phonology 111–113
 - possible inverse-forward models 128–129
 - sign iconicity and underlying neural systems 118–120
 - whispering 115–116, 117
- assisted imitation
 - and early word learning 491
 - caregiver practices 469–473, 493–494
 - correspondence problem 483–484
 - in infant development 469–473
 - transfer of skill problem 483–484
- attention
 - action-oriented 306, 308
 - and the minimal subscene 289–291, 298, 300, 338–341
 - development of minimal subscene 306, 308
 - goal-directed 306, 308
 - integration with scene description and action 309–310, 319–322
- audiovisual mirror neurons, action sound
 - recognition 150, 164–165
- auditory cortices, activation in sign language perception 123
- auditory dorsal streams 256–258, 260–261
- auditory input, mirror neuron responses 28
- auditory mirror neurons 274
- auditory system
 - human and macaque homologues 148, 158–160
 - 'what/who' and 'where' pathways 148, 150, 158–160, 163–165
- auditory ventral streams 256–259
- baboons, hunting behavior 102
- Baddely–Hitch model of working memory 302
- basis behaviors *see* movement primitives

- basis function approach to motor learning 180
- behavior sequences
 - hierarchies 101–102
 - program-level imitation 101–102
- belief
 - carrier of information 62–64
 - folk theory of 62–64
 - mediation by 62–64
 - mutual 65
 - transmitter of causality 75–77
- biological parallels to computational theory
 - of MSH 203–207
- bipedalism, evolution of 92
- bonobo (*Pan paniscus*)
 - acquisition of language skills 98
 - imitation of object manipulation
 - strategies 509, 511–512
 - phylogenetic comparison with human and chimpanzee 501–503
 - pragmatic use of repetition in discourse 520–522
 - reference point for human evolution 91–92
 - repetition to coordinate intended action 521, 522–523
 - tool use 96
 - vocabulary acquisition studies 519–520
- brain
 - size and frugivory in primates 92–93
 - size and social intelligence 93–95
 - areas engaged in sign language perception 123–127
 - changes to support language 33, 37–38
 - computer metaphor 48–49
 - evolution to language-readiness 3, 4, 6–10
 - FARS model of the grasping system 10–14
 - generation of sequences and
 - hierarchies 148, 150, 156–157
 - language capacity of each hemisphere 32–33
 - mechanisms for grasping 10–14
 - site activation during action imitation 121
 - site activation during pantomime production 121
 - sites engaged in sign language production 121, 122
 - sites engaged in speech production 121, 122
 - specialization for language 42–43
 - see also* human brain; language-ready brain
- brain evolution, emergence of first-order features 77
- brain imaging data, link to underlying
 - neural networks 20–21
- British Sign Language (BSL), perception 123–126
- Broca's area 4, 9
 - activation in production of language 20, 116–118
 - activation in recognition of manual actions 19
 - activation in sign language perception 124–126
 - activation in sign language production 120
 - activation in signing tool use 119–120
 - activation in spoken and signed
 - language 116–118
- adaptation for language performance 5–6
- assembly of argument structure constructions 365
- homologies in the macaque brain 137, 138–139, 145, 146, 152, 164, 165–167
- interaction among dorsal and ventral streams 265–266
- language coding and assembly 164, 165–166
- mirror neurons for manual action 516–519
- mirror system homologue of F5 in
 - the macaque 21–22
- modality-independent aspects of language 118
- role in imitation of manual actions 120
- role in language ontogeny and phylogeny 516–519
- role in linguistic processing 258–259
- role in sentence production 365
- role in speech production 261
- role in working memory tasks 138–139, 144–146
- support for nouns and verbs 365
- canonical neurons
 - discovery of 503–504
 - for grasping 14–15
- capuchin monkeys, hunting behavior 102
- caregiver practices
 - and early word learning 491
 - assisted imitation 469–473, 493–494
 - attuning infants to the environment 469
 - joint understanding 488–490
 - perceiving how others perceive 488–490
 - resolving ambiguity 490–491
 - responses to infants misunderstandings/
 - attempts 488–490
 - role of educating attention 469–473
 - role of extensive teaching in humans 487–490
- caregiver practices (naturalistic investigations) 473–484
 - assessing consensus or shared understanding 475–476
 - attention-directing gestures 474–475
 - becoming 'like the other' 483–484
 - caregiver response to infant's attempts 473, 482–483
 - collection of attention-directing interactions 474–476
 - correspondence problem for imitation 483–484
 - cross-cultural caregiver practices 484
 - embodiment to aid imitation 474–475
 - future challenges for research 484
 - hypotheses tested 473
 - infants attempts to imitate actions 473, 482–483
 - mirror system grounding for imitation 483–484
 - orange peeling 480–482
 - points and looks 474–475
 - pop beads (effectivities and affordances) 476–478
 - qualitative examples of assisted imitation 476–482
 - resolving ambiguity 482–483
 - sample and data collection 473
 - shows and demonstrations 474–475
 - targets of attention 474

- transfer of skill problem for imitation 483–484
- vibrating toy (sequence of actions) 478–480
- causal association, emergence of 75–77
- causality, folk theories of 61–62
- child development
 - coherence relations between words 80–81
 - false-belief task performance 383–384
 - holophrastic stage 79–80
 - intentionality in language development 524–525
 - language abilities 6
 - mechanisms underlying action, imitation
 - and language 424
 - pantomime recognition 418–419
 - pragmatic use of repetition in discourse 520–522
 - repetition to coordinate intended action
 - 521, 522–523
 - role of imitation in learning 22–23
 - seriated nesting cups experiment 428–431
 - sign language acquisition process 129
 - Theory of Mind abilities 374, 375–376
 - Theory of Mind and related linguistic
 - expression 383–390
 - two-word phase 66–67
 - see also* caregiver practices; infant development
- chimpanzee (*Pan troglodytes*)
 - acquisition of linguistic skills 97–98
 - acquisition of sign language 97–98
 - costs and benefits of hunting 104–105
 - cultural variation in tool use 92, 95–97
 - cultural variation in traits 95–97
 - food-finding abilities 92–93
 - gestural communication in the wild 97–98
 - hunting behavior 102–105
 - hunting success and number of hunters 104–106
 - imitation and understanding 99–101
 - imitation of object manipulation strategies
 - 509, 511–512
 - meat in the diet 102, 103, 104–105
 - meat-sharing in the wild 102, 104–105
 - newborn imitation 507
 - observation and imitation in cultural
 - transmission 510–511
 - observation and imitation skills 512–513
 - phylogenetic comparison with human
 - and bonobo 501–503
 - pragmatic use of repetition in discourse 521–522
 - range of prey species 102–105
 - reference point for human evolution 91–92
 - simple imitation system 22–23
 - social aspects of hunting 104–105
 - social learning 96, 97
 - social structure of groups 97
 - theory of mind issue 99–101
 - tool use 22–23, 92
 - use of tactical deception 94–95
 - vocalizations 96, 97–98
 - within-group social behaviors 96, 97
- cognition
 - folk theory of 65
 - incremental development 59–60
 - reconstructing the origins of 91–92
- cognition and reasoning, influence on minimal
 - subscene 295–296
- cognitive evolution, and language evolution 106
- cognitive structures 6–8
- collective intentionality 65
- communication
 - evolution of voluntary control over 30
 - integrated multi-modal nature 5–6, 25–26
 - open-ended and closed systems 5–6, 25–28
 - role of grammar 80–81
- communicative action 21
- complex action
 - analysis 22–23
 - generation using movement primitives 196–202
 - recognition 199–201
- complex behavior, use of hierarchical HMM 202
- complex imitation 22–23
 - system for grasping 25–26
- complex motor skills, learning process 198–199
- composite event structure 75–78
- composite model for human cognitive correlates to action,
 - imitation and language 424
- compound nominals 66–67
- computational approach
 - motor control and motor learning 177, 178–181, 182
 - to MSH language evolution 207–208
- computational framework for action-language
 - model 448, 457–464
 - action-language re-use hypothesis 460–462
 - attention-directing interactions 458–460
 - lexical grounding on sub-symbolic
 - knowledge 457–458
 - relevance to Mirror System Hypothesis 464
- computational model for action-language re-use
 - hypothesis 431–437
 - category learning 433–434
 - cell assembly concept 432, 433
 - decompositional approach to knowledge
 - representation 431–432
 - learning framework 432–436
 - learning of temporal sequences 434, 435
 - multiple constraints satisfaction
 - framework 436–437
 - storing temporal dependencies 433, 434–436
- computational theory of MSH
 - biological parallels 203–207
 - complex action generation 196–202

Cambridge University Press

978-0-521-84755-1 - Action to Language via the Mirror Neuron System

Edited by Michael A. Arbib

Index

[More information](#)

538

computational theory of MSH (cont.)
 see also dynamic movement primitives (DMPs);
 movement primitives

computer-based speech understanding, HEARSAY-II
 model 300, 302–303, 304

computer metaphor for the brain 48–49

conceptual knowledge organization
 Convergence Zone (CZ) theory 356–358, 362
 Similarity-in-Topography (SIT) principle
 357–358, 362

conjunction (property of logic) 50

connectionist level of processing 48–49
 links with symbolic level 55–59
 range of models for 48–49, 55–59

consonant gestures 227, 228–234

Construction Grammar 38–39, 331–333, 347–348
 action verbs 347–349
 argument structure constructions 347–348, 350–356
 comparison with generative grammar 331–333
 early language development 365–367
 language evolution 367

contradiction recognition (property of logic) 50

Convergence Zone (CZ) theory 356–358, 362
 division between constructional
 and verb meanings 362–364
 predictions for neuroanatomical substrates 362–365

cooperative computation 296
 in relation to HEARSAY and VISIONS 300, 303
 model of language perception and production 334–338
 VISIONS model for visual scene analysis 299–301

coordinated control program 296–297, 298

cross-linguistic diversity
 argument structure constructions 355–356
 conceptual space of manner-of-motion 349, 362
 in neuroanatomical substrates 362
 meaning of action verbs 349

cultural learning, role of imitation and observation 505–508
 see also human cultural learning

cultural variation
 in chimpanzee tool use 92
 in traits in great apes 91–92, 95–97

culture, definitions of 95 *see also* human culture

CZ theory *see* Convergence Zone (CZ) theory

Darwin, Charles 92

deception
 and theory of mind in nonhuman primates 94–95
 evolution of 100–101
 use by primates 94–95

defeasibility (property of logic) 50–51

definite references, types of 51–52

desired trajectory approach to motor learning 179–180

direct realist theory of speech perception 114–115

discontinuous elements in syntax, emergence of 71–72

Index

discourse, syntax of 80–81

discourse and interaction, before language 80–81

discourse coherence structure 80–81

discourse interpretation
 breakdown of structure 53–54
 by abduction 51–52
 definite references 51–52
 discourse as a purposeful activity 54–55
 goals of the speaker 54–55

discrete movement
 brain areas activated 203–205
 distinction from rhythmic movement 203–205
 separation from rhythmic movement 199–200
 superposition with rhythmic movement 197

discrete reaching movements, dynamic
 system for 182–186

distributed localization of schemas 300, 303

DMPs *see* Dynamic Movement Primitives

dorsal and ventral streams
 competition between 267–268
 cooperation between 265–267

dorsal ‘sensory-motor’ streams 256–258, 260–261,
 262–265
 mirror system in 261

duality of patterning
 in language 215–216
 in sign languages 111

dynamic motor primitives, biological
 realization 205–206

Dynamic Movement Primitives (DMPs) 177,
 178, 180–181, 182
 approach to action recognition 199–200
 canonical system 182–186
 coding for complex movements 187
 comparison with MSH for imitation 187
 for imitation learning 178, 187–191
 limit-cycle systems 182–186
 modeling approach to MSH language
 evolution 207–208
 motor command generation 181–182
 motor planning 182–186
 movement imitation and recognition 178, 187–196
 output system 182–186
 parameter comparison method of movement
 recognition 178, 191–193, 194–195
 phase variable 185–186
 phase velocity 185–186
 point-attractive systems 182–186
 potential for complexity 186
 predictive method of movement recognition 178,
 191–193, 194–195
 see also movement primitives

Dynamic Programming
 and Markov decision processes (MDPs) 198–199

- approach to motor learning 178–179
 - movement sequencing 198–199
- dynamic scene description, visual attention
 - pilot study 322–327
- dynamic system
 - for discrete reaching movements 182–186
 - for rhythmic movements 182–186
- dynamic systems theory
 - biological evidence to support 203–205
 - for movement primitives 178, 180–181, 182
- ecological intelligence 92–93
- effectivities
 - development of 6
 - learning by infants 469–473
- emulation, distinction from imitation 99–101, 510
- event apprehension and sentence formation 316–319
- event recognition
 - artificial intelligence research 327–328
 - in dynamically changing scenes 327–328
- expanding spiral doctrine 25–28
 - protosign and protospeech 113–114
- eye movements and language, review
 - of studies 316–319
- F5, relations with AIP and PF 12–13, 15–17
- F5 mirror neurons, triggers for discharge 14–15
- FARS model 10–14, 148–152, 320, 328–329
- first-order behavior, emergence of 77
- first-order logic 49–51
- folk psychology 10
- folk theories
 - of belief 62–64
 - of causality 61–62
 - of cognition 65
 - of goals (intentionality) 64–65
 - of how agents understand 65
 - of joint action (collective intentionality) 65
- food-finding abilities in primates 92–93
- food sharing
 - among chimpanzees 102, 104–105
 - among lions 105–106
 - among ravens 105–106
 - among social animals 105–106
 - among vampire bats 105–106
 - reciprocal altruistic behavior 105–106
 - tolerated theft 106
- forward and inverse models
 - of motor control 414–418
 - in the control of grasping 320, 328–329
 - link to motor control 320, 328–329
 - see also* IFMPs (inverse-forward model pairs)
- French, constraints on relative clauses 73
- frontal regions, representation of action verbs 358–360
- frugivory in primates, and brain size 92–93
- GAEM *see* grasp affordance learning/emergence model
- generative grammar, comparison with constructive
 - grammar 331–333
- generative-recognition model for movement
 - 187, 193–196
- genetic influences over Theory of Mind
 - 374–376, 391–392
- gestural communication
 - emergence of 75–78
 - in captive-reared chimpanzees 97–98
 - in language evolution 106
 - in wild chimpanzees 97–98
 - possible evolution of phonology 113–114
- gestural score 219–220, 222, 223
- gestural task-space, in speech production and perception
 - 241–243
- gestures (manual and facial)
 - and syntax evolution 215–216
 - association with IFMPs 269–272
 - link from iconic to symbolic 215–216
 - role in language comprehension 269–272
- gist of the scene 293–295
 - in VISIONS model 299, 300, 301
- gist extraction, visual attention pilot study 322–327
- glottal gestures 234–236
- goal-directed attention 306, 308
- goal-directed behavior, mirror system response
 - 501, 515 *see also* intentionality
- goal-directed imitation 429–430
- goal-oriented scene perception 293–296
- goals, folk theory of 64–65
- gorilla (*Gorilla gorilla*)
 - cultural variation in traits 96–97
 - divergence from the hominoid line 502
 - hierarchical behavior sequences 101–102
 - recursive behavior 24–25
 - reference point for human evolution 91–92
 - tool use 96–97
- grammar
 - Minimalist Program 332, 333
 - role in communication 80–81
 - see also* construction grammar; generative grammar
- grammar constructions, link to visual
 - scene schemas 334
- grammar for action 38–39
- grammar for language, related to actions 38–39
- grammar of action 42–43
- Grammatically Relevant Semantic Subsystem Hypothesis
 - (GRSSH) 351–355
 - division between constructional and
 - verb meanings 362–364
 - predictions for neuroanatomical substrates 362–365
- grasp affordance learning/emergence model (GAEM)
 - 401–402, 408–410

- grasping
 - conscious recognition of the object 147–149
 - development in humans 397–400
 - ‘Joy of Grasping’ feedback reward 399–400, 403–404
 - possible mirror neuron system in humans 397
 - reshaping of the hand 147–149
 - ‘what’ pathway 147–149
 - ‘where/how’ pathway 147–149
- grasping action production, compared to sign language
 - production 112, 118
- grasping system, FARS model 12–13
- great apes
 - cultural variation in traits 95–97
 - evolution of social cognition 100–101
 - imitative behavior 98–99
 - learned, culturally varied behavior 91–92
 - level of language readiness of the brain 98
 - results of natural selection 91–92
 - theory of mind issue 99–101
 - use of symbolism 98
 - see also individual species and apes*
- Gricean non-natural meaning 10
 - evolution of 61–66
 - folk theories of causality 61–62
 - folk theory of belief 62–64
 - folk theory of cognition 65
 - folk theory of goals (intentionality) 64–65
 - folk theory of how agents understand 65
 - folk theory of joint action
 - (collective intentionality) 65
 - intention of the speaker 61
 - means-end analysis 66
 - mediation by belief 62–64
 - near-Gricean non-natural meaning 64–66
 - steps from natural meaning 61–66
- GRSSH *see* Grammatically Relevant Semantic Subsystem Hypothesis
- HEARSAY model for speech understanding
 - 300, 302–303, 304
 - blackboard architecture 300, 302–303
 - possibility for distributed localization
 - of schemas 300, 303
- hidden Markov model (HMM)
 - for movement recognition (and generation)
 - 199, 200–201
 - hierarchical HMM for complex behavior 202
- hierarchical behaviors
 - abstraction from motor primitives 202
 - and MSH 202
 - and recurrent neural networks 202
 - development of 202
- hierarchical HMM, for complex behavior 202
- hierarchical structure emergence 75–77
- hierarchies and sequences, generation in
 - the brain 148, 150, 156–157
- HMM *see* hidden Markov model
- holology 136
- holophrases
 - in modern adult language 79
 - in protolanguage 4–5, 34–37
- holophrastic stage
 - in child development 79–80
 - in language evolution 78–81
- hominid evolution
 - social cognition 100–101
 - theory of mind 100–101
- hominid protolanguages 23–24
- Homo erectus*
 - evolution 74–75
 - language capabilities 77–78
 - protolanguage 4–5, 34–37
- Homo sapiens*
 - emergence of language 34–37
 - protolanguage 34–37
 - separate linguistic communities 367
- Homo sapiens sapiens*
 - competitive advantages of language 77–78
 - culture readiness 82–83
 - emergence of modern language 77–78
 - emergence of symbolic behavior 81–83
 - emergence of syntax 81–83
 - origin of fully modern language 81–84, 85
 - stage of language readiness 81–83
 - timescale for language evolution 81–84, 85
 - timescale of evolution 74–75
- homology, evidence and criteria for 136 *see also* human brain; macaque brain
- homoplastic organs 136
- human brain
 - areas associated with working memory
 - 138–139, 143–146
 - auditory system homology in the macaque
 - 148, 158–160
 - homology with macaque brain 136–137,
 - 138–139, 145, 146, 163–167
 - imaging data link to underlying neural networks 20–21
 - mirror system for grasping 3, 4
 - regions involved in grasp observation 149
 - regions involved in object recognition 149
 - relative size of frontal lobe 139
 - speech production area 3, 4
 - see also* brain; language-ready brain
- human cultural evolution 529–530
 - and the brain 503–504
 - and the mirror system 501
 - cause of language transition 21–22
 - connection between ontogeny and phylogeny 504

Cambridge University Press

978-0-521-84755-1 - Action to Language via the Mirror Neuron System

Edited by Michael A. Arbib

Index

[More information](#)

Index

541

- culture readiness in *Homo sapiens sapiens* 82–83
 - in the last five million years 513–515
 - role of mirror and canonical neurons 503–504
- human cultural learning
 - cumulative quality 512
 - imitation of object manipulation
 - strategies 509, 511–512
 - intergenerational transmission of tool culture 507–508
 - neural foundations 529–530
 - object combination to yield complex structures 512
 - symbolic transmission systems 514
- human culture
 - complexity of human neural programs 514–515
 - cumulative quality 513–514
 - influences over Theory of Mind 374–376, 391–392
- human evolution
 - common ancestor with the macaque 136, 137, 138–139
 - evolution of neurocognitive adaptations 367
 - information from nonhuman primates 91–92
 - phylogenetic comparison with chimpanzee
 - and bonobo 501–503
 - search for ancestral language traits 501–503
 - see also* human cultural evolution; language evolution
- human mirror system
 - in the frontal lobes 359–360
 - in the parietal lobes 360–361
 - in the temporal lobes 361–362
 - see also* mirror system for grasping in humans
- humans
 - action sound recognition 150, 164–165
 - extensive teaching by caregivers 487–490
 - imitation in ontogeny of tool use 507–508
 - open communication systems 5–6
- hunting behavior
 - baboons 102
 - capuchin monkeys 102
 - chimpanzees 102–105
 - nonhuman primates 102–105
 - social aspects for chimpanzees 104–105
 - success and number of hunters 104–106
 - tolerated theft 106
- hypothesis testing
 - in visual perception 250
 - speech perception model 250–256
- IFMPs (inverse-forward model pairs)
 - in speech perception 252–256, 257–258, 265, 270, 272–275
 - in sign language 128–129
 - in speech 128–129
 - activation by language perception 262–263
 - associated with auditory-only speech
 - perception 270, 272–275
 - associated with facial and manual gestures 269–272
 - evidence for forward and inverse models 262–263
 - implementation by the mirror system 128–129, 252–258, 263
 - implementation in the dorsal streams
 - 257–258, 262–265
 - types of 263–264
 - see also* forward and inverse models
- ILGM (infant learning to grasp model)
 - 401–402, 403–407, 408
- imagistic manual gesticulations 259
 - activation of words for motor acts 266–267
 - bridge between dorsal and ventral streams 266–267
 - role in language comprehension 268
- imitation
 - and evolution of mirror neurons 18–19
 - and mirror neurons 505–506, 509, 510–511, 515
 - and theory of mind 99–101
 - and understanding 99–101
 - Broca's area involvement 120
 - complex 6–8, 22–23, 24–25
 - correspondence problem 483–484
 - cortical site activation 121
 - definition of 98–99
 - distinction from emulation 99–101, 510
 - goal-directed 429–430
 - grounding in the mirror system 483–484
 - hierarchical behavior sequences 101–102
 - in chimpanzees 22–23
 - in development of object-oriented manual
 - activity 508–510
 - in human and non-human primates 487–490
 - in language evolution 21–22
 - in monkeys 22–23
 - in ontogeny of tool use 507–508
 - learning in human children 22–23
 - link to mirror system for grasping (humans) 19
 - nature of 'true' imitation 510
 - neural and behavioral development
 - hypotheses 508–515
 - newborn imitation in chimpanzees 507
 - newborn imitation in humans 505–506
 - Piaget's theories 505–506, 509, 510–511
 - program-level 101–102
 - simple 6–8, 24–25
 - social context 98–99
 - transfer of skill problem 483–484
 - see also* assisted imitation; observation and imitation; repetition; seriated nesting cups task model
- imitation and observation, role in cultural
 - learning 505–508
- imitation learning 424–425
 - comparison of MSH and DMPs 187
 - in apes, scientific contradiction 515
 - with dynamic movement primitives 178, 187–191

infant development
 assisted imitation from caregivers 469–473,
 493–494
 communicative actions leading to words 491–493
 learning affordances 469–473
 learning effectivities 469–473
 see also caregiver practices
 infant learning to grasp model (ILGM) 401–402,
 403–407, 408
 inferior frontal gyrus (BA 44), role in language
 perception 124–126
 inferotemporal pathway (ventral stream) 147–149
 intelligence
 definitions of 92–95
 ecological 92–93
 social 93–95, 100–101
 technical 92
 intentional action, mirror system response to 501
 intentional (intelligent) behavior, links
 to neurophysiology 48–49
 intentionality
 and mirror systems 515
 behavioral and cognitive features 523–524
 collective 65
 folk theory of goals 64–65
 importance in language 523–524
 in language ontogeny and phylogeny, 523–529
 mirror neuron encoding 523
 inverse models *see* forward and inverse models; IFMPs
 (inverse-forward model pairs)

 Japanese syntax 70–71, 72–74
 constraints on relative clauses 72–74
 joint action, folk theory of 65
 ‘Joy of Grasping’ feedback reward 399–400, 403–404
 ‘lack of invariance problem’, in speech
 perception model 250–251, 252–256
 language
 and human biological specializations 6–8
 as a biological development 82–83, 85
 as a cultural development 81–83
 as a driver for evolution 6–8
 capacity for metaphorical extension 38–39
 close relation with speech 25–28
 divergence of languages 34–37
 duality of patterning 215–216
 emergence from protolanguage 34–37
 emergence in *Homo sapiens* 34–37
 evolution of human brain to support 164, 165–167
 evolution of language features 34–37
 exploitation of existing brain mechanisms 6–8
 externalization of goal representation 523–524
 importance of intentionality 523–524
 interaction of vocalization and gesture 28–32

neural mechanisms 150, 163–167
 reconstructing the origins of 91–92
 relation to goal-directed action 6–10
 transition from protolanguage 42–43
 language comprehension
 role of temporal cortices 123–127
 see also speech perception model;
 speech production model
 language development (ontogeny) 365–367
 constructionist grammar approach 365–367
 early action sequences and two-word
 utterances 491–493
 prelinguistic to linguistic communication 491–493
 see also language ontogeny and phylogeny
 language evolution (phylogeny)
 components of language 75–77
 constructionist grammar approach, 367
 action/action recognition scenarios 241
 analysis of English language novels 379–383
 ancestral foundations 529–530
 and cognitive evolution 106
 and language universals 83–84
 and nonhuman primate vocalization 5–6
 and symbolic artifacts 81–83
 and the mirror system 501
 and the MSH 9
 belief as transmitter of causality 75–77
 changes in conception of unconscious thought
 379–383
 changes in Theory of Mind over time 375–376
 coherence of articulatory gestures 220, 224–228
 coherence structure of discourse 80–81
 common understanding of action 469
 competitive advantages of modern language 77–78
 components of language 75–77
 composite event structure 75–78
 computational approach to MSH 207–208
 computational theory of 48–49
 early human language 391–392
 emergence of causal association 75–77
 emergence of first-order features 77
 emergence of language 367
 evolution of new functions 241–243
 features of modern language 75–77
 from pantomimic expression 127–128
 gestural communication 77–78
 hierarchical structure 75–77
 holophrastic hypothesis 9–10
 holophrastic stage arguments 78–81
 human neurocognitive adaptations 367
 implications from sign languages 113–114
 in early *Homo sapiens sapiens* 77–78
 in *Homo erectus* 77–78
 integration of perception and action 239–240

- language differentiation 236–237
- learnability 75–77
- metonymy 69, 71–72
- naming 75–77
- parity between production and comprehension 75–77
- particularity of articulatory gestures 221–224
- phylogeny 367
- possible routes and implications 106
- re-organization of existing functions 241–243
- role of perceiving and acting 469
- role of symbolic communication 367
- semantics 75–77
- stages of 21–22
- syntax 75–77
- temporal order of elements 75–77
- text corpus analysis tool 376–379
- theory of mind 75–78
- timescale and relevant dates 74–75
- use of a lexicon 75–77
- vocal and manual gestures 241
- see also* language ontogeny and phylogeny; phonology evolution; syntax evolution
- language features, incremental development 59–60
- language of panic 66–67
- language ontogeny and phylogeny
 - role of Broca's area 516–519
 - role of intentionality 523–529
 - role of mirror neurons 516–529
 - role of repetition 519–523
 - see also* language development (ontogeny); language evolution (phylogeny)
- language parity 21–22, 23–24, 75–77, 140–142
- language perception
 - analysis 6–8
 - cooperative computation model 334–338
 - see also* speech perception model
- language processing models 55–59
- language production
 - analysis 6–8
 - cooperative computation model 334–338
 - link with action systems 116
 - see also* speech production model
- language-ready brain 42–43
 - Aboitiz–García Hypothesis 138–139, 142–146
 - basis for 424
 - emergence of 106
 - evolution to support language 164, 165–167
 - in great apes 98
 - in *Homo sapiens sapiens* 81–83
 - mirror neuron system 129
 - Mirror System Hypothesis 138–139, 140–142
- language skills acquisition, bonobos 98
- language system, multimodality 164, 165
- language transition, as cultural evolution 21–22
- language universals, in early *Homo sapiens sapiens* 83–84
- languages, construction grammar (grammatical categories) 38
- learnability, acquisition of language capabilities 75–77
- learning, to refine motor primitive sequences 198–199
- lexical development
 - and caregiver practices 491
 - perceiving reference 490–491
- lexicon
 - evolution of support mechanisms 138–139, 142–144
 - underlying brain support features 164, 165–167
 - use of 75–77
- linguistic communities in *Homo sapiens* 367
- linguistic input, action-based representations 317–319
- linguistic representation of action, in the mirror neuron system 347–348
- linguistic skills acquisition, chimpanzees 97–98
- lions, food sharing and hunting strategies 105–106
- lip reading, brain activation 260–261
- logic
 - as the language of thought 49–51
 - conjunction 50
 - defeasibility (nonmonotonicity) 50–51
 - first-order 49–51
 - modus ponens 50
 - predicate-argument relations 50
 - properties of 49–51
 - propositional 49–51
 - recognition of obvious contradictions 50
 - universal instantiation (variable binding) 50
- long-distance dependencies, in syntax evolution 72–74
- long term memory (LTM), role in SSVS model 311–314
- macaque auditory system
 - human brain homology 148, 158–160
 - 'what' and 'where' pathways 148, 158–160
- macaque brain
 - action representation in the frontal regions 358
 - action representation in the parietal regions 360
 - action representation in the temporal regions 361
 - action sound recognition 150, 164–165
 - brain structures for grasping 10–14
 - homologues of Wernicke's area 152, 154–155
 - homologues of Broca's area 152, 164, 165–167
 - homology with human brain 136–137, 138–139, 145, 146, 163–167
 - role of area F5 in grasping 10–14
- macaque mirror neurons
 - for mouth actions 28–29
 - mirror system for grasping 3, 4, 12–13, 14–17
 - responses to auditory input 28

Cambridge University Press

978-0-521-84755-1 - Action to Language via the Mirror Neuron System

Edited by Michael A. Arbib

Index

[More information](#)

544

macaque vocalization

- homology with human speech system 163
- motivation to call 161–162
- roles of the anterior cingulate cortex 160–162, 163

Machiavellian intelligence *see* social intelligence

Malagasy language, constraints on relative clauses 73

manual actions, link to speech production 9

manual communication *see* pantomime; sign language

manual gesticulations

- imagistic and non-imagistic 252
- perception of (speech perception model) 260–261
- speech perception cues 252

manual gestures *see* gestures

Markov decision processes (MDPs)

- Dynamic Programming 198–199
- motor primitives 198–199
- Reinforcement Learning 198–199

McGurk-MacDonald fusion effect 240, 251, 267–268, 271–272

MDPs *see* Markov decision processes

means-end analysis 66

mediation by belief 62–64

mental simulation, to infer the intentions of others 418

metonymy 69, 71–72

minimal subscene 289–291, 298, 300, 338–341

- agent, action or object as anchor 291–292
- and sentence formation 316–319
- definition 291–293
- development of 306, 308
- extension to anchored subscene 292
- in the short term memory 291–293
- influence of cognition and reasoning 295–296
- interface between vision and language 334–337
- recognition of objects, actors and actions 295
- resemblance of argument structure
 - constructions 350, 351
- role in scene description process 292–293
- SVSS model of development 308–311, 311–315
- task- or goal-dependent effects 291–292
- unit of recognition 291–293
- visual attention pilot study 322–327
- see also* anchored subscene

Minimalist Program (grammar) 332, 333

mirror neuron system

- cognitive coupling system 241–243
- comparison with sign language 110–111
- evolution of new patterns of organization 241–243
- for action 127–129
- for language 127–129
- inverse-forward models 128–129, 252–258, 263, 320, 328–329
- language-readiness 129
- learning capacities of mirror neurons 12–13, 15–17
- linguistic representation of action 347–348

Index

mediation of speech perception 252–256

model of action recognition 320, 328–329

possibility for sign language 122, 125, 127–129

mirror neurons

- action sound activation 150, 164–165
- activation by non-imagistic manual
 - gesticulations 264–265
- adaptive value of activity 17–19
- and speech perception theories 114–115
- and the structure of the verb 329–331
- auditory information associated with actions 240
- capabilities in monkeys 526–527
- discovery of 503
- encoding of goals of actions 264–265
- for orofacial organs 243
- functions in sign languages 114–116, 117
- hypothesis on role in language ontogeny and
 - phylogeny 527, 528–529
- in monkey culture 513–514
- in speech perception and action 240, 241
- in the macaque brain 3, 4
- macaque frontal regions 358
- possible functions in nonhuman primates 114–115
- recognition of action-object frames 329–331
- role in imitation in newborn humans 505–506
- role in language ontogeny and phylogeny, 516–523
- role in observation and imitation 512–513
- sensory predictor hypothesis 418
- triggers for discharge 14–15

mirror schemas 33, 34, 297, 298

mirror system

- action performance and recognition 501
- and evolution of human culture 501
- and evolution of language 501
- and evolution of tool use 501
- attunement to goal-directed behavior 515
- attunement to intentionality 515
- auditory mirror neurons 274
- cross sensory modality effects 264–265
- grounding for imitation 483–484
- implementation of IFMPs 256–258
- in areas of the dorsal streams 261
- in the dorsal ‘sensory-motor’ streams 256–258
- response to intentional (goal-directed) action 501

mirror system for action

- in human frontal lobes 359–360
- in human parietal lobes 360–361
- in human temporal lobes 361–362

mirror system for grasping 3, 4

- extension into imitation 6–8
- in primates 5–6

mirror system for grasping in humans 418–419

- acquisition of visuomotor frame 401–403
- action prediction capability 401–402

- action recognition and representation
 - 401–402, 410–414
- complex imitation capability 401–402, 414–418, 419
- development of repertoire of grasps
 - 401–402, 403–407, 408
- developmental stages 400–402
- evidence for 19
- existence of 397, 400–402
- forward and inverse models of motor control 414–418
- GAEM 401–402, 408–410
- ILGM 401–402, 403–407, 408
- imitation capability 401–402, 414–418, 419
- link to imitation 19
- link to speech production 19
- mirror neuron repertoire expansion 401–402, 410–414
- MNS model of development 401–402, 410–414
- pantomime recognition 401–402, 418–419
- recognition of object affordances 401–402, 408–410
- training of mirror neurons 401–402
- Mirror System Hypothesis (MSH) 9, 21–22, 138–139, 140–142
 - action-based representations of linguistic input 317–319
 - action recognition 199–200
 - action recognition and generation, and language 338–341
 - biological parallels to computational theory 203–207
 - comparison with dynamic movement primitives 187
 - computational approach to language
 - evolution 207–208
 - contribution of computational modeling 464
 - evolution of language 164, 165–167
 - from simple to complex imitation 24–25
 - generative-recognition model for
 - movement 187, 193–196
 - hierarchical behaviors 202
 - linkage of a verb to its arguments 329–331
 - mirror system evolution for language use 23–24
 - relationship between sign and signified 289
 - role of imitation 22–23
 - stages in the evolution of language 21–22
 - synthesis with AGH 148, 149–152, 163–167
- MNS model of development 401–402, 410–414
- modification, signaling 70–71
- modus ponens (property of logic) 50
- monkey culture, role of mirror neurons 513–514
- monkeys
 - F5 mirror system for grasping 149
 - imitation of object manipulation strategies 509, 511–512
 - mirror neuron capabilities 526–527
 - simple imitation system 22–23
- morphological reanalysis of words 79
- morphosyntax
 - argument structure constructions 351, 352
 - neuroanatomical substrates 365
- motivation to speak, role of the anterior
 - cingulate cortex 162–163
- motivation to vocalize, role of the anterior
 - cingulate cortex 161–162
- motor command generation, dynamic
 - movement primitives 181–182
- motor control
 - computational approach 177, 178
 - feedback from mirror neurons 17–19
 - link to forward and inverse models 320, 328–329
 - movement primitives 177, 178
- motor learning
 - basis function approach 180
 - computational approach 177, 178–181, 182
 - control policies to movement
 - primitives 178–181, 182
 - desired trajectory approach 179–180
 - dynamic programming approach 178–179
 - movement primitives 177, 178, 180–181, 182
 - reinforcement learning approach 178–179
- motor planning
 - to guide actions (speech perception
 - model) 260–261
 - with dynamic movement primitives 182–186
- motor primitive sequences
 - co-articulation 198–199
 - refinement through learning 198–199
- motor primitives
 - abstraction into hierarchical behaviors 202
 - and MDPs 198–199
 - sequencing and superposition 202
- motor schemas 33, 34, 296–297, 298
 - VISIONS model 301–302
 - see also* movement primitives
- motor system, involvement in auditory-only speech
 - perception 270, 272–275
- motor theory of speech perception 114–115
- mouth actions, mirror neuron responses 28–29
- movement generative-recognition model 187, 193–196
- movement imitation *see* imitation; imitation learning
- movement primitives
 - basis function approach 180
 - complex action generation 196–202
 - discrete 186
 - dynamic systems theory approach 178, 180–181, 182
 - identification of 177, 178
 - in Dynamic Programming 198–199
 - in Reinforcement Learning 198–199
 - movement imitation and recognition 178, 187–196
 - parsing complex movements into 199–200
 - possible biological basis 206–207

- movement primitives (cont.)
 - potential for complexity 186
 - range of possibilities for 187
 - rhythmic 186
 - role in motor learning 178, 180–181, 182
 - sequencing to generate complex actions 198–199
 - superposition of discrete and rhythmic movements 197
 - superposition to generate complex actions 196–197
 - see also* dynamic movement primitives (DMPs)
- movement recognition
 - biological possibilities 206
 - parameter comparison method 178, 191–193, 194–195, 206
 - predictive method 178, 191–193, 194–195, 206
 - with DMPs 178, 189, 191–193, 194–195
- movement recognition (and generation)
 - hidden Markov model approach 200–201
 - recurrent neural networks 201
 - spline representation approach 201
 - use of reinforcement learning 201
- MSH *see* Mirror System Hypothesis
- multisensory nature of speech perception 250–256
- mutual belief 65
- naming
 - emergence of 75–77
 - of objects 164, 165–166
- 'narrative momentum', visual attention pilot study 322–327
- natural meaning, steps to Gricean non-natural
 - meaning 61–66
- near-Gricean non-natural meaning 64–66
- neural correlates of language 150, 163–167
- neural networks, generative-recognition model for
 - movement 187, 193–196
- neuroanatomical substrates 356–365
 - action verbs 347–348, 356, 358–362
 - argument structure constructions 347–348, 362–365
 - constructional and verb meanings 362–365
 - Convergence Zone (CZ) theory 356–358, 362
 - cross-linguistic diversity 362
 - morphosyntax 365
 - semantics 362–365
 - similarity-in-topography (SIT) principle 357–358, 362
 - transitive and intransitive verbs 360–361
- neurophysiology, links to intentional
 - (intelligent) behavior 48–49
- newborn imitation
 - in chimpanzees 507
 - in humans 505–506
- Nicaraguan Sign Language 127–128
- non-human primates
 - ability to learn communication systems 5–6
 - action observation and execution 116
 - closed communication systems 5–6
 - gesture systems 5–6
 - hunting of other mammals 102–105
 - possible functions of mirror neurons 114–115
 - reference points for human evolution 91–92
 - tool use 92
 - vocalizations and language evolution 5–6
 - see also* individual species and great apes; primates
- non-imagistic manual gesticulations
 - activation of mirror neurons 264–265
 - role in language comprehension 268
- non-linguistic gesture (Tic Tac) perception 123–126
- non-monotonicity (property of logic) 50–51
- nouns
 - diversity of subcategories (English) 352, 365
 - retrieval and comprehension 164, 165–166
 - support in Broca's area 365
- object and action recognition, visual attention
 - pilot study 322–327
- object naming 164, 165–166
- object recognition, SVSS model 313–314
- observation and imitation
 - comparison of four species 509, 511–512
 - cultural transmission in chimpanzees 510–511
 - object combination comparison in
 - four species 509, 511–512
 - object manipulation strategies 509, 511–512
 - role of mirror neurons 512–513
 - skills in humans and apes 512–513
- ontogeny, clues about phylogeny 504 *see also* language
 - development (ontogeny)
- oral language, syntax 38
- orang-utan (*Pongo pygmaeus*)
 - divergence from the hominoid line 502
 - reference point for human evolution 91–92
 - tool use 96, 97
- oscillator coupling model 227, 228–231
- pantomime 9
 - cortical site activation 121
 - differences to signing 119–120, 121
 - evolution from imitation 6–8
 - evolution into language 127–128
 - evolution of 25–28
 - limitations 242–243
 - link with vocalization 29–32
 - recognition in children 418–419
 - transition to protosign 12–13, 32–34
 - underlying neural mechanisms 119–120, 121, 123–124
- parietal cortex, role in action, speech and sign
 - perception 126–127
- parietal pathway (dorsal stream) 147–149
- parietal regions, representation of
 - action verbs 358, 360–361

Cambridge University Press

978-0-521-84755-1 - Action to Language via the Mirror Neuron System

Edited by Michael A. Arbib

Index

[More information](#)

Index

547

- parity *see* language parity
- perception grammar 33, 37–38
- perceptual schemas 33, 34, 296–297, 298
- PET imaging 20–21
- PF inferior parietal area
 - mirror neurons 14–15
 - relations with F5 and AIP 12–13, 15–17
- phonological loop 302
- phonological-rehearsal loop 138–139, 142–143, 144–146
- phonological structures 6–8
- phonological working memory system 138–139, 143–144, 144–146
- phonology
 - of sign languages 110–114
 - patterning of units 215–216
- phonology evolution 75–77, 215–218, 241–243
 - and language evolution 216–218, 239–240
 - role of articulatory gestures 243–244
- phylogenetic comparison, human, chimpanzee and bonobo 501–503
- phylogeny, clues in ontogeny 504 *see also* language evolution (phylogeny)
- Piaget's theories of imitation 505–506
- planum temporale (PT), role in sign
 - language perception 123–127
- point attractor dynamics, gestural score 219–220
- point attractor models for skilled movements 218
- point attractor system, in articulatory gestures 218
- praxic action 21
- predicate-argument relations (property of logic) 50
- predication, signaling 70–71
- primate vocalization
 - relation to prelanguage 35
 - roles of the anterior cingulate cortex 160–163
- primates
 - knowledge of social relationships 94
 - social intelligence and brain size 93–95
 - see also individual species and non-human primates*
- production grammar 33, 37–38
- program-level imitation 101–102
- propositional logic 49–51
- proprioception, monitoring of sign production 121
- protolanguage 4–5, 23–24
 - evolution 6–8, 25–28
 - holophrases (unitary utterances) 34–37
 - in early *Homo sapiens* 34–37
 - in *Homo erectus* 4–5, 34–37
 - metonymy 69
 - transition to language 34–37, 42–43
 - transition to simple syntax 67–70
 - two-word stage 66–67
 - see also* protosign; protospeech
- protosign 9–10
 - evolution 6–8, 25–28, 113–114
 - dominance by protospeech 113–114
 - link with vocalization 29–32
 - stage in language evolution 21–22
 - transition from pantomime 12–13, 32–34
- protospeech 9–10
 - dominance over protosign 113–114
 - evolution 6–8, 25–28
 - link with gesture 29–32
 - stage in language evolution 21–22
- ravens, food sharing 105–106
- recognition model for movement 187, 193–196
- recurrent neural networks
 - in hierarchical behavior learning 202
- recursive behavior 24–25
- reference perception in infants 490–491
- referential domains, role in spoken language
 - understanding 317–319
- Reinforcement Learning
 - and MDPs 198–199
 - and motor primitives 198–199
 - approach to motor learning 178–179
 - in movement recognition 201
 - movement sequencing 198–199
- relative clauses
 - as universal features of language 83–84
 - constraints in various languages 72–74
- repetition
 - pragmatic use in language 520–522
 - role in language ontogeny and phylogeny 519–523
 - to coordinate intended action 521, 522–523
 - use in discourse by children and bonobos 520–522
- rhythmic movement
 - brain areas activated 203–205
 - distinction from discrete movement 203–205
 - dynamic system for 182–186
 - separation from discrete movement 199–200
 - superposition with discrete movement 197
- robotics
 - caregiver-child interactions 484
 - control policies to movement primitives 178–181, 182
 - development of imitation in robots 484–487
 - imitation and joint attention in language
 - acquisition 424–425
 - interactive learning 484
 - knowing what to imitate 484
 - mapping perceived actions onto own repertoire 485–486
 - training of robots 486–487
 - see also* artificial intelligence; computational theory of MSH
- Russian, constraints on relative clauses 73

- scene description, integration with attention and action
 - 309–310, 319–322
- scene layout, in the VISIONS model 301
- scene perception
 - gist of the scene 293–295
 - goal-oriented 293–296
- schema assemblages, coordinated control program
 - 296–297, 298
- schema networks 33, 34
 - for visual scene analysis 334
 - word linkage 39–41
- schema theory 296–297, 298, 304
 - HEARSAY model for speech understanding 300, 302–303, 304
 - mirror schemas 297, 298
 - roles of schemas in research 297
 - separation of perceptual and motor schemas 297, 298
 - VISIONS model for visual scene analysis 299–301
- schemas, distributed localization 300, 303
- segment-level valences 234–236
- semantic structures 6–8
- semantics
 - division between constructional and verb meanings 362–364
 - evolution of 75–77
 - neuroanatomical substrates 362–365
- sensorimotor sequences, linking to
 - sentences 309–310, 319–322
- sentence
 - action sentences 42–43
 - construction 38
 - evolution of 80–81
- sentence production, role of Broca's area 365
- sequences and hierarchies, generation in the brain 148, 150, 156–157
- sequencing of actions, mechanisms 11–14
- sequencing of movement primitives, to generate complex actions 198–199
- seriated nesting cups experiment (children) 428–431
 - action-grammar analogy hypothesis 429, 430–431
 - children's strategies for combining cups 428–429
 - development of goal-directed imitation 429–430
- seriated nesting cups task developmental path model 446, 447–455, 456, 462–464
 - one pair, two pairs, transfer of the cup 453–455
 - pot strategy 455, 456
 - saliency constrained behavior 451–452
 - size constrained behavior 448, 452–453
- seriated nesting cups task model 438–447, 448
 - architecture and functioning principles 440–442
 - attention module 442
 - cell assembly module 440, 443–445
 - developmental constraints 439, 441
 - feature weights learning 446
 - learning the seriated nesting cups task 439, 445–447, 448
 - pair of humanoid robots 438, 439, 440
 - precedence weights learning 446, 447
 - relation weights learning 439, 446–447, 448
 - simulation environment 438, 439, 440
- sharing *see* food sharing
- short term memory (STM)
 - in the SVSS model 308–311, 311–315
 - linking motor schemas (VISIONS model) 301–302
 - minimal subscenes 291–293
 - three component model (Baddley) 302
 - VISIONS model schemas 299–301, 306
- SHRUTI model of language processing 10
- incremental changes to axioms 59–60
- structured connectionist abduction model 55–59
- sign
 - distinction from the signified 12–13, 33–34, 164, 165–166, 289, 320, 328–329
 - evolutionary domination by speech 113–114
 - neural representation 12–13, 33–34
- sign iconicity, and underlying neural systems 118–120
- sign language
 - acquisition by chimpanzees 97–98
 - acquisition process 129
 - brain activation during comprehension and production 260–261
 - comparison with mirror neuron system 110–111
 - complexity 113–114
 - differences to speech 8–9
 - duality of patterning 111
 - evidence for sign syllables 113
 - implications for language evolution 113–114
 - linear structure and articulators 113
 - linguistic gestures 32–33
 - link between perception and production 114–116, 117
 - minimal pairs 111, 112
 - perceptual targets 115–116, 117
 - phonology 110–114
 - possible inverse-forward models 128–129
 - predominance of speech over 31–32
 - role of mirror neurons 114–116, 117, 122, 125, 127–129
 - signing for viewing 117, 128
 - underlying neural systems 122, 125, 127–129
 - variation in phonological units used 111–113
 - whispering 115–116, 117, 128
- Sign Language of the Netherlands 115–116
- sign language perception
 - differences to speech perception 115–116, 117
 - underlying neural mechanisms 122, 123–127, 127–129
- sign language production
 - activation of Broca's area 20, 116–118, 119

- compared to grasping action production 112, 118
 - cortical sites engaged 121, 122
 - determinants of hand configuration 112, 118
 - differences to pantomimic expression 119–120, 121
 - output monitoring 121
 - proprioceptive monitoring 121
 - underlying neural mechanisms 116–121, 122, 125, 127–129
- signified
 - distinction from the sign 12–13, 33–34, 164, 165–166, 289, 320, 328–329
 - neural representation 12–13, 33–34
- similarity-in-topography (SIT) principle 357–358, 362
 - division between constructional and verb meanings 362–364
 - predictions for neuroanatomical substrates 362–365
- SIT principle *see* similarity-in-topography principle
- social animals, food sharing 105–106
- social cognition, evolution in the great apes 100–101
- social intelligence 93–95, 100–101
- social interaction, and mirror neuron activity 17–19
- social learning, in chimpanzees 96, 97
- social relationships, awareness in primates 94
- speech
 - and gesture 28–32
 - close relation with language 25–28
 - differences to signed language 8–9
 - evolutionary dominance over sign 113–114
 - predominance over signed languages 31–32
- speech development in children, emergence of the syllable 237–239
- speech evolution, choking risk from physical changes 114
- speech perception
 - differences to sign perception 115–116, 117
 - direct realist theory 114–115
 - McGurk effect 240
 - motor theory of 114–115
 - role of mirror neurons 114–115
 - underlying neural mechanisms 123–127
- speech perception model
 - active processing model 250–256, 275–276
 - auditory and visual objects recognition 258–259
 - competition between streams 256–258, 267–268
 - contextual information 251–252
 - cooperation among streams 256–258, 265–267
 - cross sensory modality effects 264–265
 - cues from manual gesticulations 252
 - dorsal ‘sensory-motor’ streams 256–258, 260–261, 262–265
 - evidence for forward models 262–263
 - evidence for inverse models 262
 - evidence from neuroimaging data 269–272, 272–275
 - feedback during speech production 262–263
 - goals of actions encoded by mirror neurons 264–265
 - higher level linguistic processing 258–259
 - hypothesis testing 250–256
 - IFMPs 252–256, 257–258, 262–265, 269–275
 - imagistic manual gesticulations 259, 266–267, 268
 - ‘lack of invariance problem’ 250–251, 252–256
 - McGurk-MacDonald fusion effect 251, 267–268, 271–272
 - mirror neuron activation 264–265
 - mirror system mediation 252–256, 261, 263
 - motor planning to guide actions 260–261
 - multiple route mediation 252–256
 - multisensory associations with words 259
 - multisensory nature 250–256
 - perception and production of speech
 - sounds 260–261
 - perception of manual gesticulations 260–261
 - reafference during speech production 262–263
 - role of Broca’s area 258–259, 261, 265–266
 - speech perception and IFMPs 257–258, 265, 270, 272–275
 - ventral ‘sensory-semantic’ streams 256–258, 259
 - visual cues 251–252
- speech production
 - areas in the human brain 3
 - cortical sites engaged 121, 122
 - integration of perception and action 239–240
 - link to manual actions 19
 - link to mirror system for grasping 19
 - recognition by a perceiver 241
 - underlying neural mechanisms 116–121
- speech production and perception 337–338
 - gestural task-space 241–243
- speech production model
 - coherence of articulatory gestures 220, 224–228
 - combinatorial freedom of syllable
 - constituents 227, 231–234
 - consonants and vowels in syllables 227, 228–234
 - coupling relations among articulatory
 - gestures 220, 226–228
 - emergence of the syllable 237–239
 - gestural score 219–220, 222, 223
 - gesture-based, task-dynamic model 219–221
 - hierarchy of constraint ordering 237
 - intergestural timing 220–221
 - language differentiation 236–237
 - multi-gestural segments 234–236
 - onset relations in syllables 227, 228–231
 - organ hypothesis for particularity 221–224
 - oscillator coupling model 227, 228–231
 - particulation of articulatory gestures 221–224
 - segment-level valences 234–236
 - syllable coupling modes 227, 228–231

- speech production model (cont.)
 - syllable structure 227, 228–231
 - velic and glottal gestures 234–236
- speech system
 - homology with macaque vocalization system 163
 - motivation to speak 162–163
 - roles of the anterior cingulate cortex 162–163
- speech understanding
 - HEARSAY model 300, 302–303, 304
 - role of referential domains 317–319
- STM *see* short term memory
- STSa mirror neurons, triggers for discharge 14–15
- superior temporal gyrus (STG), role in sign language perception 123–127
- superposition of discrete and rhythmic movements 197
- superposition of movement primitives,
 - to generate complex actions 196–197
- SVSS (Salience, Vision and Symbolic Schemas)
 - model 308–311
 - anchored subscene development 308–311, 311–315
 - bottom-up and top-down modulation 308–311, 312–313
 - link to language production 334–337
 - linking sensorimotor sequences to sentences 309–310, 319–322
 - minimal subscene development 308–311, 311–315
 - mode of operation 311–315
 - Phase 1 (preparatory task binding) 309–310, 311–312
 - Phase 2 (feature analysis) 309–310, 312–313
 - Phase 3 (recognizing) 309–310, 313–314
 - Phase 4 (updating) 309–310, 314–315
 - production of verbal descriptions 314–315
 - prototype software implementation 315–316
 - relation to VISIONS model 310–311
 - role of long-term memory (LTM) 311–314
 - role of short-term memory (STM) 308–311, 311–315
 - Task Relevance Map (TRM) 308–311
 - Winner-take-all competition for attention focus 312–313
- syllable coupling modes 227, 228–231
- syllable structure 227, 228–231
 - hierarchy of constraint ordering 237
- syllables
 - combinatorial freedom of constituents 227, 231–234
 - consonant and vowel gestures in 227, 228–231, 231–234
 - emergence of 237–239
 - in sign languages 113
 - onset relations 227, 228–231
- symbolic artifacts, and language evolution 81–83
- symbolic behavior, emergence in *Homo sapiens sapiens* 81–83
- symbolic communication, role in language evolution 367
- symbolic level of processing 48–49
- symbolic material culture readiness, in *Homo sapiens sapiens* 82–83
- symbolism, use by apes 98
- synergies *see* movement primitives
- syntax
 - emergence in *Homo sapiens sapiens* 81–83
 - emergence of 34–37, 38
 - evolution of mechanisms to support 138–139, 142–143, 144–146
 - in spoken language 38
 - in the abduction framework 52–53
 - Japanese 70–71, 72–74
 - of discourse 80–81
 - origin of 20, 21–22
 - patterning of units 215–216
 - phonological-rehearsal loop 138–139, 142–143, 144–146
 - relation between production and understanding 33, 37–38
 - sentence structure 38
 - underlying brain support features 164, 165–167
- syntax evolution 66–74, 75–77, 80–81, 215–216, 241–243
 - clause structure 69
 - discontinuous elements 71–72
 - long-distance dependencies 72–74
 - metonymy 69, 71–72
 - predicate-argument relations 69, 70–71
 - protolanguage 66–67
 - protolanguage to simple syntax 67–70
 - role of manual gestures 215–216
 - signaling predication and modification 70–71
 - two-word stage 66–67
 - types of incremental change 73
- Synthetic PET imaging 20–21
- task- or goal-dependent effects on minimal subscenes 291–292
- Task Relevance Map (TRM), in the SVSS
 - model 308–311, 311–315
- technical intelligence 92
- temporal cortices, involvement in language comprehension 123–127
- temporal order of elements, significance of 75–77
- temporal regions, representation of action verbs 358, 361–362
- text corpus analysis tool 376–379
 - changes in conception of unconscious thought 379–383
 - English language novels analysis 379–383

Cambridge University Press

978-0-521-84755-1 - Action to Language via the Mirror Neuron System

Edited by Michael A. Arbib

Index

[More information](#)*Index*

551

- Theory of Mind 61, 75–77, 374
 as basis for teaching/tutoring 488–490
 and imitation 99–101
 and related linguistic expression in children 383–390
 and use of deception 94–95
 changes in conception of unconscious
 thought 379–383
 cultural change in mental models of
 psychology 379–383
 debate over genetic and cultural influences 374–376,
 391–392
 development of abilities in children 374, 375–376
 emergence of 77–78, 374–375
 evidence for 374, 375–376
 evidence from language evolution 375–376
 evolution of 100–101, 391–392
 in chimpanzees 99–101
 in early humans 374–375
 in great apes 99–101
 looking for a Freudian shift 379–383
 search for a false-belief shift in children 383–390
- Tic Tac (non-linguistic gesture) perception 123–126
- tool use
 among bonobos 96
 among chimpanzees 95–97
 among gorillas 96–97
 among orang-utans 96, 97
 and goal-directed behavior 515
 by nonhuman primates 92
 human intergenerational transmission of 507–508
- tool use evolution, and the mirror system 501
- tracking and inhibition of return, visual attention
 pilot study 322–327
- unconscious thought, changes in
 conception of 379–383, 391–392
- understanding actions, evolution of mirror neurons 17–19
- unitary utterances, in protolanguage 34–37
- units of actions *see* movement primitives
- universal features of language 83–84
- Universal Grammar (UG) concept
 and language evolution 83–84
 challenges to 365–367
 evolution of 73
- universal instantiation 50, 55–59
- vampire bats, food sharing 105–106
- variable binding (property of logic) 50
- variable-binding problem 55–59
- velic gestures 234–236
- ventral ‘sensory-semantic’ streams 256–258, 259
- verb, in terms of mirror and canonical neurons 329–331
- verb-argument structures, transition to 39–41
- Verb Island Hypothesis 365–367
- verbs *see* action verbs
- vervet monkeys
 knowledge of social relationships 94
 predator alarm calls 143
 use of tactical deception 94–95
- VISIONS model 304
 cooperative computation 299–301
 gist of the scene 299, 300, 301
 motor schemas 301–302
 relation to SVSS model 310–311
 role of short term memory 299–301, 306
 scene layout 301
 schemas for visual scene analysis 299–301
 STM linking of motor schemas 301–302
- visual attention
 focus on salient targets 293–295
 interplay of bottom-up and top-down factors 293–295
 recognition of objects, actors and actions 295
 updating of minimal subspace 293–295
- visual attention pilot study
 dynamic scene description 322–327
 gist extraction 322–327
 minimal subspace description 322–327
 ‘narrative momentum’ 322–327
 object and action recognition 322–327
 tracking and inhibition of return 322–327
- visual attention studies
 Arbib & Didday (two visual model) 304–305
 control of eye movements 306–307
 Itti & Koch model (bottom-up salience) 304,
 305–307, 309–310, 319–322
 top-down modulation of bottom-up processing
 306–308
 Winner-Take-All notion 304–307
- visual attention to language, review of studies 316–319
- visual dorsal streams 256–258, 260–261
- visual perception, hypothesis testing 250
- visual scene analysis
 basic schema networks 334
 link to grammar constructions 334
- visual scene perception
 use of distributed computation 299–301, 306
 VISIONS model 299–301, 306
- visual system
 dorsal stream (‘where/how’ pathway) 147–149
 ventral stream (‘what’ pathway) 147–149,
 256–258, 259
- visuomotor frame acquisition in humans 401–403
- visuospatial sketchpad 302
- vocal communication, emergence of 75–77
- vocal tract action gestures
 articulatory gestures 216–218
 non-iconic, non-meaningful nature 215–216
 role in phonological evolution 215–216

vocalization
 chimpanzees 96, 97–98
 recognition by a perceiver 241
 roles of the anterior cingulate cortex 160–162, 163
vowel gestures in syllables 227, 228–231, 231–234

Wernicke’s area 123
 auditory dorsal stream 260–261
 homologies in the macaque 137, 138–139, 145, 146,
 152, 154–155
 role in language processing 138–139, 143–144,
 145, 146
 usefulness of the concept 164, 165

Winner-Take-All (WTA)
 competition for attention focus
 (SVSS model) 312–313
 in visual attention 304–307
word learning, and caregiver
 practices 491

words
 linkage to schema network 39–41
 morphological reanalysis 79
working memory
 linguistic 138–139, 143–144, 144–146
 three-component model (Baddley) 302
 visuospatial 144–146