

# HANDBOOK OF DEVELOPMENTAL COGNITIVE NEUROSCIENCE

Second Edition

*Edited by*

Charles A. Nelson and Monica Luciana

A BRADFORD BOOK  
THE MIT PRESS  
CAMBRIDGE, MASSACHUSETTS  
LONDON, ENGLAND

© 2008 Massachusetts Institute of Technology

All rights reserved. No part of this book may be reproduced in any form by any electronic or mechanical means (including photocopying, recording, or information storage and retrieval) without permission in writing from the publisher.

MIT Press books may be purchased at special quantity discounts for business or sales promotional use. For information, please e-mail [special\\_sales@mitpress.mit.edu](mailto:special_sales@mitpress.mit.edu) or write to Special Sales Department, The MIT Press, 55 Hayward Street, Cambridge, MA 02142.

This book was set in Baskerville by SNP Best-set Typesetter Ltd., Hong Kong and was printed and bound in the United States of America.

Library of Congress Cataloging-in-Publication Data

Handbook of developmental cognitive neuroscience / edited by Charles A. Nelson and Monica Luciana.—2nd ed.

p. ; cm.—(Developmental cognitive neuroscience)

Includes bibliographical references and index.

ISBN 978-0-262-14104-8 (hardcover : alk. paper)

1. Developmental neurobiology—Handbooks, manuals, etc.  
2. Cognitive neuroscience—Handbooks, manuals, etc.  
I. Nelson, Charles A. (Charles Alexander) II. Luciana, Monica. III. Series.

[DNLM: 1. Nervous System—growth & development.  
2. Central Nervous System Diseases—physiopathology.  
3. Cognition—physiology. 4. Human Development. 5. Perception—physiology. WL 102 H23535 2008]

QP363.5.H365 2008

612.8'2—dc22

2008007886

10 9 8 7 6 5 4 3 2 1

# INDEX

## A

ABB grammar vs. ABC grammar, in young infants, 328  
ABPs (actin-binding proteins), in regulation of actin filament organization, 7–8  
Absolute thresholds  
  auditory, 98–99  
  visual, 128  
Abuse  
  and attachment, 790  
  child, 869–870. *See also* Maltreatment, childhood  
  cocaine. *See also* Cocaine, prenatal exposure to  
  in adults, 654  
Acetylcholine, and recovery from early brain injury, 394  
Acoustic environment, in auditory cortex organization, 102–103  
Acoustic parameters, nonphonemic, 108  
Acoustic startle reflex, 841  
Acquired prosopagnosia, childhood onset of, face processing impairment and, 516  
ACTH (adrenocorticotrophic hormone), secretion of, 63, 65  
Actin filament(s)  
  adhesive contacts of, 10  
  microtubule interactions with, 9  
  in neurons, 6–7  
Actin filament organization  
  in cells, 7  
  regulation of  
    actin-binding proteins in, 7–8  
    and dynamics of cytoplasmic signaling pathways, 8–9  
Actin-binding proteins (ABPs), in regulation of actin filament organization, 7–8  
Action approach, to motor development, 147–148  
Activation functions  
  mathematical expression of, 369  
  in neural network models, 369–370  
Active fixation tasks, in eye tracking, 264  
Active memory representations, vs. latent memory traces, 555  
Activity, level of, in motor development, 149–151  
Acuity, visual. *See* Visual acuity  
ADC (apparent diffusion coefficient), 301  
  in newborns, 304  
ADHD. *See* Attention-deficit/hyperactivity disorder (ADHD)  
Adhesion receptors, of actin filaments, 10  
Adolescent(s)  
  acute effects of nicotine on, 861–862  
  behavioral traits of, 855

brain development in, 855–863  
  acute effects of nicotine and, 861–862  
fMRI of, 856  
mechanism of nicotine action and, 859–860  
microarray forebrain analysis in, 857, 859  
morphological changes during, 855–856  
MRS imaging of, 341, 343  
neurological changes during, 856–857  
smoking and influence of nicotine associated with, 859–862  
brain maturation in, 772–773  
eye tracking in  
  atypical development and, 276–288. *See also* specific disorder  
  normative development saccades and, 269–276  
frontal circuitry organization in, 231  
generalized anxiety disorder in, attention avoidance and, 764  
LHPA regulation in, 73–74  
prefrontal cortex in  
  behavioral inhibition and, 585–586  
  development of, 575–587  
  structural, 577–578  
dorsolateral, 575–576  
  development of, 582–584, 586  
functions of, 578–581  
  in different prefrontal areas, 582–586  
planning ability and, 582–583  
process vs. content of, 581–582  
recognition memory and, 581  
selected tasks and, 583–584  
self-ordered search tasks and, 582  
self-organized behavior and, 583  
span tasks and, 581–582  
spatial delayed-response tasks and, 582  
structure and connectivity of, 575–577  
ventrolateral, 575–576  
ventromedial, 576  
  development of, 584–585, 586  
prenatally cocaine-exposed. *See also* Cocaine, prenatal exposure to  
  outcomes for, 663–666  
smoking among, 859–862  
  acute effects of nicotine and, 861–862  
  mechanism of nicotine action and, 859–860  
vulnerability of, 855  
Adrenal steroids, regulating adult neurogenesis, 53  
Adrenalectomy, 53  
Adrenocorticotrophic hormone (ACTH), secretion of, 63, 65  
Adult(s)  
  cocaine-abusing, 654. *See also* Cocaine, prenatal exposure to  
face processing in, 509–511  
core cortical system of, 509–511  
  fusiform face area of, 510–511  
  superior temporal sulcus/gyrus of, 511  
extended cortical-subcortical system of, 511  
subcortical system of, 509  
localization of auditory system in, recalibration of, 101–102  
neurogenesis in, 51–59. *See also* Neurogenesis, adult  
recognition-memory abilities in, emergence of, 501–502  
relational-memory abilities in, emergence of, 502–503  
Adversity, resilience resulting from, 780  
Affective disorders, genetic influence on, 353  
Affective neuroscience, and pediatric anxiety, 763–766  
Affective policy domains, relevance of sleep to, 813  
Afferent pathways, in prefrontal cortex  
  corticocortical connections in, 224  
  extrathalamic, 214–215, 222  
  long associative connections in, 224–225  
  sequential development of, 221–225  
  thalamocortical, 215, 222–224  
Affiliation, in autism, 709  
Age  
  at cochlear implantation, performance affected by, 447  
  at early brain injury, functional outcome associated with, 388–389  
  in language acquisition, 374–375  
  at traumatic brain injury, impact of, 406–407  
Aggression  
  in abused and neglected children, 869, 870  
  sleep deprivation and, 813–814  
Aging  
  and cognition  
    dementia and, 607–616. *See also* Alzheimer's disease; Dementia  
  reserve, underactivation, and compensation in, 600–601  
  typical development in, 591–601  
differential effects of, on retrieval processing, 600  
executive functions and, 595–597  
  in childhood, 556–562  
and memory  
  long-term, 597–600  
  working, 592–595  
structural brain changes associated with, 591–592

Alcohol use disorders, development of  
affective pathway for, 361

Alzheimer's disease  
diagnosis of  
CANTAB-PAL scores in, 610  
criteria for, 607

early-stage, cognition in, 608–611

memory in, neuropsychological tests of,  
609–611

mild cognitive impairment in, 608–609

vs. dementia with Lewy bodies, 613–614

vs. frontotemporal dementia, 612

vs. vascular dementia, 612–613

Alzheimer's Disease Assessment Scale—  
Cognitive Scale (ADAS-cog), 610

Amacrine–ganglion cell interaction, in  
retina, 130

American Sign Language, 444–446  
visuospatial nature of, 444–445  
vs. spoken language, 444

Ammon's horn, in hippocampal  
development, 187, 188, 189

cytoarchitectonics of, 191, 207

Amnesia, developmental, pattern of  
impairment in, 548–549

Amygdala  
and attachment, 792–793

corticosterone action on, 794–795

cytoarchitectonic maturation of, 222

functional studies of, 165–167

innervation of, 5-HT receptors in, 356

lesion studies of, 167

neuroanatomy of, 165

prefrontal cortex connection to, 215

reactivity of, 5-HTTLPR S allele  
affecting, 356–358

role of  
in autism, 709–711

in object-emotion associations, 871

in social behavior, 165–168

Amygdala-frontal connections, in  
autism, 710

Amygdala-fusiform connections, in  
autism, 710

Anesthesia, bird's own song memory  
during, 459–460

Animal models  
of autism, 706

LHPA system in, 70–71

nonprimate, memory development in,  
499–504. *See also* Memory

plasticity of speech in, 453–461. *See also*  
Birdsong

of social development, 173–175

Anterior cingulate cortex  
emotion processing in, 871

functional studies of, 169

lesion studies of, 169

neuroanatomy of, 168–169

performance monitoring in, 558–560,  
887. *See also* Performance  
monitoring

role of, in social behavior, 168–169

Anterior forebrain pathway  
in neural song system, 458

in song plasticity, 460

Antisaccade response times, age-related  
changes in, 269, 272

Antisaccade tasks  
in eye tracking, 264

warning stimulus on, age-related changes  
in CNV to, 269

Antisocial behavior, development of,  
360–361

Anxiety. *See also* Fear entries  
chronic. *See* Posttraumatic stress disorder  
(PTSD)

definition of, 755

in maltreated children, 869

normal vs. pathological, 755–756

“stranger,” 789

Anxiety disorder(s)  
clinical  
integrative framework of, 758–759

model of, 758–763

DSM-IV definitions of, 755

generalized, 755

genetic influence on, 353, 844

major advances in, 756–758

pediatric, 756

affective neuroscience and, 763–766

clinical classification of, 763–764

clinical questions concerning, 758

information-processing and fear-circuit  
functions in, 764–766

separation, 755

social, 755

Anxious behaviors, 841

Aortic stenosis, supravalvular, in Williams  
syndrome, 691, 692

Apparent diffusion coefficient (ADC), 301  
in newborns, 304

Appraisal theory, of depression, 775

Approach-avoidance decisions, of executive  
function in childhood, 557

*arc* gene, basal levels of, in adolescent vs.  
adult brain, 862, 863

Arginine vasopressin, secretion of, LHPA  
stress response and, 63

Arousal attention system, 479–480  
in prenatally cocaine-exposed children,  
664

Asperger syndrome. *See also* Autism spectrum  
disorders (ASDs)  
DMS-IV definition of, 701

Association genetic studies  
of affective disorders, 353

involved in emotion regulation, 352–353

limitations of, 353–354

of personality, 353

traditional, 352

Atkinson's model, of visual development,  
138

Attachment  
abuse and, 790

amygdala involved in, 792–793

attenuated aversion learning and, neural  
basis of, 792–795

behavioral system of, 789

emotion in, emergence of, 795–797

and implications for human development,  
798–799

and infant development, 797–798

and maternal behavior in next generation,  
797–798

and maternal separation responses,  
795–797

mother-infant interaction patterns of,  
797–798

neurobiology of, 787–799

in newborns, 789

olfactory preference learning and, neural  
basis of, 790–792

perinatal transition in, 788–789

postnatal learning and, 789–790

prenatal origins of, 788

specific, initial formation of, 787–795

vocal communication in, origins of,  
795–797

Attention  
in adolescence  
generalized anxiety disorder and, 764

prefrontal development and, 581–582

anterior system of, joint attention  
initiation and, 828–829

as coping resource, 847

effect of, on cognitive processes, 490

familiar stimulus and, 489–490

impaired  
depression and, 779–780

fetal alcohol syndrome and, 647

joint, development of, 819–833. *See also*  
Joint attention

negative central (Nc) component in,  
490–491

novel stimulus and, 489–490

posterior system of, 481–482

gaze following/joint attention and,  
827–828

in preterm children, 402

pupillary dilation studies of, in children  
and adolescents, 276

selective, 870

in executive function in childhood,  
561–562

shifting, brain activation patterns  
associated with, 526

spatial, development of, 525–527

specific systems of, 480–482

sustained, 482

phases of, 482–483

role of, in behavior, 487

visual-spatial  
after treatment of congenital cataracts,  
425

impaired  
in fetal alcohol syndrome, 647

in schizophrenia, 280

in young infants  
arousal system of, 479–480

brain systems involved in, 479–482

briefly presented stimuli and,  
recognition of, 489–494

covert (orienting), 482

definition of, 479

developmental psychological perspective  
on, 479–495

direct measure of, 484

- Attention (continued)
- event-related potentials and, scalp-recorded, 483–484
  - eye movements and, 484–489. *See also Eye movements*
  - heart rate in, 482–483, 489
  - indirect measure of, 484
  - psychophysiological measures of, 482–484
- Attention Network Task (ANT), 845–846
- Attention-deficit/hyperactivity disorder (ADHD)
- clinical depression and, 774
  - in cocaine-exposed children, 89
  - decision making in, 886
  - dyslexia with, 745
  - eye tracking studies in, 284, 285–288
    - review of, 289–291
  - in fetal alcohol syndrome, 647
  - MRS imaging of, 345–346
  - onset of, after traumatic brain injury, 405
  - overactivity in, 156
  - risk of, preterm birth and, 402
  - treatment effects on, using fMRI studies, 319–320
- Attenuated aversion learning, neural basis of, 792–795
- Attribution theory, of depression, 775
- Audition, interactions between vision and, after cochlear implantation, 446–447
- Auditory feedback, in song system, study of, 456–457
- Auditory perception, in autism, 709
- Auditory stimuli, ERP response to
- in cognitive development, 249–252
  - components related to lexical and syntactic processing in, 252
  - mismatch responses in, 251–252
- Auditory system
- fundamental capacity of
    - absolute thresholds in, 98–99
    - in infants, 97–100
    - intensity, frequency, and duration discrimination in, 99–100
    - onset of hearing and, 97–98
  - lexicon in, reference and learning of, 107–109
  - localization of
    - in infants, 101
    - in nonhumans, 100–101
    - recalibration of, in adults, 101–102
  - neural specializations in, 100–104
  - phonetic reorganization of, 104–107
    - distributional modifications in, 105
    - distributional sensitivity in, 105–106
      - second language and, 106–107
    - universal inventories in, 104
  - plasticity of
    - brain correlates of, 109–111
    - in humans, 103–104
    - in nonhumans, 102–103
  - reorganization of
    - mechanisms of, 97–111
    - phonetic, 104–107
  - visual system and, 100
- Auditory/visual speech fusion, sensitive period for, in young recipients of cochlear implants, 444–448
- Autism
- affiliation in, 709
  - amygdala in, 709
    - role of, 710
  - amygdala-frontal connections in, 709–711
  - amygdala-fusiform connections in, 709
  - animal models of, 706
  - auditory perception in, 709
  - brain development in, 703–706
    - complex information processing in, 705–706
    - executive function in, 704–705
    - head/brain growth and, 703–704
    - neurochemistry in, 704
    - prenatal course of, 703
    - theory of mind in, 705
    - weak central coherence in, 705
  - brain imaging studies of, 344–345, 703–704, 708–709
    - cognitive models in, 704–706
    - developmental course of, 701
    - diagnosis of, 701
    - DSM-IV criteria for, 165
    - etiology of, 702–706
    - facial expression processing in, 708
    - facial identity processing in, 706–708
      - gaze in
        - abnormal, 281
        - eye tracking studies of, 282–284, 708
      - genetic basis of, 702–703
      - gyrification index in, 46
      - joint-attention impairments in, 822–823
      - mirror neurons in, 708–709
      - neurocognitive development in, 701–712
      - prevalence of, 702
      - repetitive behavior in, 711
      - and social brain, 706–710
      - social deficits in, 165
      - social motivation in, 709–710
      - social perception in, 706–710
    - executive function in, 704
    - facial expression processing deficits in, 708
    - facial identity processing deficits in, 706–707
- Autism spectrum disorders (ASDs), 701
- executive function in, 704
  - facial expression processing deficits in, 708
  - facial identity processing deficits in, 706–707
  - fMRI abnormalities observed in, 707
  - fusiform face area in, 707–708, 710
  - mode of transmission of, 702
  - serotonin levels in, 704
  - weak central coherence tasks in, 705
- Autopsy studies, in fetal alcohol syndrome, 643–644
- Axial diffusivity, in DTI data processing, 302
- Axon(s)
- corticospinal, navigation of, 16
  - corticothalamic
    - navigation of, 15–16, 17
    - prefrontal, 215
  - differentiation of, 13
  - distinguishing microtubule features in, 6
  - formation of, developing neurons in, 5–20
  - initial growth of, neuronal polarization and, 13–14
- injury to, 403–404. *See also Brain injury*
- myelination of, in central nervous system, 544
- targets of
- patterning distribution in, 17–18
  - stereotypical routes to, 14–15
- Axonal-tension concept, of brain development, 42
- Axo-somatic inhibitory cell(s), parvalbumin-containing, 203

## B

- Backpropagation learning algorithm, 370
- Basal forebrain–prefrontal cholinergic system, of prefrontal cortex, 215
- Basal ganglia
- in fetal alcohol syndrome, neuroimaging studies of, 645
  - involved in song learning and production, 454–455
- Basilar membrane, in auditory development, 102
- BclII polymorphism, and individual LHPA function, 76
- BDNF. *See* Brain-derived neurotropic factor (BDNF)
- Behavior(s)
- adaptive and maladaptive patterns of, in maltreated children, 876–877
  - antisocial, development of, 360–361
  - anxious, 841. *See also Anxiety entries*
  - habitual. *See also Obsessive-compulsive disorder (OCD); Tourette's syndrome*
  - disturbances in self-regulatory control of, 717–731
  - in prenatally cocaine-exposed children, 665
  - repetitive, in autism, 711
  - self-organized, 583
  - social. *See also Social behavior*
    - neurobiology of, 161–172
  - of songbirds, 453. *See also Birdsong*
  - understanding, from neural network models, 367–368
- Behavior genetics, 351–354
- association studies in
    - affective disorders and, 353
    - involving emotion regulation, 352–353
    - limitations of, 353–354
    - personality and, 353
    - traditional, 352
  - study of genes in, 351–352
- Behavioral attachment system, 789. *See also Attachment*
- Behavioral development, fMRI studies of, 318–319
- Behavioral evidence, of dorsal and ventral dissociation, in infants, 471–474
- Behavioral inhibition, 74–75, 585–586
- in temperament, 841–843
  - in unipolar depression, 778
- Behavioral paradigms, in fMRI research, 315–316
- Behavioral profile, in dyslexia, 740–741

Behavioral sequelae, after early brain injury, 387–389  
measurement of, 389

Behavioral studies, of neonates' perception, attention, and learning abilities, 326–328

Behavioral therapy, for early brain injury, 391–393

Behavioral traits, in adolescence, 855

Biases  
in learning mechanisms, 373  
in unipolar depression, 778–779

Bilingualism  
auditory development in, 106–107  
brain responses in, 110–111  
facilitating executive function in childhood, 565

Biocular deprivation  
congenital cataracts and, 417, 420–421.  
*See also* Cataract(s), congenital restrictions after, 418

Bird's own song (BOS) memory  
during anesthesia and sleep, 459–460  
response to, 456  
vs. tutor song memory, 457

Birdsong  
brain areas involved in, 454–456  
features of bird behavior in, 453  
future research into, 461  
as model of speech, 453  
neural song system in, 453–458  
anterior forebrain pathway of, 458  
motor loop of, 457  
sensorimotor integration loop in, 456–457

sensorimotor system in, 458–461  
behavior and role of sleep in, 458  
development of synapses in, 459  
and implications for human speech, 460  
neuromodulators in, 458–459  
sensory development in, 459–460  
vocal development in, genetic aspects of, 459

vocal learning/production of  
brain-behavior relationship in, 453–454  
nuclei involved in, 454–455

Birth  
LHPA system at, 71  
preterm. *See* Preterm birth

Birth weight, very low, neuropsychological outcome associated with, 402

Blind person  
auditory cortical plasticity in, 103  
visual cortical plasticity in, 427

Blood Phe levels, in phenylketonuria, 678, 682

Blood-oxygenation-level-dependent (BOLD) imaging, 313

Brain. *See also* specific part  
activation patterns of, with shifting attention, 526  
adult, neurogenesis and, 51–59. *See also* Neurogenesis, adult  
areas of, involved in birdsong, 454–456  
arousal system of, 479–480

changes in  
age-related structural, 591–592  
motor development and, 151–155  
postnatal, gyration and, 43–44  
functional abnormalities of, in dementia, 614–615

increased growth of, autism and, 703–704  
influence of corticotropin-releasing hormone on, 68–69  
influence of cortisol on, 67–68  
language processing in, 109–111. *See also* Language acquisition  
lexical processing in, 119–122  
phonotactic knowledge and, 121  
stress patterns of words and, 119–121  
word familiarity and, 121

locations of, involved in attention, 479–482

maturity of, during childhood and adolescence, 772–773

measurement of activity of, in early development, 117–118

metabolism of  
in fetal alcohol syndrome, 645  
role of sleep in, 809

normal, changes in, 385–387

postnatal changes in, gyration and, 43–44

prenatal and postnatal, dendritogenesis in, 19

prosodic processing in, 118–119

semantic processing in  
sentences in, 122–123  
words in, 121–122

social. *See* Social brain

structural abnormalities of  
in dementia, 614–615  
in Williams syndrome, 691

structural changes in, age-related, 591–592

syntactic processing in, 123–124

Brain development, 23–36  
in adolescence, 855–863. *See also* Adolescent(s), brain development in  
after early brain injury, 389–391  
in autism, 703–706  
complex information processing in, 705–706  
executive function in, 704–705  
head/brain growth and, 703–704  
neurochemistry in, 704  
prenatal course of, 703  
theory of mind in, 705  
weak central coherence in, 705

basics in, 83

choline in, 627, 634–635

differential effects of sleep on, 810

dynamic and regressive changes in, age-related, 23–24

effect of selected nutrients on, 625–635

experience-dependent changes in, 386–387

fMRI studies of, 317–318

gray matter changes in, cognitive correlates of, 33–36

gray matter density in, 26–30

gray matter loss in, 25, 26

gray matter thickness in, 30–33

growth factors in, role of, 624–625

gyration in  
disorders of, clinical conditions associated with, 44–46  
heritability of, 43  
mechanical folding hypothesis of, 42–43  
phylogeny in, 41  
postnatal morphology changes in, 43–44  
theories of, 41–44

impact of prenatal cocaine exposure on, 88–91, 653–666. *See also* Cocaine, prenatal exposure to  
in infancy, declarative memory performance and, 543. *See also* Declarative memory, in infancy

influence of corticotropin-releasing hormone on, 70

influence of cortisol on, 69–70

introduction to, 23

iodine in, 626, 633–634

iron in, 626, 630–632

measurement of activity in, 117–118

monoamines in  
balance of receptor signaling and, 91–92  
effects of, 83–92  
modulatory influence of, 88–91  
neuropharmacology of, 85–88

MRS imaging of, 337–347  
in children and adolescents, 341, 343  
developmental disorder profiles in, 343–346  
in fetuses, 339–340  
limitations of, 346–347  
in neonates, 340–341, 342, 343

neuronal changes during, 385–386  
normal, 385–387

postmortem studies of, synaptic modification and myelination in, 23–25

primary neurulation in, 771–772

prior to gyration, 39–40

protein-energy status and, 625, 627–630

role of sleep in, 813

selenium in, 627, 634

stress influencing, 69–77. *See also* Limbic-hypothalamic-pituitary-adrenocortical (LHPA) system

whole-brain mapping methods of, voxel-based morphometry in, 25–26

zinc in, 626, 632–633

Brain injury  
early, 385–396  
behavioral sequelae of, 387–389  
measurement of, 389

behavioral therapy for, 391–393

brain development after, 389–391

cortical connectivity changes in, 390

developmental outcomes after, 399–409

endogenous changes in, manipulation of, 391–395

Brain injury (continued)  
 experience-dependent changes in, 386–387  
 frontal cortical, modification of effects of, 392  
 gonadal hormones for, 394–395  
 Hebb hypothesis of, 387–388, 400  
 impact of age at, functional outcome associated with, 388–389  
 Kennard hypothesis of, 387–388  
 moderators influencing outcome of, 407–408  
 neurogenesis changes in, 390–391  
 neuromodulators for, 394  
 neurotrophic factors in, 393  
 plasticity and, 385–396, 399–409  
 preterm birth resulting from, 400  
 neurodevelopmental changes and, 400–403  
 psychoactive drug therapy for, 395  
 synaptic space and, 389  
 timing of, 400  
 type of, 400  
 focal, spatial analytical functioning disorders associated with, 528  
 prenatal, face processing impairment and, 515–516  
 traumatic, 403–407  
 impact of age at, 406–407  
 long-term neuropsychological outcome associated with, 405–406  
 neurodevelopmental process disruption in, 403–404  
 neuroimaging studies of, 404  
 Brain models, of repetitive behavior, 711  
 Brain stem, involved in song learning and production, 454–455  
 Brain-behavior relationship in visual development, 127–141. *See also* Visual system  
 cortically motivated, models of, 135–139  
 subtleties and assumptions in, 139–141  
 in vocal learning/production of birdsong, 453–454  
 Brain-derived neurotropic factor (BDNF), 625  
 cocaine-induced suppression of, 661  
 gene transcription of, 75  
 suppression of, 70  
 Branch formation, along neurites, 13  
 BrdU-labeled cells, in dentate gyrus, 52, 53, 56  
 Breast milk, in promotion of CNS development, 629–630  
 5-Bromo-2'-deoxyuridine (BrdU) labeling, in neurogenesis, 52

## C

Cajal-Retzius cells  
 calretinin-secreting, 197  
 hippocampal, 196–200  
 prefrontal, 221  
 reelin-secreting, 196–197  
 Calbindin marker, of granule cells, 200–203

Calbindin-containing interneuron(s), 204  
 Callous-unemotional (CU) traits, in antisocial behavior, 360  
 Calretinin-containing interneuron(s), 204  
 Cambridge Neuropsychological Test Automated Battery (CANTAB) for Alzheimer's disease, 609–610 for depression, 779  
 Cambridge Neuropsychological Test Automated Battery (CANTAB) Paired Associates Learning (PAL) scores, 609–610 utility of, in Alzheimer's disease diagnosis, 610  
 cAMP response element-binding (CREB) protein, cocaine-induced suppression of, 661  
 Carbohydrate(s), in cognitive development, 623  
 Cardiac concomitants, of feedback processing, 889–890  
 Cardiovascular function, effects of cocaine on, 654  
 Cataract(s), congenital bilateral, treatment of, sleeper effects in, 428–429  
 high-level vision and, 420–426  
 low-level vision and, 417–420  
 sensitive period for damage with, variability of, 429–431  
 sensitive period for recovery from, prediction of, 431  
 treatment of contrast sensitivity after, 417 pace perception after, 422–426 peripheral vision after, 417–418 sensitivity to global form after, 421–422 sensitivity to global motion after, 420–421 sensitivity to motion perception after, 419 visual acuity after, 416–417 visual spatial attention after, 426 unilateral, treatment of, 418 vision deprivation from, 416  
 Catecholamine, synthesis of, 86  
 C-domain, of growth cone, 10  
 Cell(s). *See also specific cell type*  
 actin organization in, 7 microtubule formation in, 5  
 Cell count, cortical, age-related changes in, 44  
 Cell death, 83 cocaine-induced, 654–655 hippocampal, evidence of, 195 programmed, in brain development, 772  
 Cell migration, hippocampal, 195–196 in preterm infants, 203, 207–208  
 Cell proliferation, hippocampal, in preterm infants, 203, 207–208  
 Cellular events, neurogenetic, in prefrontal cortex development, 216, 218–219  
 Central nervous system (CNS). *See also* Brain entries development of breast milk promoting, 629–630  
 impact of prenatal cocaine exposure on, 88–91, 653–666. *See also* Cocaine, prenatal exposure to nutrients in, 626, 627, 630–635 dysfunction of in autism, 704 in fetal alcohol syndrome, 643 myelination of axons in, 544  
 Central pattern generators, in development of walking, 150  
 Central visual field (CVF), in deaf and hearing subjects, 440  
 Cerebellum in fetal alcohol syndrome, neuroimaging studies of, 644 in Williams syndrome, 691  
 Cerebral cortex. *See also* specific cortical specialization axonal-tension-based morphogenesis of, 42 Cajal-Retzius cells in, 197 cell counts in, age-related changes and, 44 development of anomalies in, 83 fundamentals of, 83–85 growth cone navigation along pathways during, 15–18 early injury to. *See also* Brain injury, early connectivity changes after, 390 histogenesis of, 83–85 intricate architecture of, 41 mechanical folding hypothesis in, implications of, 42–43 morphology of, cocaine-related effects on, 654–655 myelin proliferation into, age-related, 24 neuronal migration into, 40 plasticity of, in auditory development brain correlates of, 109–111 in humans, 103–104 in nonhumans, 102–103 and projections to superior colliculus, in saccade triggering, 265, 266 subcortical structures of, connectivity between, 40–41  
 Cerebral hemisphere(s) left. *See* Left hemisphere right. *See* Right hemisphere  
*c-fos* gene, basal levels of, in adolescent vs. adult brain, 862, 863  
 Change, mechanisms of, in neural network models, 372–375 age-of-acquisition effects and, 374–375 learning about words and semantic categories and, 373–374  
 Children. *See also* Adolescent(s); Infant(s); Newborn(s)  
 acquired prosopagnosia onset in, face processing impairment and, 516 antisocial behavior in, CU traits and, 360–361 anxiety disorders in, 756 affective neuroscience and, 763–766 clinical classification of, 763–764 clinical questions concerning, 758 information-processing and fear-circuit functions in, 764–766

Children (continued)  
brain development in, MRS imaging of, 341, 343  
brain maturation in, 24  
cataracts in, 416. *See also* Cataract(s), congenital  
circuitry elements in, overproduction of, 230–231  
EEG of, 248  
executive function in  
age-related changes in, 556–562  
approach-avoidance decisions in, 557  
bilingualism facilitating, 565  
correlates of, 562–564  
cognitive, 563  
demographic, 564  
socioemotional, 563–564  
decision making in, 558  
delay-of-gratification paradigms in, 557–558  
development of, 553–567  
theories of, 554–556  
influences on, 564–566  
labeling facilitating, 564–565  
measurement issues in, 566–567  
performance monitoring in, 558–560  
reward learning in, 558  
rule use at various complexity levels in, 560–561  
selective attention in, 561–562  
symbolism facilitating, 565–566  
task set selection in, 562  
training facilitating, 566  
working memory in, 561  
eye tracking in  
atypical development and, 276–288  
normative development saccades and, 269–276  
malreatment of, 869–877  
behavioral response and regulation in, 876–877  
cognitive processing of emotion signals in, neural mechanisms involved in, 870–874  
consequences of, on LHPA system, 72–73  
developmental outcomes associated with, 869–870  
emotion elicitation in, 874–875  
emotion regulatory processes in, 875–876  
prefrontal cortex in, development of, 553–554  
prenatally cocaine-exposed. *See also* Cocaine, prenatal exposure to  
attention-deficit/hyperactivity disorder in, 89  
neurobehavioral and developmental findings in, 664–666  
neurochemical findings in, 664  
outcomes of, 663–666  
prosodic, lexical, semantic, and syntactic processing in, 117–125

regulation of LHPA function in, 72–73  
sleep patterns and neurocognitive functioning in, 810–811  
Cho/Cr ratio  
in attention-deficit/hyperactivity disorder, 345–346  
in autism, 344  
in developmental delays, 344  
Choline, in brain development, 627, 634–635  
Cholinergic afferents, prefrontal, 222  
Cholinergic system  
in arousal aspect of attention, 480  
basal forebrain–prefrontal, 215  
Cingulate cortex, anterior  
functional studies of, 169  
lesion studies of, 169  
neuroanatomy of, 168–169  
role of, in social behavior, 168–169  
Circadian process, 809  
Circular reaction, in infant motor development, 148  
Clinical policy domains, relevance of sleep to, 813  
Closure positive shift (CPS), in processing intonational phrase boundaries, 119  
CNS. *See* Central nervous system (CNS)  
CNV (contingent negative variation) in adolescence, 586  
age-related changes in, to warning stimulus on pro- and antisaccade tasks, 269  
Cocaine  
pharmacological sites of action of, 88–89  
prenatal exposure to  
affecting neurotransmitter function, 655–660  
altered CNS development in, 88–91, 653–666  
cortical morphology in, 654–655  
dopaminergic system and, 656–657  
and expression of immediate early genes, 660–661  
GABAergic system and, 657–658  
human model of, 663–666  
incidence of, 653  
neuroadaptive changes in response to, 89–90  
neurobehavioral and developmental findings in infants and children after, 664–666  
neurobehavioral teratologic effects of, candidate mechanisms for, 653–654  
neurochemical findings in infants and children after, 664  
noradrenergic system and, 660  
preclinical models of, 654–660  
behavioral correlates in, 661–663  
serotonin system and, 658–659  
Cochlear implantation  
advent of, 446  
age at, performance affected by, 447  
speech perception after, 446  
cross-modal plasticity in, 446–448  
success of, 103–104  
young recipients of, auditory/visual speech fusion in, sensitive period for, 444–448  
Cognition  
aging and  
dementia and, 607–616  
reserve, underactivation, and compensation in, 600–601  
typical development in, 591–601  
diffusion-tensor-imaging studies of, 305 in early-stage Alzheimer's disease, 608–611  
impaired, in dyslexia, 742–743  
negative, mood-valent theories of, depression and, 775–776  
social. *See also* Social brain  
definition of, 162  
elements of, 162  
neurobiology of, 161–172  
unipolar depression and, 774–775  
Cognition-emotion interactions, abuse and neglect impacting, 876  
Cognitive correlates, of executive function in childhood, 563  
Cognitive development, 247–258  
electroencephalogram in, 247–248  
event-related oscillations in, 256–257  
event-related potentials in, 248–249  
auditory stimuli and, 249–252  
components related to lexical and syntactic processing in, 252  
mismatch responses in, 251–252  
multimodal stimuli and, 255–256  
saccade-related, 256  
visual stimuli and, 252–254  
future directions in, 257–258  
macronutrients in, 623  
effects of, 629–630  
micronutrients in, 623–624  
neural network models of, 367–379. *See also* Neural network models  
benefits of, 367–368  
challenges to, 375–376  
contributions of, 371–375  
critical elements of, 368–371  
nutrients in  
categories of, 623–624  
deprivation and subsequent repletion of, role of timing in, 635–636  
effect of selected, 625–635  
nutrition in, 623–637  
future directions of, 636  
role of, 624–625  
in prenatally cocaine-exposed children, 665  
Cognitive function, relationship between myelination and, 240  
Cognitive models, in autism, 704–706  
Cognitive neuroscience  
developmental  
behavior genetics in, 351–354  
fMRI studies of, 316–320  
behavioral development and, 318–319  
behavioral paradigms and, 315–316

- Cognitive neuroscience (continued)
- brain development and, 317–318
  - history of, 316–317
  - intervention or treatment effects using, 319–320
  - imaging genetics in
    - conceptual basis of, 354–355
    - findings of, 355–358
    - importance of, 358–360
    - ongoing investigations in, 360–362
    - transitional aspects of, 361–362  - of sleep, 807. *See also* Sleep
- Cognitive process(ing)
- effect of attention on, 490
  - of emotion signals
    - effects of early adversity in, 872–873
    - neural mechanisms involved in, 870–874  - of emotional states, 874
    - effects of early adversity in, 874–875  - role of, as modulators of temperament, 840
- Cognitive reserve, age-related, 600
- Cognitive resilience, 780
- Cognitive resource regulation, pupillary dilation studies of, in children and adolescents, 276
- Cognitive skills, slower gains of, in preterm children, 403
- Cognitive-linguistic profile, in Williams syndrome, 693
- Coherence thresholds
- in global motion sensitivity, 420
  - weak central, in autism, 705
- Communication, vocal, origins of, 795–797
- Comorbid disorders, associated with dyslexia, 745–746
- Compensation, cognitive, age-related, 600–601
- Compensation-related utilization of neural circuits hypothesis (CRUNCH), evidence supporting, 594
- Complementary nutritional measures, cognitive development and, 636
- Complex information processing, in autism, 705–706
- Complexity
- levels of, in executive function in childhood, 560–561
  - neural network models dealing with, 367–368
- Compulsions, 717, 729. *See also* Obsessive-compulsive disorder (OCD)
- CSTC circuitry in, 726–729
- Computerized decision-making task, development of, 776–777
- Conditioned head-turning procedure, in auditory development, 99
- Conditioned tone stimulus, in auditory cortex organization, 103
- Conduct disorder, clinical depression and, 774
- Cones, in retina, 129–130
- neonatal morphology of, 129
- Congenital prosopagnosia, face processing impairment and, 516
- Connectivity
- development of, between cortical and subcortical structures, 40–41
  - intricate pattern of, in prefrontal cortex, 576–577
- Consonants, in linguistic theory, 329–330
- Contingent negative variation (CNV)
- in adolescence, 586
  - age-related changes in, to warning stimulus on pro- and antisaccade tasks, 269
- Contrast sensitivity, after treatment of congenital cataracts, 417
- Control, in neural network models, 367
- Coping resource, attention as, 847
- Core cortical system, in face processing in adults, 509–511
- fusiform area of, 510–511
  - superior temporal regions of, 511
- eye gaze and, 514–515
- in infants, 512–515
- fusiform area of, 512–514
  - superior temporal regions of, 514–515
- sensitivity to emotion and, 514
- Corpus callosum
- corticocortical fibers forming, guidance decisions of, 16–17
  - effect of traumatic brain injury on, 404
  - in fetal alcohol syndrome, neuroimaging studies of, 644–645
  - peak growth rate of, 553
  - in Williams syndrome, 691
- Cortex
- cerebral. *See* Cerebral cortex; *specific cortical specialization*
  - visual. *See* Visual cortex
- Cortical mapping methods
- of gray matter density, 26–30, 403
  - of gray matter thickness, 30–33
- Cortical parcellation hypothesis, of visual information processing, 140–141
- Cortical plate
- glial cell migration to, 40
  - neuron cell migration to, 40–41
  - subcortical structures of, development of connectivity between, 40–41
- Cortical-subcortical system, extended, in adult face processing, 511
- Corticocortical connections, prefrontal, 215–216
- development of, 224
  - long associative, 224–225
- Corticohypothalamic connections, prefrontal, 215
- Corticospinal axons, navigation of, 16
- Corticosterone
- action of, on amygdala, 794–795
  - in learning avoidance, 793
  - natural fluctuations of, 793–794
- Corticostratial fibers, prefrontal, 215
- Corticostriatothalamocortical (CSTC)
- circuitry
  - components of, 718, 726
  - in perceptually cued learning, 729–730
  - in tics and compulsions, 726–729
- Corticothalamic axons
- navigation of, 15–16, 17
  - prefrontal, 215
- Corticotropin-releasing hormone (CRH)
- influence of
    - on brain, 68–69
    - on brain development, 70
    - involved in stress reactivity, 841
    - secretion of, LHPA stress response and, 63
- Cortisol
- elevated
    - in children attending day-care, 73
    - in hippocampus, 69
    - in puberty, 73–74  - influence of
    - on brain, 67–68
    - on brain development, 69–70
    - salivary, collection of, 65
    - synthetic form of, 69
- Covert orienting attention, 482
- CPS (closure positive shift), in processing intonational phrase boundaries, 119
- Cretinism, iodine deficiency causing, 633–634
- CRH. *See* Corticotropin-releasing hormone (CRH)
- Critical elements, of neural network models, 368–371
- challenges to, 376–377
  - learning algorithms as, 370–371
  - net input and activation functions as, 369–370
  - units and weights as, 368–369
- CSTC circuitry. *See*
- Corticostriatothalamocortical (CSTC) circuitry
- CVF (central visual field), in deaf and hearing subjects, 440
- CYLIN2 gene, in Williams syndrome, 692
- Cytoplasmic signaling pathways, dynamics of, regulation of microtubule and actin organization and, 8–9

## D

- Day-care, elevated cortisol in children attending, 73
- DCCS (Dimensional Change Card Sort), 558, 559, 561, 566, 846
- Deafness, 439–449
- American Sign Language and, 444–446.
  - See also* American Sign Language
  - cochlear implantation for, 446–448. *See also* Cochlear implantation
  - cortical plasticity in, 103–104
  - effects of
    - on processing of visual motion, 439–443
    - on processing of visual space, 443–444
- Decision making
- in attention-deficit/hyperactivity disorder, 886
  - autonomic signals in, using Iowa Card Gambling Task, 884–885

- Decision making (continued)
- behavioral and cognitive disinhibition in, 886–887
  - development of, 883–887
  - in executive function in childhood, 558
  - approach-avoidance, 557
  - fMRI studies in, 887
  - future directions of, 892–893
  - Hungry Donkey Task in, 885
  - Iowa Card Gambling Task in, variants of, 886
  - in unipolar depression, 776–778
- Declarative memory
- adult recognition abilities in, emergence of, 501–502
  - adult relational abilities in, emergence of, 502–503
  - beyond infancy, 547–548
  - development of, 501–503
  - cognitive neuroscience approach to, 541–550
  - hippocampus in, 543
  - early damage to, 548–549
  - in infancy, 542–543
  - brain development and, 543
  - deferred imitation and, 543
  - development of, 543–547
  - encoding and, 543–544
  - retention and, 544–545
  - retrieval and, 545–547
  - visual paired-comparison (VPC) task and, 542–543
  - neural circuits mediating, maturation of, 503
- Deferred-imitation task, infant performance on, declarative memory and, 543
- Delayed nonmatch to sample (DNMS) task, 541
- in assessing recognition-memory abilities, 502
  - in joint-attention study, of autistic children, 823–824
- Delay-of-gratification paradigms, in executive function in childhood, 557–558
- Delay-of-gratification task, in assessing attention and behavioral inhibition, 846
- Deliberate phase, of walking, 150
- Dementia, 607–616. *See also* Alzheimer's disease
- brain abnormalities in, functional and structural, 614–615
  - differential cognitive profiles of, 612–614
  - measuring change over time in, 611
  - types of, 607
  - vs. normal aging, 607
- Dementia with Lewy bodies, 607
- vs. Alzheimer's disease, 613–614
- Demographic correlates, of executive function in childhood, 564
- Dendrite(s)
- development of, 18–19
  - differentiation of, 13
  - distinguishing microtubule features in, 6
  - formation of, developing neurons in, 5–20
- initial growth of, neuronal polarization and, 13–14
- in normal brain, 386
- structural abnormalities of, prenatal cocaine exposure associated with, 655
- Dendritogenesis, in prenatal and postnatal brain, 19
- Dentate gyrus
- Cajal-Retzius cells in, 197
  - cell proliferation suppression in, 54
  - development of, 52
  - granule cells in, 187, 200
  - calbindin immunoreactivity of, 200–202
  - in hippocampal formation
  - cell formation and, 191, 192
  - location of, 189
- Depression
- associated with 5HTT gene, in maltreated children, 76
  - clinical characteristics of, 773–774
  - cognitive resilience and, 780
  - cognitive theories of, 775–776
  - genetic influence on, 353
  - onset of, critical stressor in, 359
  - symptoms of, 773
  - unipolar
  - behavioral inhibition and biases in, 778–779
  - decision making in, 776–778
  - developmental neuropsychology of, 771–781
  - diagnosis of, 773–774
  - executive dysfunctions of, 776–780
  - impaired attention in, 779–780
  - malfuction of brain regions and, 774–775
- Detroit principle, of developmental plasticity, 429
- Developmental cognitive neuroscience
- behavior genetics in, 351–354
  - fMRI studies of, 316–320
  - behavioral development and, 318–319
  - behavioral paradigms and, 315–316
  - brain development and, 317–318
  - history of, 316–317
  - intervention or treatment effects using, 319–320
- imaging genetics in
- conceptual basis of, 354–355
  - findings of, 355–358
  - importance of, 358–360
  - ongoing investigations in, 360–362
  - transitional aspects of, 361–362
- Developmental delay(s), MRS imaging of, 343–344
- Developmental neuropsychology, of unipolar depressions, 771–781. *See also* Depression, unipolar
- Dexamethasone, fetal exposure to, 69
- Diagnostic and Statistical Manual of Mental Disorders*, fourth edition (DSM-IV), criteria in
- for Alzheimer's disease, 607
  - for anxiety disorders, 755
- for Asperger syndrome, 701
- for autism, 165
- Dialects, 108–109
- Diet, low phenylalanine, for phenylketonuria, 683
- Dietary therapy, for phenylketonuria, 678
- Diffusion coefficient, apparent, 301
- in newborns, 304
- Diffusion spectral imaging (DSI), 307
- Diffusion tensor imaging (DTI), 301–307
- advanced methods of, 305–307
  - anatomical and physiological correlates of, 303–304
- of brain
- in autistic children, 704
  - in preterm-born children, 401
  - in socioemotional deprivation studies, 408
- of corpus callosum, memory performance and, 592, 593
- data acquisition in, 301–302
- methodological challenges of, 304
  - data processing in, 302–303
  - developmental correlates of, 304–305
  - limitations of, 306
  - principles of, 301
  - of traumatic brain injury, 404, 405
  - of white matter, 578
- Dimensional Change Card Sort (DCCS), 558, 559, 561, 566, 846
- Dissociation, dorsal and ventral, behavioral evidence of, 471–474
- Distributional modifications, in phonetic reorganization, 105
- Distributional sensitivity, in phonetic reorganization, 105–106
- of second language, 106–107
- Division-of-labor hypothesis, in linguistic theory, 330
- Dopamine
- abnormalities of, disorders associated with, 86
  - developmental neuropharmacology of, 85–87
  - influence of, in emotion regulation, 352
  - synthesis of, 86
  - tyrosine in, 683
  - in vitro studies of, 87
- Dopamine receptor(s), 727
- subfamilies of, 86
  - transcripts for, 86–87
- Dopamine receptor coupling, reduced, prenatal cocaine exposure and, 91
- Dopamine receptor signaling
- balance of, 91–92
  - loss of, prenatal cocaine exposure and, 90
- Dopamine transmission, abnormalities of, in Tourette's syndrome, 727
- Dopaminergic system
- in arousal aspect of attention, 480
  - effect of prenatal cocaine exposure on, 656–657
  - of prefrontal cortex, 214–215
- Dorsal visual pathway. *See* Visual pathways, dorsal
- “Double bouquet” neurons, 221

Double-deficit hypothesis, of dyslexia, 742  
Down syndrome, vs. Williams syndrome, 695  
DSI (diffusion spectral imaging), 307  
DSM-IV. *See* Diagnostic and Statistical Manual of Mental Disorders-IV edition (DSM-IV) entries  
DTI. *See* Diffusion tensor imaging (DTI)  
Duration discrimination, in auditory development, 99–100  
Dynamic systems approaches (DSAs), to motor development, 148–149  
critical implications of, 149  
Dynein, in regulation of microtubule organization, 5  
Dyslexia, 739–749  
attention-deficit/hyperactivity disorder and, 745  
behavioral profile in, 740–741  
comorbid disorders with, 745–746  
core cognitive impairment in, 742–743  
definition of, 739–740  
functional anatomy and, 743–744  
future goals for, 749  
genetic studies of, 744–745  
reading intervention for, 746–747  
neurobiological basis of, 747–749  
reading-related deficits in, 740  
recognition of, 739  
risk assessment and prediction of, 746  
specific language impairment with, 745–746  
theories of, 741–743

## E

Earlier left anterior negativity (ELAN), in sentence processing, 124  
Echo time (TE), in proton MRS, 338  
Eigenvalues, in DTI data processing, 302  
Eigenvectors, in DTI data processing, 302  
ELAN (earlier left anterior negativity), in sentence processing, 124  
Electrode(s), placement of, for electroencephalography, 247  
Electroencephalography (EEG)  
asymmetry of, as maker of negative reactivity in temperament, 843  
in cognitive neuroscience, 247–248  
of joint-attention development, 826  
*ELN* gene, deletion of, in Williams syndrome, 692  
Emotion  
in attachment, emergence of, 795–797  
elicitation of, 874  
effects of early adversity in, 874–875  
expression of, deficit identification of, orbitofrontal cortex lesions in, 168  
regulation of  
genes involved in, 352–353  
sleep and, 813–814  
sensitivity to, in face processing, 514  
Emotion processing  
effects of maltreatment on, 870  
regulatory, 875  
effects of early adversity in, 875–876

Emotion signals, cognitive processing of effects of early adversity in, 872–873  
neural mechanisms involved in, 870–874  
Encoding of information  
age-related differences in, 544  
developmental changes in, 544  
episodic, long-term memory and, 598–599  
in infancy, declarative memory and, 543–544  
Endophenotype(s), 759  
in autism, 702  
Entorhinal cortex, in declarative memory, 503  
Environment  
acoustic, in auditory cortex organization, 102–103  
influence of  
on brain-behavioral development, 869–877  
on early brain injury recovery, 393, 407  
on traumatic brain injury, 407–408  
stressful and adverse, children exposed to, 869–877  
Environmental factors  
in fear circuit function variations, 762–763  
and pediatric anxiety, 763–764  
Epigenetic processes, in neurodevelopment, 636  
Epigenetics, 797  
Equifinality, in LHPA function, 74  
ER22/23EK polymorphism, and individual LHPA function, 76  
EROs. *See* Event-related oscillations (EROs)  
ERPs. *See* Event-related potentials (ERPs)  
Error-driven learning algorithms, 370  
Error-related negativity (ERN)  
in behavioral inhibition, 847  
in performance monitoring, 558, 887–888  
Estrogen, regulating adult neurogenesis, 53–54  
Event-related oscillations (EROs), 256–257  
and object processing, 471  
Event-related potentials (ERPs)  
abnormal, in Williams syndrome, 693–694  
in behavioral inhibition, 847–848  
in brain activity, measurement of, 117–118  
in cognitive development, 248–249  
auditory stimuli and, 249–252  
lexical and syntactic processing and, components related to, 252  
mismatch responses in, 251–252  
multimodal stimuli and, 255–256  
saccade-related, 256  
visual stimuli and, 252–254  
in language development, 119–122, 124  
scalp-recorded, as psychophysiological measure of attention, 483–484  
in self-regulation, 847  
studies of  
in deafness and visual motion processing, 439–440  
in dorsal and ventral visual pathways, 469–471

Excitatory neurons, hippocampal, 200–203  
Executive function  
and aging, 595–597  
in autism, 704–705  
development of, in childhood, 553–567.  
*See also* Children, executive function in impaired  
in fetal alcohol syndrome, 647–648  
in phenylketonuria, 681  
in unipolar depression, 776–780  
Experience, and brain development, normal, 386–387  
Experience-dependent processes, in early brain injury, 407–408  
Experience-dependent synaptogenesis, 386–387  
Experience-expectant processes, in early brain injury, 407–408  
Explicitness, in neural network models, 368  
Extinction, fear conditioning and, 760  
Extrathalamic afferent system, of prefrontal cortex, 214–215  
basal forebrain–prefrontal cholinergic fibers in, 215  
development of, 222  
dopaminergic fibers in, 214–215  
Eye. *See also* Vision; Visual entries; specific part optics of, 129–130  
Eye contact, diminished, temporal cortex lesions and, 170  
Eye gaze. *See* Gaze entries  
Eye monitors, 263, 265  
Eye movements  
and attention, 484–489  
ballistic, 263, 264, 265. *See also* Saccades control of, brain area involved in, 485  
main sequence in, 487–489  
reflexive saccadic effect of attention in, 487  
in tracking visual stimuli, 485  
during scene and face perception, 264, 266–267  
in children and adolescents, 273  
smooth pursuit, 266, 267  
in children and adolescents, 269, 273  
effect of attention on, 486–487  
in tracking visual stimuli, 485  
types of, 485  
effect of attention on, 486–487  
voluntary saccadic, in tracking visual stimuli, 485  
Eye tracking studies, 263–294  
in children and adolescents  
atypical development and, 276–288. *See also* specific disorder  
normative development saccades and, 269–276  
limitations of, 292  
potentials of, conclusions regarding, 292–294  
review of, in normative and atypical development, 284, 289–292  
tasks and measures in, 263–269

## F

- Face(s), detection of, 511–512  
  after treatment of congenital cataracts, 422, 423
- Face perception, 422–426  
  deficits in, autism and, 707–708  
  face detection in, 422, 423  
  facial identity in, 425–426  
  holistic processing in, 422, 424–425  
  neural substrates of, 442  
  visual processing in, effects of deafness on, 442
- Face perception tasks, in eye tracking, 264, 266–267  
  in children and adolescents, 273
- Face processing  
  adult, 509–511  
    core cortical system in, 509–511  
    fusiform face area of, 510–511  
    superior temporal sulcus/gyrus of, 511  
  extended cortical-subcortical system in, 511  
  subcortical system in, 509  
in autism, 706–708  
development of, 511–515  
  core cortical system in  
    fusiform area of, 512–514  
    superior temporal regions of, 514–515  
  impairments in, 515–516  
  neurocognitive mechanisms for, 509–517  
  subcortical system in, 511–512  
holistic  
  composite face effect in, 422  
    deaf vs. hearing subjects and, 443  
  visual deprivation preventing, 424–425  
  whole-part advantage in, 422, 424
- Impairments in  
  childhood onset of acquired prosopagnosia and, 516  
  congenital prosopagnosia and, 516  
  development of, 515–516  
  fusiform gyrus lesions and, 171  
  perinatal brain injury and, 515–516  
  Williams syndrome and, 693–694  
  right and left hemispheres in, 442
- Face-voice pairs, emotionally congruent and incongruent, infants' ERP responses to, 255
- Facial anomalies, in fetal alcohol syndrome, 643
- Facial expressions  
  imitation of, in neonates and infants, 830  
  processing of. *See also* Face processing  
    deficits in, autism spectrum disorders and, 708
- Facial identity  
  processing of. *See also* Face processing  
    in autism, 706–708  
  recognition of, 425–426
- Familiar stimulus, and attention, 489–490
- Familiarity, retrieval process of, differential effects of aging on, 600
- FAS. *See* Fetal alcohol syndrome (FAS)
- FASD (fetal alcohol spectrum disorders), 643
- Fast-spiking GABAergic interneurons, 730
- Fat(s), in cognitive development, 623
- “Fate map” concept, in neurulation, 39
- Fatty acids, long-chain polyunsaturated, in breast milk, 629, 630
- Fear. *See also* Anxiety entries  
  definition of, 755  
  elictor of, 841
- Fear circuit function  
  information-processing and, 761–762  
    in pediatric anxiety, 764–766  
  modulators of, 762–763
- Fear conditioning  
  conceptualization of, 761  
  and extinction, 760  
  neural circuit engaged during, 759–760  
  research on, 760
- Fear-potentiated startle, 841
- Fear-related impairment, amygdala lesions causing, 167
- Feedback processing  
  cardiac concomitants of, 889–890  
  developmental change in, 890–892  
  in performance monitoring, 888–892
- Fetal alcohol spectrum disorders (FASD), 643
- Fetal alcohol syndrome (FAS), 643–648  
  attention deficits in, 647  
  autopsy studies of, 643–644  
  diagnosis of, criteria for, 643  
  executive function deficits in, 647–648  
  fMRI studies of, 645–646  
  future research in, 648  
  intellectual function deficits in, 646  
  learning and memory impairments in, 646–647  
  methodological considerations in, 643  
  motor dysfunction in, 648  
  neuroimaging studies of, 644–646  
    basal ganglia in, 645  
    brain metabolism in, 645  
    cerebellum in, 644  
    corpus callosum in, 644–645  
    neuropsychological studies of, 646–648  
    speech and language deficits in, 648  
    visual-spatial dysfunction in, 647
- Fetal origins hypothesis, of nutritional environment, 636
- Fetus  
  auditory development in, 97–98  
  brain development in  
    cocaine-compromised, 654. *See also* Cocaine, prenatal exposure to  
    MRS imaging of, 339–340  
  exposure of, to dexamethasone, 69  
  late-gestation, iron deficiency in, 632  
  malnutrition in  
    insulin-like growth factor-1 and, 625  
    protein-energy, effects of, 625, 627–628  
  origins of attachment in, 788  
  prefrontal intrinsic circuitry in, 227, 229  
  prenatal experiences in, influencing postnatal brain structure, 387
- FFA. *See* Fusiform face area (FFA)
- Fibroblast growth factor (FGF), 625
- Fibroblast growth factor-2 (FGF-2), administration of, regeneration of injured cortical tissue after, 390–391
- Flasker task, in assessment of temperament, 847
- Fluoxetine, prenatal exposure to, brain development and, 395
- fMRI. *See* Functional magnetic resonance imaging (fMRI)
- Focal brain insults, 403. *See also* Brain injury
- Folic acid deficiency, 624
- Forebrain  
  adolescent rodent  
    microarray analysis of, 857, 859  
    nicotine affecting gene expression in, 862  
  anterior pathway of. *See* Anterior forebrain pathway  
    developmental milestones in, 84
- FOXP2 gene mutation, 459
- Fractional anisotropy (FA), in DTI data processing, 302, 578
- Frequency discrimination, in auditory development, 99–100
- Frontal cortex  
  dorsal medial, joint attention and social-cognitive performance involving, 827  
  early injury to. *See also* Brain injury, early modification of effects of, 392  
  microstructural asymmetry and hemispheric specialization of, 231–232  
  studies of, in obsessive-compulsive disorder, 722
- Frontotemporal dementia, 607  
  vs. Alzheimer's disease, 612
- Functional magnetic resonance imaging (fMRI), 311–321  
  in auditory cortex mapping, 104  
  basic principles of, 312–316  
  of brain, 118  
    in adolescents, 856  
    in autistic children, 704, 708–709  
    speech stimuli and, 111  
  in decision making, 887  
  in developmental cognitive research, 316–320  
    behavioral development and, 318–319  
    behavioral paradigms and, 315–316  
    brain development and, 317–318  
    history of, 316–317  
    intervention or treatment effects using, 319–320
- of fetal alcohol syndrome, 645–646
- future directions of, 320–321
- of gaze following activities, 824, 825
- of neural activation associated with reading, 327
- of obsessive-compulsive disorder, 723
- of pediatric anxiety disorders, 764–766
- in performance monitoring, 891
- physics of, 312
- physiologic basis of, 312–314

Functional magnetic resonance imaging (fMRI) (continued)  
 in reading processing, 743  
 safety considerations for, 314–315  
 of schizophrenia, 825  
 signal artifact in, sources of, 314

Fusiform face area (FFA)  
 in adult face processing, 510–511  
 in autism spectrum disorders, 707–708, 710  
 in infant face processing, 512–514

Fusiform gyrus  
 functional studies of, 170–171  
 lesions of, 171  
 neuroanatomy of, 170  
 role of, in social behavior, 170–171

**G**

Gain, in smooth-pursuit eye movement, definition of, 266

Gamma-aminobutyric acid (GABA) neurons, in prefrontal cortex, 214

Gamma-aminobutyric acid (GABA) neurotransmitter, inhibitory, 135, 726

Gamma-aminobutyric acid (GABA) receptor genes, repetitive behavior in autism and, 711

Gamma-aminobutyric acid (GABA) system  
 effect of prenatal cocaine exposure on, 657–658  
 role of, in autism, 704

Ganglia, basal. *See* Basal ganglia

Ganglion cells, of retina, 130, 139

Gap and overlap tasks, in eye tracking, 264

Gaze  
 alternating, 822  
 in autism  
   abnormal, 281  
   eye tracking studies of, 282–284, 708  
 direction of, in face processing, 514–515

Gaze following activity  
 in early development  
   importance of, 821–822  
   individual differences in, 821  
   nature of, 819–821  
 fMRI of, 824, 825  
 and ventral social brain, 823–825

Gaze shifting, 819–820

Gene(s). *See also specific gene*  
 candidate, in autism, 702–703  
 identification of, in adolescent rodent brain, 857–859  
 involved in emotion regulation, association studies of, 352–353  
 regulation of, recognized system of, 797–798  
 study of, 351–352

Gene expression  
 immediate early, prenatal cocaine exposure and, 660–661  
 nicotine affecting, in adolescent rodent brain, 862

Generalized anxiety disorder, 755. *See also Anxiety disorder(s)*  
 attention avoidance in adolescents with, 764

Genetic aspects, of vocal development, 459

Genetic markers, of negative reactivity in temperament, 843–844

Genetic polymorphism  
 impact of, on behavior, 354  
 in individual LHPA function, 75–76

Genetic studies  
 association, 352–354. *See also Association genetic studies*  
 of behavior, 351–354. *See also Behavior genetics*  
 of dyslexia, 744–745  
 of phenylketonuria, 684–685

Genotype, in Williams syndrome, 691–692

Geodesic sensor net, for electroencephalography, 247

Germinal matrices, in hippocampal development, 187–195  
 proliferating cells of, 189

GGF (glial growth factor), 625

GH (growth hormone), mother–infant interactions and, 795

GI (gyrification index), 42  
 utilization of, in neuropsychiatric disorders, 45–46

Glial cells, migration of, to cortical plate, 40

Glial growth factor (GGF), 625

Global form, sensitivity to, after treatment of congenital cataracts, 421–422

Global motion, sensitivity to  
 after treatment of congenital cataracts, 420–421  
 in high-level vision, 420–421

Glucocorticoid(s), regulating adult neurogenesis, 53

Glucocorticoid receptor(s), in cortisol binding in brain, 67–68

Glycogen synthase kinase-3 $\beta$ , cocaine-induced suppression of, 661

Goldman-Rakic's model, of prefrontal function, 579

Gonadal hormone(s), and recovery from early brain injury, 394–395

Go-no-go task, 585–586  
 in assessment of brain activation, 847  
 impairments of, obsessive-compulsive disorder and, 722

GR gene, and individual LHPA function, 76

Granule cell(s), of dentate gyrus, 187, 200  
 calbindin immunoreactivity in, 200–203

Granule cell neurogenesis, in dentate gyrus, 52, 53

Grasping, precision in, 150

Gratification, delay of, in executive function in childhood, 557–558

Grating acuity, deficits in, congenital cataracts and, 416–417

Gray matter  
 cortical rim of, 39–40  
 development of  
   back-to-front pattern of, 577–578  
   changes in, cognitive correlates of, 33–36  
 effect of traumatic brain injury on, 404

volume decrease of  
 age-related, 25, 26, 44, 553  
 rate and pace of, 772

Gray matter density, cortical mapping methods of, 26–30

Gray matter thickness, cortical mapping methods of, 30–33

Growth cone elongation, in neurite maturation, 10–12

Growth cone navigation  
 in neurite maturation, 12  
 pathways for, 14–15  
 during cerebral cortex development, 15–18  
 thalamocortical, 17

Growth cone organization, in neurite maturation, 10

Growth factor(s), 624–625

Growth hormone (GH), mother–infant interactions and, 795

Growth hormone releasing factor, mother–infant interactions and, 795

Growth retardation, intrauterine, 627–628, 632

GTF2IRD1 gene, in Williams syndrome, 692

Gyrification  
 abnormalities of, clinical conditions associated with, 44–46  
 brain development prior to, 39–40  
 heritability of, 43  
 ontogeny of, theories of, 41–44  
 phylogeny in, 41  
 postnatal changes in brain morphology and, 43–44

Gyrification index (GI), 42  
 utilization of, in neuropsychiatric disorders, 45–46

Gyrus  
 alterations in, 45  
 dentate. *See* Dentate gyrus  
 fusiform, role of, in social behavior, 170–171  
 middle temporal, activation in, deaf vs. hearing subjects and, 440  
 superior temporal  
   in face processing, 511, 514–515  
   in social perception, 823

## H

Habit-learning systems, 723–726  
 in obsessive compulsive disorder, 725–726  
 PCL assessment of, 724  
 in Tourette's syndrome, 725

Habitual behaviors. *See also Obsessive-compulsive disorder (OCD); Tourette's syndrome*  
 disturbances of self-regulatory control in, 717–731

Hansen and Fulton model, of visual development, 128–129

HARDI (high-angular-resolution diffusion imaging), 307

Head, increased growth of, autism and, 703–704

Hearing. *See also* Auditory system  
loss of. *See* Deafness  
onset of, 97–98

Heart rate, as psychophysiological measure of infant attention, 482–483, 489

Hebb hypothesis, of early brain injury, 387–388, 400

Hebbian algorithm, 370

Heel-toe progression phase, of walking, 150

Hemispheric asymmetry reduction in older adults (HAROLD) model, 598–599

Hemispheric encoding/retrieval asymmetry (HERA) model, 598

Heritability, of gyration, 43

High variability phonetic training (HVPT) regime, 107

High-angular-resolution diffusion imaging (HARDI), 307

Hilar mossy cells, spines of, formation of, 202

Hippocampus  
activation of, during transitive inference task, 546  
in declarative memory performance, 543  
early damage to, 548–549  
dentate gyrus in  
cell formation in, 191, 192  
location of, 189  
effect of traumatic brain injury on, 404  
elevated cortisol in, 69  
in expression of novelty preference, 542–543

formation of  
Cajal-Retzius cells in, 196–200  
calretinin-secreting, 197  
in newborns, 200  
reelin-secreting, 196–197  
cell migration in, 195–196, 203, 207–208  
cell proliferation in, 203, 207–208  
evidence of cell death in, 195  
germinal matrices and cell proliferation in, 187–195  
morphological changes of  
cytoarchitectonics in, 187, 190, 191  
postmortem studies in, 188  
pyramidal cells in, 187, 200, 202–203

neurogenesis in  
in adults, 51–59  
discovery of, 51–52  
methodological advances leading to, 52  
experience regulating, 54–57  
functional significance of, 57–58  
hormones regulating, 52–54  
learning and, 55–57  
blockade of, 58  
parallel changes in, 57–58  
stress affecting, 54–55

neurons of, excitatory and inhibitory, 200–203  
in Williams syndrome, 691

Holistic face processing. *See also* Face processing  
composite face effect in, 422  
deaf vs. hearing subject and, 443  
visual deprivation preventing, 424–425  
whole-part advantage in, 422, 424

Hormone(s). *See also specific hormone*  
regulating adult neurogenesis, 52–54

5-HT. *See* Serotonin (5-HT)

5-HT gene, in threat response behavior, 762

5-HTT gene, 75  
depression associated with, in maltreated children, 76  
in personality genetics, 353, 844  
polymorphism of, 355–358  
temperament associated with, 844  
in threat response behavior, 762

5-HTTLPR S allele  
in depression and anxiety, 844  
effects of  
on amygdala reactivity, 356–358  
on brain circuitry, 358

Hungry Donkey Task, in decision making, 885

Hyperactivity disorders, in fetal alcohol syndrome, 647

Hyperphenylalaninemia, 678

Hyperserotoninemia, in autism spectrum disorders, 704

Hypersociability, in Williams syndrome, 165

Hypothalamus, prefrontal cortex connection to, 215

**I**

IEGs (immediate early genes), expression of, prenatal cocaine exposure and, 660–661

IGF-1 (insulin-like growth factor-1), 625

Imaging genetics  
conceptual concept of, 354–355  
findings in, 355–358  
importance of, in understanding development and psychopathology, 358–360  
ongoing developmental studies in, 360–362  
transitional aspects of, 361–362

Immediate early genes (IEGs), expression of, prenatal cocaine exposure and, 660–661

Implants, cochlear. *See also* Cochlear implantation  
advent of, 446  
success of, 103–104

Impulsivity, increased, in unipolar depression, 777

In utero cocaine exposure. *See* Cocaine, prenatal exposure to

Independent stepping phase, of walking, 150

Indexical factors, in speech processing, 108–109

Indoleamine 5-HT, 87

Infant(s). *See also* Children; Newborn(s)  
attachment of  
development of, 797–798  
neurobiology of, 787–799

attention in  
arousal system of, 479–480  
brain systems involved in, 479–482  
briefly presented stimuli and, recognition of, 489–494  
covert (orienting), 482  
definition of, 479  
developmental psychological perspective on, 479–495  
direct measure of, 484  
event-related potentials and, scalp-recorded, 483–484  
eye movements and, 484–489. *See also* Eye movements  
heart rate in, 482–483, 489  
indirect measure of, 484  
psychophysiological measures of, 482–484

auditory development in  
absolute thresholds and, 98–99  
bilingual exposure and, 106–107  
distributional sensitivity of, 105–106  
fundamental capacity of, 97–100  
intensity, frequency, and duration discrimination and, 99–100  
reference and learning in, 107–109  
sound thresholds in, 99  
in utero experiences and, 97–98

auditory localization in, 101

cognitive development studies in, 247–258

electroencephalogram in, future directions in, 247–248

event-related oscillations in, 256–257

event-related potentials in, 248–249  
auditory stimuli and, 249–252  
multimodal stimuli and, 255–256  
saccade-related, 256  
visual stimuli and, 252–254

future directions in, 257–258

declarative memory in, 542–543  
brain development and, 543  
deferred imitation and, 543  
development of, 543–547  
encoding and, 543–544  
retention and, 544–545  
retrieval and, 545–547  
visual paired-comparison (VPC) task and, 542–543

face processing in  
core cortical system in  
fusiform area of, 512–514  
superior temporal regions of, 514–515  
development of, 511–515  
impairments in, 515–516  
neurocognitive mechanisms for, 509–517  
subcortical system in, 511–512

imitation of facial expressions in, 830

language acquisition in, NIRS studies of, 326–328

- Infant(s) (continued)
- movement in, 147–148. *See also* Motor system, development of
  - overall level of motor activity in, 151
  - prenatally cocaine-exposed. *See also* Cocaine, prenatal exposure to neurobehavioral and developmental findings in, 664–666
  - neurochemical findings in, 664
  - outcomes of, 663–666
  - physical abnormalities in, 89
  - preterm. *See* Preterm birth
  - prosodic, lexical, semantic, and syntactic processing in, 117–125
  - reaching abilities of, 149–150
  - walking phases in, 150–151
- Infant start state, vs. phenotypic end state in Williams syndrome, 695
- Information processing
- complex, in autism, 705–706
  - and fear circuit function, 761–762
  - in pediatric anxiety, 764–766
- Inhibition
- behavioral, 74–75, 585–586
  - in temperament, 841–843
  - in unipolar depression, 778
  - and pediatric anxiety, 763
- Inhibitory cells, axo-somatic, parvalbumin-containing, 203
- Inhibitory control, relations between temperament and, 846
- Inhibitory neurons, hippocampal, 200–203
- Inhibitory processes, age-related impairment in, 595
- Insulin-like growth factor-1 (IGF-1), 625
- Integrated walking phase, 150
- Intelligence, impaired, in fetal alcohol syndrome, 646
- Intelligence quotient (IQ) score
- after traumatic brain injury, 406
  - in children with phenylketonuria, 678
  - everyday-memory function impairment and, 548
  - fetal alcohol syndrome and, 646
  - in preterm children, 402
  - relationship between executive function and, 647
  - relationship between gray matter structure and, 34–35
  - Williams syndrome and, 693
- Intelligence quotient (IQ) tests, reading achievement and, 740
- Intensity discrimination, in auditory development, 99–100
- Interindividual variability, of sleep patterns, 811
- Interneuron(s)
- calbindin-containing, 204
  - calretinin-containing, 204
  - parvalbumin-containing, 203, 205, 206
- Intonational phrase boundaries, sentential prosody marking, 118–119
- Intra-Dimensional, Extra-Dimensional (ID-ED) Set Shifting Task, in depression, 779
- Intraindividual stability, of sleep patterns, 811
- Intrauterine growth retardation (IUGR), 627–628, 632
- Intrinsic circuitry, prefrontal, 214
- endogenous and sensory-driven, 229, 230
  - neonatal, 229–230
  - overproduction of elements of, in infancy and childhood, 230–231
  - preterm infant (endogenous), 229
  - prolonged plasticity and reorganization of, in adolescence and postadolescence, 231
- Iodine
- in brain development, 626, 633–634
  - deficiency of, 633–634
- Iowa Gambling Task (IGT), 884–885
- in decision making, 884–885
  - variants of, 886
- reward and punishment schedules in, 884
- Iron
- in brain development, 626, 630–632
  - deficiency of, 631
  - in late-gestation fetuses, 632
- Isolation, ultrasonic vocalization response to, 796
- IUGR (intrauterine growth retardation), 627–628, 632
- J**
- Joint attention. *See also* Attention
- adoption of term, 819
  - anterior attention system and, 828–829
  - development of, 819–833
  - gaze following, 829–833
  - individual differences in, 821
  - and dorsal social brain, 825–827
  - impairment of, in autism, 822–823
  - importance of, 821–822
  - initiation of, 820
  - related to language outcome, 821
- multi-process model of, 831
- nature of, 819–821
- posterior attention system and, 827–828
- responding to, 820
- and ventral social brain, 823–825
- K**
- Katanin, in regulation of microtubule organization, 5–6
- Kennard hypothesis, of early brain injury, 387–388
- Kinesin, in regulation of microtubule organization, 5
- Knowledge
- neural network models of, 371–372
  - phonotactic, and lexical form, 121
- L**
- Labeling, facilitating executive function in childhood, 564–565
- Lactose, in breast milk, 629–630
- LAD (language acquisition device), 332
- Lamination, in prefrontal cortex development, 219–221
- Language(s). *See also* Speech entries
- deficits of, in fetal alcohol syndrome, 648
  - multiple. *See also* Bilingualism
  - simultaneous acquisition of, 326
  - outcome of, initiating-joint-attention skills related to, 821
  - spoken, vs. American Sign Language, 444. *See also* American Sign Language
  - stress patterns of words in, 119–121
  - visual plasticity in, 444–446
- Language acquisition
- distributional information and linguistic categories in, interaction of, 329–330
  - evolutionary accounts of, 326
  - in infants, NIRS studies of, 326–328
  - mechanisms of, 325–333
  - nonlinear change in, 374–375
  - perceptual primitives in, 330–332
  - productivity in, 326
  - statistics and prosodic structures in, interaction of, 328–329
  - theories of, 325–326
  - Williams syndrome and, 694–695
- Language acquisition device (LAD), 332
- Language impairment, specific, 741–742
- diagnosis of, 741
  - dyslexia with, 745–746
- Larmor relationship, in diffusion tensor imaging, 301
- Latent memory traces, vs. active memory representations, 555
- Lateral geniculate nucleus (LGN), in visual cortex, 131, 133, 139
- Learning
- and adult neurogenesis, 55–57
  - blockade of, 58
  - parallel changes in, 57–58
  - attenuated aversion, and attachment, 792–795
  - brain correlates of, 109–111
  - disabilities in, dyslexia and, 739, 740. *See also* Dyslexia
  - fetal
  - and attachment, 788
  - transition of, 788–789
- habit, 723–726
- in obsessive compulsive disorder, 725–726
  - PCL assessment of, 724
  - in Tourette's syndrome, 725
- impaired, in fetal alcohol syndrome, 646–647
- lexicon, 107–109
- mechanisms of, 373–374
- olfactory preference
- and attachment, 790–792
  - end sensitive period in, 792
  - role of neurotransmitters in, 791–792
- perceptually cued, CSTC circuits in, 729–730
- postnatal, and attachment, 789–790

Learning (continued)  
reward, in executive function in childhood, 558  
role of sleep in, 813  
Learning algorithms, in neural network models, 370–371  
Learning environment, retrieval cues in, infants' memory and, 545–546  
Left hemisphere  
in face processing, 442  
in forward and backward speech, 118  
injury to, spatial functioning after, 530–531  
visuospatial processing in, 528–529  
Lewy bodies, dementia with, 607  
vs. Alzheimer's disease, 613–614  
Lexical form  
development of, in Williams syndrome, multiple factors contributing to, 696  
identification of, 119–121  
phonological familiarity of words in, 121  
phonotactic knowledge in, 121  
stress patterns of words in, 119–121  
Lexicon, auditory, reference and learning of, 107–109  
LGN (lateral geniculate nucleus), in visual cortex, 131, 133, 139  
LHPA system. *See* Limbic-hypothalamic-pituitary-adrenocortical (LHPA) system  
Limbic-hypothalamic-pituitary-adrenocortical (LHPA) system, 63–77  
anatomy and physiology of, 63, 65  
in animal models, 70–71  
function of, individual differences in, 74–76  
hyperreactivity and hyporeactivity of, 74  
measurement of, in developmental research, 65–67  
regulation of, social experience and, 71–74  
stress responses of, 63, 65  
influence of cortisol and corticotropin-releasing hormone on, 67–69  
regions associated with, 64  
*LIMK-1* gene, deletion of, in Williams syndrome, 692  
Linguistic theory, in language, 325  
12-Lipoxygenase (12-*lox*), in rodent adolescent brain, 857–859  
Lissencephaly, 45  
Local motion, sensitivity to, after treatment of congenital cataract, 419  
Localization  
auditory  
in infants, 101  
recalibration of, 101–102  
spatial, in dorsal visual pathway, 523–525  
Locomotor development, nervous system maturation in, 151  
Long-chain polyunsaturated fatty acids, in breast milk, 629, 630

Long-term memory  
aging and, 597–600  
episodic deficits in, 598–599  
episodic retrieval in, 599–600  
Low phenylalanine diet, for phenylketonuria, 683  
**M**  
MAA (minimum audible angle), in auditory localization in infants, 101  
Macrocephaly, benign, definition of, 703  
Macronutrients, 623. *See also specific macronutrient*  
specific, effects of, 629–630  
Magnetic resonance imaging (MRI) of brain  
after traumatic injury, 404  
in autistic children, 703  
in children born preterm, 401  
functional. *See* Functional magnetic resonance imaging (fMRI)  
of myelination, 237  
vs. MRS, 337  
Magnetic resonance spectroscopy (MRS) of brain, 337–347  
in children and adolescents, 341, 343  
developmental disorder profiles in, 343–346  
in fetuses, 339–340  
limitations of, 346–347  
in neonates, 340–341, 342, 343  
multivoxel mode of, 338  
proton, 338  
single-voxel mode of, 338  
spectral quantitative, 339  
using MR sensitive nuclei, 337  
vs. MRI, 337  
Malnutrition, protein-energy and brain development, 625, 626, 627–630  
postnatal, effects of, 628–629  
prenatal, effects of, 625, 627–628  
risk of, weaning and, 628  
Maltreatment, childhood  
behavioral response and regulation in, 876–877  
cognitive processing of emotion signals in, neural mechanisms involved in, 870–874  
consequences of, on LHPA system, 72–73  
developmental outcomes associated with, 869–870  
emotion elicitation in, 874–875  
emotion regulatory processes in, 875–876  
MAPs (microtubule-associated proteins), in regulation of microtubule organization, 5–6  
Material bias, in learning mechanisms, 373  
Maternal attachment, in next generation, 797–798  
Maternal behavior, postpartum, role of oxytocin in, 798  
Maternal separation responses, 795–797  
Maternal voice, newborn preference for, 98  
Maturation hypothesis, differential, in visual development, 139–141  
MCI. *See* Mild cognitive impairment (MCI)  
Measurement issues, in executive function in childhood, 566–567  
Mechanical folding hypothesis, in brain development, implication of, 42–43  
Medial temporal lobe  
age-related changes in, 592, 599  
damage to, 547  
in declarative memory, 546–547  
Memory  
in Alzheimer's patients, neuropsychological tests of, 609–611  
bird's own song  
during anesthesia and sleep, 459–460  
response to, 456  
vs. tutor song memory, 457  
declarative. *See* Declarative memory  
development of  
interneurons role in, 203  
nonprimate models in, 499–504  
vs. human memory, 503–504  
impaired, in fetal alcohol syndrome, 646–647  
long-term  
aging and, 597–600  
episodic deficits in, 598–599  
episodic retrieval in, 599–600  
procedural, 725  
adult abilities in, emergence of, 500  
development of, 499–501  
neural circuits mediating, maturation of, 500–501  
recognition  
adult abilities in, emergence of, 501–502, 581  
attention and, 490–494  
relational, adult abilities in, emergence of, 502–503  
sensory, physical location of, reassessment of, 460  
working. *See* Working memory  
Memory consolidation, role of sleep in, 809  
Memory-guided saccade task, in eye tracking, 264  
Mental arithmetic problems, pupillary dilation studies of, in children and adolescents, 273, 276  
Mental retardation, phenylketonuria and, 678  
Mental rotation  
developmental studies of, 527–525  
in spatial operations, 527  
Metabolism, brain  
in fetal alcohol syndrome, 645  
restorative, role of sleep in, 809  
Microarray analysis, of adolescent rodent brain, 857, 859  
Micronutrients, 623–624. *See also specific micronutrient*

- Microtubule(s)**
- actin interactions with, 9
  - formation of, 5
  - support and transport provided by, 5
- Microtubule organization, regulation of and dynamics of cytoplasmic signaling pathways**, 8–9
- microtubule-associated proteins in, 5–6
- Microtubule-associated proteins (MAPs), in regulation of microtubule organization**, 5–6
- Middle temporal gyrus, activation in, deaf vs. hearing subjects and**, 440
- Mild cognitive impairment (MCI)**
- in Alzheimer's disease, 608–609
  - markers of, 609
  - in dementia, 614–615
- Mineralocorticoid receptors, in cortisol binding in brain**, 67–68
- Minerals**, 623
- Minimum audible angle (MAA), in auditory localization in infants**, 101
- Minnesota study, of long-term neuropsychological outcome, in preterm-born children**, 402
- Mirror neurons**
- in autism, 708–709
  - in social behavior, 171
- Mismatch negativity (MMN)**, 251
- in behavioral inhibition, 848
- Mismatch response (MMR)**
- in ERPs to auditory stimuli, 251–252
  - during processing of word stress patterns, 120
- Monetary incentive delay (MID) task, in behavioral inhibition studies**, 842
- Monoamine(s), in brain development**
- balance of receptor signaling and, 91–92
  - effects of, 83–92
  - modulatory influence of, 88–91
  - neuropharmacology of, 85–88
- Monoamine oxidase A (MAOA) gene, in maltreated children**, 876–877
- Monoaminergic afferents, prefrontal**, 222
- Monocular deprivation**
- congenital cataracts and, 416–417, 420–421. *See also Cataract(s), congenital*
  - restrictions after, 418
- Mood, negative, sleep deprivation and**, 813
- Mood-valent theories, of negative cognition, depression and**, 775–776
- Mother-infant interaction patterns, of attachment**, 797–798
- Motion perception, sensitivity to, after treatment of congenital cataracts**
- global, 420–421
  - local, 419
- Motor activity**
- linked to behavioral and mental health conditions, 156
  - overall level of, in infants, 151
- Motor behavior, neural substrates of**, 151–155
- Motor dysfunction, in fetal alcohol syndrome**, 648
- Motor loop, of brain, in neural song system**, 457
- Motor response inhibition**, 585–586
- Motor system**
- components, pathways, and functions of, 153
  - development of, 147–157
  - level of activity in, 149–151
  - motor-cognitive relationships in, 155–156
  - motor-emotional relationships in, 156
  - neural substrates in, 151–155
  - reaching in, 149–150
  - relevance of movement in, 147–148
  - theoretical approaches to, 148–149
  - therapeutic interventions in, 156–157
  - walking in, 150–151
- Motor-cognitive relationships, in motor development**, 155–156
- Motor-emotional relationships, in motor development**, 156
- Movement**
- in motor development, 149–151
  - relevance of, in developing human, 147–148
- MRI. *See* Magnetic resonance imaging (MRI)**
- MRS. *See* Magnetic resonance spectroscopy (MRS)**
- Multifinality, in LHPA function**, 74
- Multimodal stimuli, ERP response to, in cognitive development**, 255–256
- Musty odor, associated with phenylketonuria**, 677
- Myelination**
- age and, 24
  - of axons
  - aberrant, disrupted dopamine synthesis and, 683
  - in central nervous system, 544
- in brain development**, 24–25
- Flechsig's map of**, 237, 238
- functional consequences of**, 239–241
- magnetic resonance imaging of**, 237
- in prefrontal cortex, during childhood**, 553
- relationship between cognitive function and**, 240
- Myosin(s)**, 8
- N**
- N170**
- adult, 513
  - infant, 513, 515
- N170/N290, in ERP responses to visual stimuli**, 253
- N290, infant**, 513
- N400 index, of lexical-semantic processes**, 121–123
- NAA metabolite, concentration of**
- in children and adolescents, 343
  - in fetuses, 339–340
  - in neonates, 340–341
- NAA/Cho ratio**
- in autism, 344
  - in children and adolescents, 341, 343
  - in developmental delays, 344
- NAA/Cr ratio**
- in attention-deficit/hyperactivity disorder, 345–346
  - in autism, 344
  - in children and adolescents, 341
  - in developmental delays, 344
- n-back task, in assessment of working memory**, 594–595
- Near-infrared spectroscopy (NIRS) study of brain activity**, 118
- of language dispositions in infants, 326–328
- Negative central (Nc) component in attention**, 490–491
- of ERP research, 254
- Negative reactivity, in temperament, EEG asymmetry as maker of**, 843
- Negative slow wave activity, in event-related potential**, 254
- Neglect, childhood**, 870. *See also Malreatment, childhood*
- in residential nurseries and orphanages, 873
- Neocortex**
- Cajal-Retzius cells in, 197, 199
  - circuitry elements in, postnatal development of, 225–227
  - histogenesis of, 83–85
- Net input**
- mathematical expression of, 369
  - in neural network models, 369–370
- Neural bases**
- of attenuated aversion learning, 792–795
  - of developmental processes, techniques for studying, 175–178
  - of olfactory preference learning, 790–792
- Neural circuits**
- compensation-related utilization of, hypothesis involving, 594
  - engaged by threats, 759–761
  - involved in temperament regulation, 846–848
  - maturational
  - mediating declarative memory, 503
  - mediating procedural memory, 500–501
- Neural groove**, 39
- Neural network models**
- benefits of, 367–368
  - challenges to, 375–376
  - of change mechanisms, 372–375
  - age-of-acquisition effects in, 374–375
  - learning about words and semantic categories in, 373–374
  - of cognitive development, 367–379
  - contributions of, 371–375
  - challenges to, 377–378
  - control in, 367
  - critical elements of, 368–371
  - challenges to, 376–377
  - explicitness of, 368
  - learning algorithms in, 370–371

Neural network models (continued)  
net input and activation factors in, 369–370  
of origins of knowledge, 371–372  
object continuity in, 371–372  
object permanence in, 372  
understanding behavior from, 367–368  
units and weights in, 368–369

Neural plate, 39

Neural song system, 453–458. *See also* Birdsong  
anterior forebrain pathway in, 458  
motor loop in, 457  
sensorimotor integration loop in, 456–457

Neural specializations, in auditory system, 100–104

Neural substrates  
of face perception, 442  
of motor behavior, 151–155

Neural system, reorganization of, during adolescence, 772–773

Neural tube, formation of, 39  
neuronal migration in, 39–40

Neurite(s), initiation and growth of  
branching in, 13  
growth cone elongation in, 10–12  
growth cone organization in, 10  
growth cone turning in, 12  
mechanism for, 10–13

Neurobehavioral profiles, cocaine-related  
human model of, 664–666  
preclinical model of, 661–663  
teratologic effects of, 653–654

Neurobehavioral systems, developing, early  
adversity associated with, 870–877

Neurochemical maturation, hippocampal, in  
preterm infants, 203, 207–208

Neurochemistry studies  
of adolescent brain, 856–857  
of arousal aspects of attention, 480  
of autism, 704  
of prenatally cocaine-exposed children  
and infants, 664

Neurocognitive development  
in autism, 701–712  
in face processing, 509–517. *See also* Face processing  
in prenatally cocaine-exposed children, 664

Neurocognitive functioning, in children,  
sleep patterns and, 810–811

Neurodevelopment  
changes in, associated with preterm birth, 400–403  
of social cognition, 161–178. *See also* Social cognition

Neurodevelopmental processes, disruption of, after traumatic brain injury, 403–404

Neurogenesis  
adult, 51–59  
discovery of, 51–52  
methodological advances leading to, 52  
experience regulating, 54–57  
functional significance of, 57–58

in hippocampus, 51–59  
hormones regulating, 52–54  
learning and, 55–57  
blockade of, 58  
parallel changes in, 57–58  
stress affecting, 54–55  
changes in, early brain injury and, 390–391  
cortical, 83–85  
in perirhinal cortex, 503

Neurogenetic cellular events, in prefrontal cortex development, 216, 218

Neuroimaging studies, of fetal alcohol syndrome, 644–646  
basal ganglia in, 645  
brain metabolism in, 645  
cerebellum in, 644  
corpus callosum in, 644–645

Neuromodulator(s)  
and recovery from early brain injury, 394  
in song system, 458–459

Neuromotor system, changes of, during first year, 150

Neuron(s)  
actin filaments in, 6–7  
changes in, during development, 385–386  
dendritic arborization of, 18–19  
development of, axon and dendrite formation in, 5–20  
differentiation of, in brain development, 83  
GABA, in prefrontal cortex, 214  
hippocampal, excitatory and inhibitory, 200–203  
migration of, 13  
into cortex, 40  
in neural tube formation, 39–40  
reduced, prenatal cocaine exposure associated with, 655

mirror  
in autism, 708–709  
in social behavior, 171

organization of, in prefrontal cortex, 213

polarization of, initial growth of axons and dendrites and, 13–14

preplate, 84, 221  
responding to social stimuli, 165  
spindle-shaped (Von Economo), 169

subplate, 84, 221  
supraplate, 84  
tonically active, 730

Neuronal cells, formation of, in hippocampal development, 187–195

Neuronal morphogenesis  
dynamic properties of, 5–10  
actin filaments and, 6–8  
cytoplasmic signaling pathways and, 8–9  
microtubules and, 5–6

in vivo regulation of, 13–15  
axonal guidance in, 14–15  
neuronal migration in, 13  
neuronal polarization and axon/dendrite growth in, 13–14

Neuronal phenotypes, prenatal development of, in prefrontal cortex, 221

Neuronal polarity, 85

Neuropathology, of phenylketonuria, 678–680

Neuropsychiatric disorders, 717–731. *See also* Obsessive compulsive disorder (OCD); Tourette's syndrome  
associated with altered gyration, 45–46

Neuropsychological outcome, long-term, associated with preterm birth, 402–403

Neuropsychological studies, of fetal alcohol syndrome, 646–648

Neuropsychology, developmental, of unipolar depressions, 771–781. *See also* Depression, unipolar

Neuroscience  
affective, and pediatric anxiety, 763–766  
cognitive. *See* Cognitive neuroscience; Sleep

Neurotransmitter(s). *See also* specific neurotransmitter  
in brain development, 771–772  
function of, effects of prenatal cocaine exposure on, 655–660  
role of  
in emotion regulation, 352–353  
in olfactory preference learning, 791–792

Neurulation, primary, in brain development, 771–772

Newborn(s). *See also* Children; Infant(s)  
attachment system in, 789  
auditory development in, 98  
brain development in, MRS imaging of, 340–341, 342, 343  
brain maturation in, 23–24  
frontal circuitry in, 229–230  
hippocampal formation in, Cajal-Retzius cells in, 200  
imitation of facial expressions in, 830  
LHPA system in, 71  
movement in, 147–148. *See also* Motor system, development of  
perception, attention, and learning abilities of, behavioral studies of, 326–328  
phenylketonuria screening in, 677  
preterm. *See* Preterm birth  
vision in, limitations of, 415. *See also* Visual entries

Nicotine  
acute effects of, 861–862  
and adolescent rodent brain, 860–861  
influence of, on adolescent brain, 859–862  
mechanism of action of, 859–860

N-methyl-D-aspartate receptors (NMDARs), role of, in song learning, 459

Noise-vocoded speech stimuli, 109

Non–Cajal-Retzius cells, reelin-positive, in hippocampal formation, 202

Non-fear-potentiated startle, 841

Nonnutritive sucking, in neonates, 326–327

Nonprimate models, of memory development, 499–504

Non-rapid eye movement (NREM) sleep, 807. *See also Sleep*  
  effects of, on brain development, 810  
Nonverbal learning, impaired, in fetal alcohol syndrome, 646  
Noradrenaline, and recovery from early brain injury, 394  
Noradrenergic system  
  in arousal aspect of attention, 480  
  effect of prenatal cocaine exposure on, 660  
Norepinephrine  
  developmental neuropharmacology of, 88  
  role of, in olfactory preference learning, 791–792  
Novel stimulus, and attention, 489–490  
Novelty preference  
  expression of, hippocampus in, 542–543  
  in memory testing, 542  
NREM (non-rapid eye movement) sleep, 807. *See also Sleep*  
  effects of, on brain development, 810  
Nucleotides, in breast milk, 630  
Nucleus basalis of Meynert, 222  
Nutrients, in cognitive development  
  categories of, 623–624  
  deprivation and subsequent repletion of, 635–636  
  selected, effect of, 625–635  
Nutrition, in cognitive development, 623–637  
  future directions of, 636  
  role of, 624–625

## O

Object continuity, neural network model of, 371–372  
Object permanence, neural network model of, 372  
Object processing, dorsal and ventral visual pathways in  
  computational model of, 474–475  
  event-related oscillations and, 471  
Observer-based procedure, in auditory development, 99  
Obsessive compulsive disorder (OCD)  
  age of onset of, 718–719  
  components of, 717  
  habit-learning systems in, 725–726  
  self-regulatory systems in, 722–723  
  tics in, 719  
  with Tourette's syndrome, 717–718  
Ocular dominance (OD) columns, development of, 133  
Oculomotor suppression task, impairments of, obsessive-compulsive disorder and, 722  
Odor, musty, associated with phenylketonuria, 677  
Olfactory bulb, neonatal, norepinephrine input in, 791–792  
Olfactory preference learning  
  end sensitive period in, 792  
  neural basis of, 790–792  
  role of neurotransmitters in, 791–792

Oligosaccharides, in breast milk, 629–630  
Optics, of eye, 129–130. *See also Visual entries*  
Orbitofrontal cortex  
  in approach-avoidance decisions, 557  
  in decision making, 883–887  
  development of, 554  
  neuroanatomy of, 168  
  role of  
    in behavior mediation, 877  
    in social behavior, 168  
Oregon Adolescent Depression Project (OADP), 775  
Orphanages, preschool children reared in, profound social neglect of, 873  
Ovarian steroids, regulating adult neurogenesis, 53–54  
Oxytocin, role of, in postpartum maternal behavior, 798

## P

P1, in ERP responses to visual stimuli, 252–253  
P1-N1-P2 complex, in ERP response to auditory stimuli, 249–250  
P400  
  in ERP responses to visual stimuli, 253  
  infant, 513  
Pachygryria, 45  
PAH gene mutations, 678, 683, 684  
Pallium, involved in song learning and production, 454–455  
Parvalbumin interneurons, 203, 205, 206  
Parvalbumin-containing axo-somatic inhibitory cell(s), 203  
PDDNOS (pervasive developmental disorder not otherwise specified), 701  
P-domain, of growth cone, 10  
PEM. *See Protein-energy malnutrition (PEM)*  
Performance monitoring  
  development of, 887–892  
  error detection in, 887–888  
  of executive function in childhood, 558–560  
  feedback processing in, 888–892  
    cardiac concomitants of, 889–890  
    developmental change in, 890–892  
  future directions of, 892–893  
  measurement of, error-related negativity in, 558  
Perinatal transition, in attachment, 788–789  
Peripheral vision, after treatment of congenital cataracts, 417–418  
Peripheral visual field (PVF), in deaf and hearing subjects, 440  
Perirhinal cortex, in declarative memory, 503  
Personality  
  changes in, orbitofrontal cortex lesions causing, 168  
  genetic influence on, 353, 844  
Personality profile, in Williams syndrome, 693  
Pervasive developmental disorder(s), eye tracking studies in, 280–284

Pervasive developmental disorder not otherwise specified (PDDNOS), 701  
Phe tolerance test, 677  
Phenotype, in Williams syndrome, 693  
Phenylalanine, diet low in, for phenylketonuria, 683  
Phenylalanine hydroxylase deficiency, tetrahydrobiopterin-responsive form of, 684–685  
Phenylketonuria (PKU), 677–686  
  atypical, 678  
  blood Phe levels in, 678  
  classical, 678  
  early-treated  
    blood Phe levels in, 682, 683  
    dopamine/tyrosine theory in, 683  
    executive function impairment in, 681  
    low phenylalanine diet in, 683  
    myelin/axonal theory in, 683  
    neurocognitive outcomes in, meta-analytic approach to, 680–683  
  genetic studies of, 684–685  
  musty odor associated with, 677  
  neonatal screening for, 677  
  neuropathology of, 678–680  
  PAH mutations in, 678, 683, 684  
  prefrontal dysfunction in, 679  
  tetrahydrobiopterin for, 684  
    white matter abnormalities in, 679–680  
Phenylpyruvic acid, identification of, 677  
Phobia, specific, 756  
Phonetic reorganization, 104–107  
  distributional modifications in, 105  
  distributional sensitivity in, 105–106  
    in second language, 106–107  
  universal inventories in, 104  
Phonological processing, developmental changes in gray matter and, 33–34  
Phonological representation, in dyslexia, 742–743  
Phonological skills, poorly developed, in dyslexia, 740  
Phonotactic knowledge, and lexical form, 121  
Photon absorption, in visual acuity, 129–130  
Photoreceptors, development of, 128–130  
Photosensitive pigment, developmental increase in, 128  
Phrase boundaries  
  intonational, 118–119  
  syntactic, 118  
Physics, of MRI, 312  
PKU. *See Phenylketonuria (PKU)*  
Plasticity  
  of auditory system  
    brain correlates of, 109–111  
    in humans, 103–104  
    in nonhumans, 102–103  
  cross-modal  
    in development, 439–449  
    in speech perception, after cochlear implantation, 446–448  
  early brain injury and, 385–396, 399–409  
  of speech, in animal model, 453–461. *See also Birdsong*

Plasticity (continued)

- synaptic, mechanisms of, in adolescent brain, 862, 863
- of visual system, 415–431
  - in blind person, 427
  - congenital cataracts and, 426–427
  - Detroit principle of, 429
  - developmental changes in, 427–428
  - high-level vision and, 420–426
  - in language, 444–446
  - low-level vision and, 416–420
- Policy domains, relevance of sleep to, 813
- Polymycrogryria, 45
- Polyunsaturated fatty acids, long-chain, in breast milk, 629, 630
- Positive slow wave activity, in event-related potential, 254
- Positron emission tomography (PET) study of neural activation associated with reading, 743
- of obsessive-compulsive disorder, 722
- Posterior superior temporal sulcus, sine-wave speech in, 110
- Postmortem studies, of brain, synaptic modification and myelination in, 23–25
- Postnatal growth deficiency, in fetal alcohol syndrome, 643
- Postnatal learning, and attachment, 789–790
- Posttraumatic stress disorder (PTSD), 756, 762–763
  - in abused children, 870
- Posture, in motor development, 149–151
- Predictive saccade task, in eye tracking, 264
- Prefrontal cortex

  - afferent pathways in
    - corticocortical connections in, 215–216, 224
    - extrathalamic, 214–215, 222
    - long associative connections in, 224–225
    - sequential development of, 221–225
    - thalamocortical, 215, 222–224
  - architecture and connectivity of, 213–216
  - basal forebrain–prefrontal cholinergic system of, 215
  - behavioral inhibition and, 585–586
  - corticocortical connections in, 215–216, 224
    - long associative, 224–225
  - corticohypothalamic connections in, 215, 217
  - cytoarchitectonics of, 213
    - laminar development of, 216, 218
  - delineation of, 213
  - development of
    - in adolescence, 577–578
    - afferent pathways in, 221–225
    - in children, 553–554
    - early, 216–225
    - laminar events in, 219–221
    - neurogenetic cellular events in, 216, 218
    - structural, 213–232
  - dopaminergic system of, 214–215

dorsal, in obsessive-compulsive disorder, 722

dorsolateral, 575–576

- development of, 582–584
  - vs. ventromedial development, 586
- emotion processing in, 871
- in feedback processing, 892–893
- functions of, 579–580
- in performance monitoring, 887. *See also Performance monitoring*
- reprocessing of rules in, 560–561
- selective attention in, 561

functions of

- by different prefrontal areas, 582–586
- impaired, in phenylketonuria, 679

immature

- circuitry elements in, development of, 225–227
- dendritic spine development in, 225, 227
- development of intrinsic circuitry in, 227
- interneuron development in, 225, 227, 228
- neuronal differentiation in, 225, 226

injury to, spontaneous tissue regeneration after, 390–391

intrinsic circuitry in, 214

- endogenous and sensory-driven, 229, 230
- neonatal, 229–230
- overproduction of elements of, in infancy and childhood, 230–231
- preterm infant (endogenous), 229
- prolonged plasticity and reorganization of, in adolescence and postadolescence, 231

neuronal organization of, 213

neuronal phenotypes in, prenatal development of, 221

planning ability of, 582–583

process vs. content of, 581–582

recognition memory and, 581

rostralateral, task set selection in, 562

rule of representation in, 556, 557

selected tasks and, 583–584

self-ordered search tasks and, 582

self-organized behavior and, 583

span tasks and, 581–582

spatial delayed-response tasks and, 582

structure and connectivity of, 575–577

subregions of, 553

thalamocortical pathways in, 215

- development of, 222–224

ventrolateral, 575–576

- emotion processing in, 871
- reprocessing of rules in, 560–561

ventromedial, 576

- development of, 584–585
- vs. dorsolateral development, 586
- functions of, 579–580

Prefrontal processes, in temperament regulation, 845–846

Preplate neurons, 84, 221

Preschool children, orphanage-reared, profound social neglect in, 873

Preterm birth

- cell proliferation, migration, and neurochemical maturation with, 203, 207–208
- long-term neuropsychological outcome associated with, 402–403
- neurodevelopmental changes associated with, 400–403
- neuroimaging studies in, 401–402
- prefrontal endogenous and sensory-driven circuitry in, 229

Proactive interference (PI), in working memory, 595

Probabilistic classification learning (PCL) tasks, in assessment of habit learning, 724

Procedural memory

- adult abilities in, emergence of, 500
- development of, 499–501
- neural circuits mediating, maturation of, 500–501

Process C, in sleep regulation, 809

Process S, in sleep regulation, 808–809

Productivity, in language acquisition, 326

Progenitor cells, development of, in normal brain, 39–40, 83, 385

Programmed cell death, in brain development, 772

Proliferation process, in brain development, 83

Proliferative zones, neurons arising from, 84–85

Prosaccade response times, age-related changes in, 269, 272

Prosaccade tasks

- neurological bases of, 265, 266
- warning stimulus on, age-related changes in CNV to, 269

Prosopagnosia

- acquired and congenital, face processing impairment and, 516
- lesions resulting in, 707–708

Protein(s). *See also specific protein*

- actin-binding, in regulation of actin filament organization, 7–8
- in cognitive development, 623
- microtubule-associated, in regulation of microtubule organization, 5–6

Protein-energy malnutrition (PEM) and brain development, 625, 626, 627–630

- postnatal, effects of, 628–629
- prenatal, effects of, 625, 627–628
- risk of, weaning and, 628

Protein-energy status, in brain development, 625, 627–630

Psychoactive drug therapy, for early brain injury, 395

Psychobiological models, of temperament, 839

Psychopathology

- developmental
  - research areas in, 756–758
  - theoretical perspective of, 757
- developmental course of, 358–360

PTSD. *See* Posttraumatic stress disorder (PTSD)  
Pupillary dilation  
  phasic changes in, 267  
  task-specific, 268–269  
Pupillary dilation tasks, in eye tracking, 264, 267–269  
  in children and adolescents, 273, 276  
Purkinje cells, 500  
Pursuit studies, in eye tracking, 264, 266  
  in children and adolescents, 269, 273  
Pursuit-rotor task, in assessment of motor-skill habit learning, 725  
PVF (peripheral visual field), in deaf and hearing subjects, 440  
Pyramidal cells  
  hippocampal, 187, 200, 202–203  
  development of, 187  
  in prefrontal cortex, 215

## Q

Quantitative trait loci (QTLs), associated with temperamental variability, 843  
Quinoid dihydropteridine reductase (QDR), in rodent adolescent brain, 858, 859

## R

Radial diffusivity, in DTI data processing, 302  
Rapid eye movement (REM) sleep, 807–808. *See also* Sleep  
  effects of, on brain development, 810  
Rapid odor preference learning, termination of, 792  
Reaching, development of, 149–150  
Reading, neural mechanisms for, development of, 743  
Reading acquisition, skills necessary for, 741, 746  
Reading intervention, 746–747  
  neurobiological basis for, 747–749  
Reading skills, genes influencing, 744–745  
Reading-related deficits, in dyslexia, 740, 741  
Reciprocal connections, in prefrontal cortex, 576  
Recognition memory  
  adult abilities in, emergence of, 501–502, 581  
  attention and, 490–494  
Recollection, retrieval process of, differential effects of aging on, 600  
Reelin, secretion of, in hippocampal formation, 196  
Reelin gene mutation, 196  
Referential mapping errors, in gaze following/joint attention, 820  
Reflex, acoustic startle, 841  
Reflexive saccadic eye movement. *See also* Eye movements  
  effect of attention in, 487  
  in tracking visual stimuli, 485

Reflexive stepping phase, of walking, 150  
Refocusing pulse, in diffusion tensor imaging, 302  
Regions of interest (ROI), in DTI data processing, 303  
Relational memory, adult abilities in, emergence of, 502–503  
*RELN* gene, in autism, 702  
REM (rapid eye movement) sleep, 807–808.  
  *See also* Sleep  
  effects of, on brain development, 810  
Repetitious action, in development, 148  
Repetitive behavior, in autism, 711  
Residential nurseries, social and emotional neglect in, 873  
Resilience, cognitive, 780  
Retention of information  
  age-related changes in, 545  
  in infancy, declarative memory and, 544–545  
Retina, development of, 128–130  
  cones in, 129–130  
  rods in, 128–129  
Retrieval cues  
  age-related changes in, 546  
  in infancy, declarative memory and, 545–547  
Retrieval processing, differential effects of aging on, 600  
Reward, hyposensitivity to, in unipolar depression, 777  
Reward learning, in executive function in childhood, 558  
Rey-Osterrieth Complex Figure (ROCF), in evaluation of spatial planning, 530–531  
Rho family, of GTPase proteins, 9  
Rhodopsin, developmental increase in, 128  
Right hemisphere  
  activation of  
    in face processing, 442  
    in perception of American Sign Language, 444–445  
  injury to, spatial functioning after, 530–531  
  visuospatial processing in, 528–529  
RMSE (root-mean-square error), in eye movement performance, 266  
ROCF (Rey-Osterrieth Complex Figure), in evaluation of spatial planning, 530–531  
Rod(s)  
  in retina, 128–129  
  rhodopsin in, 128  
Rod outer segment lengths, in infants vs. adults, 128–129  
Rodent brain, adolescent  
  microarray analysis of, 857, 859  
  nicotine affecting gene expression in, 862  
  nicotine and, 860–861  
Root-mean-square error (RMSE), in eye movement performance, 266  
Running, as positive stressor, in adult neurogenesis, 54–55

## S

Saccade(s)  
  externally guided, 263  
  in eye tracking, 263, 264, 265  
  internally guided, 265  
  memory-guided, impaired, in schizophrenia, 280  
  neural correlates of, in children, 269  
  in normative development, 270–271  
  physiologic characteristics of, 487  
Saccade sequence, two-dimensional, in response to visual targets, 470–471  
Saccade-related event-related potentials, 256  
Saccadic response times, 263, 265  
Safety considerations, in fMRI studies, 314–315  
Salivary cortisol, collection of, 65  
Scalp-recorded event-related potentials, as psychophysiological measure of attention, 483–484  
Scene perception tasks, in eye tracking, 264, 266–267  
  in children and adolescents, 273  
Schizophrenia  
  eye tracking studies in, 277, 278–279, 280  
  fMRI of, 825  
  gyrification index in, 45–46  
  MRS imaging of, 346  
  onset of, critical stressor in, 359  
School performance, in prenatally cocaine-exposed children, 665  
Selective attention, 870  
  in executive function in childhood, 561–562  
Selenium, in brain development, 627, 634  
Self-ordered search task, 582, 583  
Self-organizing facilities, in gaze following/joint attention, 820  
Self-organizing learning algorithms, 370  
Self-regulation, 719–723  
  in obsessive-compulsive disorder, 722–723  
  of temperament, 847  
  in Tourette's syndrome, 720–722  
Semantic categories, acquisition of, 373–374  
Semantic processes  
  at sentence level, 122–123  
  at word level, 121–122  
Sensorimotor integration loop, of brain, in neural song system, 456–457  
Sensorimotor phase, of motor development, 148  
Sensorimotor system, in birdsong, 458–461.  
  *See also* Birdsong  
  behavior and role of sleep in, 458  
  development of synapses in, 459  
  and implications for human speech, 460  
  neuromodulators in, 458–459  
  sensory development in, 459–460  
  vocal development in, genetic aspects of, 459  
Sensory memory, physical location of, reassessment of, 460  
Sentences, semantic processing of, 122–123

Sentential prosody  
definition of, 118  
processing of, 118–119

Separation anxiety disorder, 755. *See also Anxiety disorder(s)*

Serial reaction time (SRT) task, in  
assessment of obsessive-compulsive disorder, 725

Serotonin (5-HT). *See also 5-HT gene; 5-HTT gene; 5-HTTLPR S allele*  
developmental neuropharmacology of, 87–88

effect of prenatal cocaine exposure on, 658–659

influence of, on emotion regulation, 352–353

levels of, in autism spectrum disorders, 704

Serotonergic system, in arousal aspect of attention, 480

Severe mood dysregulation syndrome, 774

Sex hormone(s), and recovery from early brain injury, 394–395

Shape bias, in learning mechanisms, 373

Sign Language, American, 444–446  
visuospatial nature of, 444–445  
vs. spoken language, 444

Signal artifact, sources of, in fMRI studies, 314

Simon spatial incompatibility task  
performance of, Tourette's syndrome and, 720, 721  
vs. Stroop task, 719–720

Sine-wave speech stimuli, 109, 110

Single nucleotide polymorphism (SNP), in *BDNF* gene, 75

Single-photon emission computed tomography (SPECT) study, of obsessive-compulsive disorder, 722

Sleep  
bird's own song memory during, 459–460  
cognitive neuroscience of, 807  
differential effects of, on brain development, 810  
and emotion regulation, 813–814  
functions of, 809  
homeostatic component of, 808–809  
NREM, 807  
organization and regulation of, during human development, 807–809  
patterns of  
and developmental outcome, 811–812  
and pediatric neurocognitive functioning, 810–811  
prolonged deprivation of, effects of, 54, 55, 813–814  
REM, 807–808  
role of  
in learning and memory, 813  
in song learning, 458  
slow-wave, 807, 808  
synaptic homeostasis hypothesis of, 812–813

Sleep-wake states, control of, 795

SLI. *See Specific language impairment (SLI)*

Slow waves, in event-related potential, negative and positive, 254

Slow-wave activity (SWA), in sleep, 809  
homeostatic regulation of, 812

Slow-wave sleep (SWS), 807, 808. *See also Sleep*

Smoking, in adolescence, 859–862  
acute effects of nicotine and, 861–862  
mechanism of nicotine action and, 859–860

Smooth pursuit eye movement. *See also Eye movements*  
effect of attention on, 486–487  
gain in, definition of, 266  
impaired, in schizophrenia, 277  
in normative development, 274–275  
substrates and connections in, 267  
in tracking visual stimuli, 485

Social adversity  
developmental implications of, 74  
resilience resulting from, 780

Social anxiety disorder, 755. *See also Anxiety disorder(s)*

Social behavior  
definition of, 162  
evolutionary perspective on, 164  
input vs. output of, 825  
of neglected children, 870  
neurobiology of, 161–172  
selective changes in, developmental disorders and, 165  
trajectory characterizing, 164–165

Social brain  
autism and, 706–710  
components of, 163  
development of, 172–178  
animal model in, 173–175  
neural bases in, 175–178  
dorsal, joint attention/social cognition and, 825–827  
lesion research of, 177–178  
mirror neuron system in, 171  
neural components of, 162  
neuroanatomical studies of, 175–176  
neurophysiology and imaging of, 176  
plausibility of, 163–165  
putative structures of, 165–172  
role of amygdala in, 165–168  
role of anterior cingulate cortex in, 168–169  
role of fusiform gyrus in, 170–171  
role of orbitofrontal cortex in, 168  
role of temporal cortex in, 169–170  
ventral, gaze following/joint attention and, 823–825

Social cognition  
and dorsal social brain, 825–827  
elements of, 162  
gaze following/joint attention reflecting, 820–821  
impaired, in Williams syndrome, 693  
neurobiology of, 161–172  
unipolar depression and, 774–775

Social context, affecting speech, 460

Social deficits, in autism, 165

Social development, animal model of, 173–175

Social dominance  
impact of, on adult neurogenesis, 55, 56  
orbitofrontal cortex damage affecting, 168

Social experience, in regulation of LHPA system, 71–74

Social knowledge, vs. other knowledge domains, 164

Social motivation, in autism, 709–710

Social partner, gaze of, 819

Social perception, in autism, 706–710

Social policy domains, relevance of sleep to, 813

Social processing  
components of, 162  
model of, 162, 163  
neural regions implicated in, 165, 166

Social skills, slower gains of, in preterm children, 403

Social stimuli  
amygdala response to, 166–167  
neurons responding to, 165

Socially relevant information, orbitofrontal cortex processing of, 168

Socioeconomic status, impact of, on early brain injury recovery, 407

Socioemotional correlates, of executive function in childhood, 563–564

Socioemotional deprivation, of Romanian orphans, neuroimaging study of, 408

Somatosensory information, in mother-infant interactions, 790

Somatostatin, mother-infant interactions and, 795

Songbirds, behavior of, 453. *See also Birdsong*

Sound thresholds, in infants, assessment of, 99

Spatial analytical processing  
complexity and sophistication of, changes in, 529  
disorders of, focal brain injury associated with, 528, 530  
neural system associated with, development of, 530

Spatial attention, development of, 525–527

Spatial delayed-response task, 582

Spatial localization, in dorsal visual pathway, 523–525

Spatial location processing, in dorsal visual pathway  
during infancy, 524–525  
in older children, 525

Spatial location task, 523

Spatial planning, ROCF in evaluation of, 530–531

Spatial planning ability, 582–583

Spatial processes, associated with dorsal visual pathways, 523–528

Spatial span test, 581–582

Spatial working memory, neuroimaging studies of, 525

Specific language impairment (SLI), 741–742

- Specific language impairment  
 (SLI) (continued)  
 diagnosis of, 741  
 dyslexia with, 745–746
- Speech. *See also* Language(s) entries  
 birdsong as model of, 453. *See also*  
 Birdsong  
 forward and backward, left-hemispheric  
 asymmetry in, 118  
 human, implications of birdsong in, 460  
 impaired, in fetal alcohol syndrome, 648  
 infant-directed, 98  
 maternal input in, 98  
 noise-vocoded, 109  
 plasticity of, in animal model, 453–461.  
*See also* Birdsong  
 sine-wave, 109, 110
- Speech fusion, auditory/visual, sensitive  
 period for, in young recipients of  
 cochlear implants, 444–448
- Speech perception  
 cross-modal plasticity in, after cochlear  
 implantation, 446–448  
 talker-specific effects in, 109
- Speech processing, indexical factors in,  
 108–109
- Speed-of-processing deficits, in  
 phenylketonuria, 680
- Spelling ability, poor, in dyslexic children,  
 741
- S-shaped curve, of activation function,  
 369–370
- Startle, fear-potentiated vs. non-fear-  
 potentiated, 841
- Startle reflex, acoustic, 841
- Statelike effects, of sleep patterns, 810–811
- Static phase, of walking, 150
- Stem cells, development of, in normal brain,  
 385
- Steroids, regulating adult neurogenesis  
 adrenal, 53  
 ovarian, 53–54
- STG. *See* Superior temporal gyrus (STG)
- Stimulation theory, of gaze following/joint  
 attention, 832
- Stop-signal task, 585
- “Stranger” anxiety, 789
- Stress, effect of, on adult neurogenesis,  
 54–55
- Stress hyporesponsive period  
 in attachment-learning period, 794  
 in humans and animals, 71–72  
 postnatal, 69
- Stress patterns, of words, 119–121
- Stress responses, of LHPA system, 63, 65  
 influence of cortisol and corticotropin-  
 releasing hormone on, 67–69  
 regions associated with, 64
- Striatal activation, enhanced, in behavioral  
 inhibition studies, 842–843
- Stroop task  
 impairments of, obsessive-compulsive  
 disorder and, 722  
 limitations of, 719–720  
 performance of, Tourette’s syndrome and,  
 720, 721
- in study of self-regulation, 719
- STS. *See* Superior temporal sulcus (STS)
- Subcortical plate, development of  
 connectivity between cortical  
 structures and, 40–41
- Subcortical system, in face processing  
 in adults, 509  
 in infants, 511–512
- Subplate neurons, 84, 221
- Subthalamic nucleus (STN), 726, 730
- Sulcus  
 alterations in, 45  
 superior temporal. *See* Superior temporal  
 sulcus (STS)
- Superior temporal gyrus (STG)  
 in face processing, 511, 514–515  
 in social perception, 823
- Superior temporal sulcus (STS)  
 activation in, deaf vs. hearing subjects  
 and, 440  
 in face processing, 511, 514–515  
 autism spectrum disorders and, 708  
 in social perception, 823, 824
- Supplementary nutritional measures,  
 cognitive development and, 636
- Supraplate neurons, 84
- Supravalvular aortic stenosis, in Williams  
 syndrome, 691, 692
- SWA (slow-wave activity), in sleep, 809  
 homeostatic regulation of, 812
- SWS (slow-wave sleep), 807, 808. *See also*  
 Sleep
- Symbolism, facilitating executive function in  
 childhood, 565–566
- Synapse(s)  
 in brain development, modification of,  
 23–24  
 formation of. *See* Synaptogenesis  
 from Purkinje cells, 500  
 in song learning, development of, 459
- Synaptic homeostasis hypothesis, purpura  
 fulminans sleep, 812–813
- Synaptic plasticity, mechanisms of, in  
 adolescent brain, 862, 863
- Synaptic pruning, in brain development,  
 23–24
- Synaptic space, early brain injury and, 389
- Synaptic targets, axonal  
 patterning distribution in, 17–18  
 stereotypical routes to, 14–15
- Synaptogenesis  
 in brain development, 23–24, 83, 385–386  
 experience-dependent, 386–387
- Syntactic phrase boundary, 118
- Syntactic processes, in brain, 123–124
- T
- Tactile stimulation, for early brain injury,  
 391–392  
 prenatal, 387
- TANs (tonically active neurons), 730
- Task set selection, in executive function in  
 childhood, 562
- Temperament  
 behavioral inhibition in, 841–843
- biology of, 839–848  
 integrative approach to, 839–841  
 model system studying, 841–843  
 in individual LHPA function, 74–75  
 modulators of, cognitive processes as, 840  
 negative reactivity in  
 EEG asymmetry as maker of, 843  
 genetic markers of, 843–844  
 and pediatric anxiety, 763  
 psychobiological models of, 839  
 reactivity in, regulation of, 844–848  
 regulation of  
 neural circuitry measurement involved  
 in, 846–848  
 prefrontal processes involved in,  
 845–846  
 relations between inhibitory control and,  
 846  
 self-regulation of, 847
- Temporal cortex  
 functional studies of, 169–170  
 lesions of, 170  
 neuroanatomy of, 169  
 role of, in social behavior, 169–170
- Temporal lobe, medial  
 age-related changes in, 592, 599  
 damage to, 547  
 in declarative memory, 546–547
- Temporal sulcus, posterior superior, sine-  
 wave speech in, 110
- Test of Everyday Attention for Children  
 (TEA-Ch), 779
- Tetrahydrobiopterin (BH<sub>4</sub>), 684
- Thalamocortical afferent pathways,  
 prefrontal, 215  
 development of, 222–224
- Thalamus  
 involved in arousal aspects of attention,  
 480  
 involved in song learning and production,  
 454–455
- Theory of mind (ToM) task  
 in autism, 705  
 performance of, 822, 827
- Threats  
 neural circuits engaged by, 759–761  
 response to  
*5 HT* gene and *5HTT* gene in, 762  
 role of environment in, 757
- Tics  
 age of onset of, 718  
 chronic, 718  
 CSTC circuitry in, 726–729  
 in obsessive-compulsive disorder, 719  
 in Tourette’s syndrome, 717
- Tissue regeneration, spontaneous, after  
 prefrontal injury, 390–391
- Tonically active neurons (TANs), 730
- Tourette’s syndrome  
 habit-learning systems in, 725  
 natural history of, 718–719  
 neural basis for, 718  
 with obsessive compulsive disorder,  
 717–718
- self-regulatory systems in, 720–722
- tics in, 717

Tower of London test, 582–583  
TPs (transition probabilities), in language acquisition, 328–329  
Trace elements, 623. *See also specific element*  
Training, facilitating executive function in childhood, 566  
Traitlike effects, of sleep patterns, 811–812  
Transition phase, of walking, 150  
Transition probabilities (TPs), in language acquisition, 328–329  
Transitive interference (TI) task, hippocampal activation during, 546  
Trauma, brain. *See* Brain injury  
Tutor song memory, 457  
Twin studies  
    gyral patterns evaluation in, 43  
    traditional behavioral genetics in, 352  
Twin-level theoretical framework, for dyslexia, 742  
Tyrosine hydroxylase, in dopamine synthesis, 86

## U

UCS-CS+ relationship, threats and, 759  
Ultrasonic vocalization response, to isolation, 796  
Underactivation, cognitive, age-related, 600  
Unipolar depression, developmental neuropsychology of, 771–781. *See also* Depression, unipolar  
Units, in neural network models, 368–369  
Universal inventories, in phonetic reorganization, 104  
Urbach-Wiethe disease, 167

## V

Valproic acid, maternal ingestion of, risk of autism with, 703  
Vascular dementia, 607  
    vs. Alzheimer's disease, 612–613  
Vasopressin, secretion of, LHPA stress response and, 63  
Velocardiofacial syndrome, schizophrenia and, 46  
Ventral visual pathway. *See* Visual pathways, ventral  
Ventricular germinal layers, in hippocampal formation, cell proliferation in, 191, 193  
Verbal learning, impaired, in fetal alcohol syndrome, 646  
Very low birth weight, neuropsychological outcome associated with, 402  
Vision  
    high-level, 420–426  
        face detection in, 422, 423  
        face perception in, 422–426  
        holistic face processing in, 422, 424–425  
        sensitivity to global form in, 421–422  
        sensitivity to global motion in, 420–421  
        visual spatial attention in, 425

interactions between audition and, after cochlear implantation, 446–447  
low-level, 416–420  
    acuity in, 416–417  
    contrast sensitivity in, 417  
    peripheral, 417–418  
    sensitivity to local motion in, 419  
    summary of, 419–420  
Visual acuity  
    after treatment of congenital cataracts, 416–417  
    development of, 129–130  
    in infants and children, 415–416  
    in newborn vs. adult, 129, 415  
Visual attention difficulty, in preterm infant, 402  
Visual cascade, 128  
Visual cortex  
    of blind person, plasticity of, 427  
    cross-modal plasticity of, postlingual deafness and, 446  
    development of, 130–136  
        anatomical data on, 139  
        events in, time line illustrating, 134  
        ocular dominance (OD) columns in, 133  
    GABA neurotransmitter in, 135  
    lateral geniculate nucleus in, 131, 133  
    pathways in, 130–133  
    postnatal reorganization of, factors responsible for, 133  
    striate  
        absence of, 136, 138  
        in newborn vs. 6-month-old infant, 136–137  
    visual processes in, 133  
Visual fields  
    central and peripheral, in deaf and hearing subjects, 440  
    receptive, responses of, to attention, 480–481  
    restricted, after treatment of congenital cataracts, 417–418  
    shift attention in, infant's ability to, 526–527  
Visual motion processing, effects of deafness on, 439–443  
Visual paired-comparison (VPC) task, 541  
    in assessing recognition-memory abilities, 501–502  
    in infancy  
        declarative memory and, 542–543  
        performance of, 546  
Visual pathways  
    dorsal  
        anatomy of, 521–522  
        development of, 467–476  
        dissociation of, with ventral pathway, behavioral evidence of, 471–474  
        function of, 468  
        high-density ERP studies of, 469–471  
        mental rotation in, developmental studies of, 527–528  
    processing in  
        computational model of, 474–475  
        event-related oscillations and, 471  
        spatial systems in, 468  
    spatial attention in, 525–527  
    spatial localization in, 523–525  
        during infancy, 524–525  
        in older children, 525  
    spatial processes associated with, 523–528  
        as “where” or “action” pathway, 467  
    information transmission in, 128–130  
    retinocortical, 131–133  
    subcortical and cortical, 130–131, 132  
    ventral  
        anatomy of, 521–522  
        development of, 467–476  
        dissociation of, with dorsal pathway, behavioral evidence of, 471–474  
        function of, 468  
        high-density ERP studies of, 469–471  
        processing in, 468–469  
            computational model of, 474–475  
            event-related oscillations and, 471  
            spatial processes associated with, 528–531  
        as “what” or “perception” pathway, 467  
    Visual perception, in newborns, limitations of, 415  
    Visual processing  
        dorsal and ventral routes of, 467–469  
        identifying presence of visual streams in, 469–475  
    Visual search task, effects of color and motion in, deaf vs. hearing subjects and, 440–441  
    Visual space processing, effects of deafness on, 443–444  
    Visual stimuli  
        briefly presented, recognition in, 489–494  
        ERP response to, in cognitive development, 252–254  
    Visual system  
        abnormal, in dyslexia, 742  
        auditory system and, 100  
        development of  
            absolute threshold in, 128  
            acuity in, 129–130. *See also* Visual acuity  
                Atkinson's model of, 138  
                Banks and colleagues model of, 129  
                bottle-neck developmental theories in, 141  
                brain-behavior relationships in, 127–141  
                cortical, 130–136. *See also* Visual cortex  
                cortical parcellation hypothesis in, 140–141  
                cortically motivated models in, 136–139  
                differential maturation hypothesis in, 139–141  
                Hansen and Fulton model of, 128–129  
                involved in visual tracking, 485  
                at neural level, 127  
                optical properties in, 129

- Visual system (continued)
- retinal, 128–130
  - cones in, 129–130
  - rods in, 128–129
- plasticity of, 415–431
- in blind person, 427
  - congenital cataracts and, 426–427
  - developmental changes in, 427–428
  - high-level vision and, 420–426
  - in language, 444–446
  - low-level vision and, 416–420
- Visual tracking, reflexive, 136
- Visual-spatial attention
- after treatment of congenital cataracts, 425
  - impaired
    - in fetal alcohol syndrome, 647
    - in schizophrenia, 280
- Visuospatial nature, of American Sign Language, 444–445
- Visuospatial processing, development of, 521–533
- associated with dorsal stream, 523–528.
  - See also* Visual pathways, dorsal trajectories of, 531–533
  - associated with ventral stream, 528–531.
  - See also* Visual pathways, ventral trajectories of, 531–533
- Vitamin(s), 623–624
- deficiency of, 624
- Vitamin A deficiency, 624
- Vocal behavior, development of
- genetic aspects of, 459
  - in song learning, 458
- Vocal communication, origins of, 795–797
- Vocal learning and production, in song birds. *See also* Birdsong
- brain-behavior relationship in, 453–454
  - nuclei involved in, 454–455
- Voice, mother's, newborn preference for, 98
- Voice onset time (VOT), 105
- Voice quality, of talker, 108
- Volumetric studies, in brain development, 25
- Voluntary saccadic eye movement. *See also* Eye movements
- in tracking visual stimuli, 485
- Von Economo neurons, 169
- VOT (voice onset time), 105
- Vowels, in linguistic theory, 329–330
- Voxel-based morphometry methods, of brain development study, 25–26
- W**
- Walking, development of, 150–151
- Weak central coherence (WCC), in autism, 705
- Weaning, and risk of protein-energy malnutrition, 628
- Weights, in neural network models, 368–369
- Weschler Intelligence Scale for Children-III (WISC-III), 581
- White matter
- abnormalities of, in phenylketonuria, 679–680, 683
  - development of, 237–238
  - effect of traumatic brain injury on, 404
  - myelination of
    - Flechsig's map of, 237, 238
    - functional consequences of, 239–241
    - magnetic resonance imaging of, 237
  - volume increase in
    - age-related, 25, 577
    - rate and pace of, 772
- Whole-brain mapping methods, voxel-based morphometry in, 25–26
- Williams syndrome, 691–697
- brain size in, 691
  - building developmental trajectories in, 695
  - clinical features of, 691
  - genetic basis of, 692
  - genotype in, 691–692
- gyrification index in, 46, 691
- hypersociability in, 165
- lexical development in, multiple factors contributing to, 696
- phenotype in, 693
- phenotypic outcome in
- face processing and, 693–694
  - language and, 694–695
  - vs. infant start state, 695
- prevalence of, 692
- Wisconsin Card Sort task
- in depression, 779
  - feedback processing using, 888–889
- Wisconsin Card Sorting Test (WCST), 553, 556
- Woodstock Johnson III Broad Reading score, 746
- Words
- learning about, 373–374
  - phonemic structure of, dyslexic children and, 740–741
  - phonological familiarity of, 121
  - semantic processing of, 121–122
  - stress patterns of, 119–121
- Working memory
- in adolescence, prefrontal development and, 581–582
  - aging and, 592–595
  - assessment of, *n*-back task in, 594–595
  - development of, during childhood, 240
  - effect of traumatic brain injury on, 406
  - in executive function in childhood, 561
  - importance of, 555
  - neuroimaging studies of, 593–594
  - role of experience in, 241–242
  - spatial, neuroimaging studies of, 525
- Z**
- Zinc
- in brain development, 626, 632–633
  - deficiency of, 633

