

6.S196 / PPAT: Principles and Practice of Assistive Technology

Today: The Human User of
Assistive Technology [C&H Ch. 3]

Monday, 26 Sept. 2011
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Activity-Limiting Disabilities

- **Widespread**
 - Tens of millions of Americans have a limitation that affects a major life activity (e.g. working, attending school, managing a household)
- **Unevenly distributed**
 - Disproportionately affect minorities, elderly, and those with lower socioeconomic status
- **Expensive**
 - Disability-related costs exceed hundreds of billions of dollars annually in the U.S. alone

Today

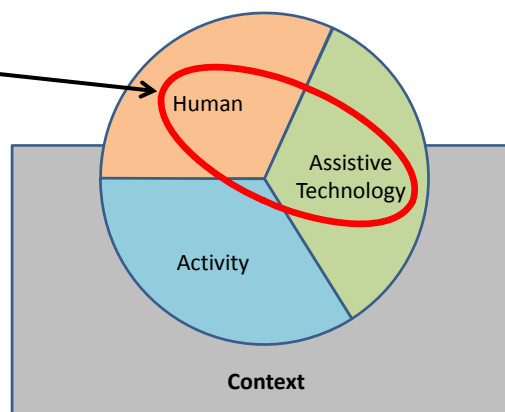
- Information processing model of human operator with a disability
- Consideration of how disabilities affect human performance model
- Implications of disabilities for design, selection and use of assistive technologies

- Also: expectations for Week 7 Panels

Review: HAAT Model

- Someone doing something, somewhere, involving the use of an assistive technology

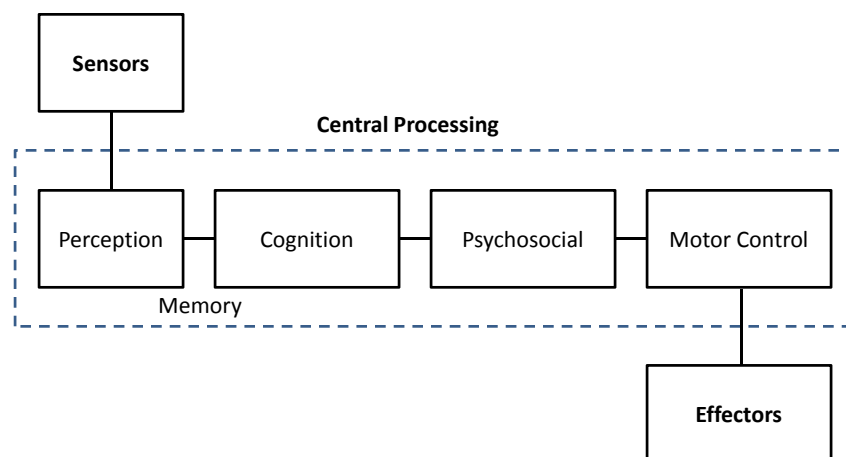
Today's focus:
implications of disabilities
for AT design, selection, use



Strategy for AT System Designer

- Focus on remaining (not on lost) function
- Determine what user can do (skills)
 - ... what user cannot do (limitations)
 - ... and what user will do (motivation)
- *Intrinsic enablers* of human performance:
 - Sensors
 - Central processing
 - Effectors
- Elements of *information processing model*

Information Processing Model



Sensory Function and AT Use

- Obtain data from environment
 - Exteroceptive systems
 - Visual, auditory, tactile sensory systems
 - Levels of light, sound, mechanical pressure
- Obtain data from body
 - Proprioceptive, kinesthetic, vestibular systems
 - Body motion, limb motion, head orientation
- Limitations:
 - Sensitivity (minimum detectable levels)
 - Range (variation in size, amplitude, magnitude)

Visual Function

- Visual scanning
 - Finding a target in a field of several targets
- Visual tracking
 - Following during target or head/body motion
- Visual acuity
 - Distinguishing a small or low-contrast target
- Visual range
 - Visual attention as location or depth varies

Capabilities and Deficits

- Visual acuity
 - Object size, color, contrast; inter-object spacing
 - Inability to detect/distinguish items, background
- Visual field and range
 - Ordinary range $> 165^\circ$ to either side of midline
 - Loss in visual field(s), achievable range of gaze
- Tracking, scanning, vergence, accommodation
 - Focus on target as it moves laterally or in depth
 - Inability to stabilize, transfer gaze to new target
- Implications?

Auditory Function

- Auditory thresholds
 - Audible sound *amplitude* (dB w.r.t. reference)
 - Audible sound *frequency* (Hz)
- Deficits in degree and type of hearing loss
 - Loss of input information (from environment)
 - Loss of feedback (from user's own speech)
- Important in consideration of *context*
 - Use in a quiet vs. loud environment
 - Power, form factor considerations
- Other implications?

Somatosensory Function

- "Where body ends and the world begins"
- Peripheral sense, feedback to motor system
 - Pressure
 - Hot-cold
 - Tactile
 - Kinesthetic
- Deficits can result in tissue damage
 - Especially important for seating/cushion systems
- Other implications?

Sensing for Posture and Position

- Posture and body position control are fundamental to effective use of AT
 - To support tracking, reaching, selection etc.
- Accommodation to gravity, movement
- Integrative function of visual, vestibular, proprioceptive, and kinesthetic senses
- Impairment can hinder integration (e.g., mismatch of visual, vestibular data)
 - Sometimes correctable by prismatic lenses

Central Processing Functions

- Interposed between sensors and effectors
- Include:
 - Perception
 - Cognition
 - Psychological factors
 - Neuromuscular control & motor planning

Perceptual Function and AT Use

- Addition of *meaning* to raw sensory data
- Threshold
 - Minimal input level that produces an output
- Figure-ground discrimination
 - Separating one portion of signal from another
- Localization
 - Placement of visual/auditory source in space
- Discrimination of physical parameters
 - Length, distance, time (reaching, selection, control etc.)

Cognitive Function and AT Use

- Cognitive development
 - Maturation, experience, changes in ability
- Piaget's stages of development
 - Sensorimotor actions to symbolic thinking
- Memory
 - Sensory, short-term, long-term
 - Encodings, recall, recognition
- Language
- Problem-solving

Cognitive Development

- Development is a function of both:
 - Biological maturation (growth)
 - Interaction with environment (learning)
- AT designers and providers must consider both current status, development change
- Capabilities for manipulation or other purposive motor actions, symbolic thinking, logical problem-solving

Piaget's Stages of Development

- Sensorimotor (to age ~2)
 - Schemes for dealing with immediate world
- Preoperational (to age ~7)
 - Use of symbols and internal images/models
- Concrete operational (to age ~11)
 - Logical thinking about concrete objects, actions
- Formal operational (age ~11 to adult)
 - Systematic thinking, abstract problem-solving

Key Concepts for ATP

- Observational learning (as young as 9 mos.)
 - Imitation of observed (but unpracticed) acts
- Co-occurrences
 - Inferences about causality, contingent results
- Animism
 - Attribution of life, consciousness to objects
- Active vs. passive learning
 - E.g., driver vs. passenger of wheelchair
- Implications?

Cognitive Deficits

- Undesirable to model impairments due to trauma simply as developmental delay
 - Delay or impairment is due to other factors than development
 - Often, individual with impairment exhibits a mix of significant skills and severe deficits
 - So, must attend to cognitive demands, and include learning and operational aids
 - Not *simpler*, but *different*: alternative modes of information presentation, sequencing etc.

Memory

- Sensory memory
 - Storage of data after cessation of stimulus
 - Afterimages (~250 msec.), auditory echoes (~5 sec.)
- Short-term (or working) memory
 - Temporary storage (20-30 sec.) of task information
 - Maximizing STM use: grouping, patterns
- Long-term memory (information of lasting value)
 - Turning on/using AT device; goals, destinations
 - Somatosensory memory, e.g. feel of joystick
- Recall vs. recognition

Language

- Symbol system used by speaker, listener
 - Orthography, pictography, hand movements
- Spoken language
 - Phonology (sounds) to pragmatics (function)
 - Children who can't speak still develop language
- Communicative intents
 - Needs, commands, interaction, personal, inquisitive, imaginative, informative
 - AT should support as many of these as possible

Problem Solving, Decision Making

- Problem solving
 - Discovery of a solution in a new situation
- Decision making
 - Weighing and selection among alternatives
- Both PS and DM depend on memory
 - Of past actions and contingent outcomes
- As novice AT user becomes expert user, dominant strategy shifts from PS to DM
- Training can facilitate both sets of skills

Psychosocial Function and AT Use

- Identity & self-protection
- Motivation
- Variation of characteristics over life span

Identity and Self-Protection

- Identity
 - Self-concept, locus of control, well-being
- Self-protection
 - Regulation of behavior, avoidance of harm
- Dependence on AT can cause anxiety
 - If device use causes emotional discomfort... may result in avoidance or abandonment
 - Those w/ congenital (vs. acquired) disability more likely to view AT as opening up opportunities

Motivation

- Influences that give rise to performance
 - From user, activity, context or the AT itself
 - Lack of motivation a major cause of abandonment
- Internal factors (primarily desire to succeed)
- External factors (praise, feedback)
 - Knowledge about performance
 - Motivation to continue until goal is achieved
 - Reinforcement (conversational interaction)
 - Coupling with social interaction
 - ... Examples?

AT Use Over the Life Span

- Childhood to early teenage years
 - Eager to explore, interesting in experimenting
- Young to middle-aged adult
 - Engaged in job pursuits, want to succeed
- Middle-aged adults
 - May find technology awkward, threatening
 - Prefer to learn and practice in private
- Older adults
 - Little exposure to technology; may be fearful

Motor Control and AT Use

- Central processing functions that lead to planned, coordinated motor outputs
 - Sensing for scanning, movement regulation
- Motor learning
 - Improved speed, accuracy with repetition
 - Lower cognitive burden, greater consistency
- Maps of internal neuromuscular system and external world, constructed as user encounters and experiences environment
- Example maps, potential disturbances?

Aimed Movement to Targets

- Requires several sensorimotor tasks
 - Scanning (device affordances, locations, objects)
 - Desired element must be chosen
 - Element must be activated or manipulated
- Speed generally subject to Fitt's Law (1954)
 - Time required to move to a target decreases for closer or larger targets, and increases for more distant or smaller targets
 - Holds for wide variety of body parts, controls
- Accuracy decreases with increasing speed
 - May not hold for expert users

Motor Learning and Patterns

- Huge number of potential motor trajectories for a given action
 - Few are exercised in actual situations
 - Path variability decreases with practice
- AT should exploit this tendency
 - Consistency of activation, rest affordances
 - Consistency of placement in dynamic displays
 - Predictability of choices

Relationship to Stimuli

- Motor performance is improved when correspondence between stimulus (e.g. AT system item or prompt) and user response is high
 - E.g., appearance of icons in file system GUI
- This is simply good interface design
- For AT systems, spatial mapping of stimulus to response is often best
 - Fastest response times, fewest errors

Effectors

- Neural, muscular, skeletal body elements that provide movement or motor output
... under control of central processing
... in response to sensory input
- Often AT controlled by hand movements
... but many other control sites are possible
- Postural control and reflexes contribute to the generation of motor output

Effector Function and AT Use

- Motor outputs for stabilization, control
 - Large muscles of trunk and pelvis
- Control effectors for manipulation
 - Hand or fingers, shoulders, arm, head, eyes, eyelids, eyebrows, mouth, tongue, leg, foot
 - Respiration (flow of air, sip, puff)
 - Phonation (sound production, whistling, speech)
- Oculomotor control (via PCA or device)
 - Approach, grasp, manipulation, release

Factors Underlying Effector Use

- Primitive reflexes
 - Tonic labyrinthine reflex (TLR): stiffening of back and leg muscles when head tilts back
 - Asymmetrical tonic neck reflex (ATNR): extension of arm & leg when head turns to side
 - May be pronounced with neurological damage
- Righting and equilibrium reactions
 - Implications for upright posture, stable seating
- Muscle tone (flaccidity, spasticity, rigidity)
 - Fluctuation throughout the day

Characterizing Effector Movement

- Resolution
 - Degree of reliable fine control of objects
- Range
 - Maximal extent of movement possible
- Strength
 - Minimal force required to activate an interface
- Endurance
 - Ability to sustain a force, and repeat over time
 - Performance may decrease until total *fatigue*

Summary

- Emphasis on human operator
 - Information processing model
- Components underlying performance
 - Sensory, perceptual, cognitive, psychosocial, motor, effector movement characterization
 - Implications for AT design, selection and use

Week 7 Panels

- During lab, M & W Oct 17th & 19th (in 3 weeks)
 - Scheduled to accommodate those with time conflicts
 - Convened with projected slides in lab room 32-044
- Invited panels of clinicians, AT practitioners
 - From MIT, TBH, TCC, BRH etc.
- Each team will have 25 minutes total:
 - Presentation: client, inquiry, metrics, ideas, plan (15 m.)
 - Suggestions, Q&A from panel members (10 m.)
 - We will use a talk timer to keep on schedule

Coming Up

- This afternoon's lab
 - Discussion, analysis of contextual inquiry results
- Wednesday lecture
 - Melissa Simonian, Braintree Rehabilitation Hospital
 - Communication disabilities arising from TBI, SCI etc.
- Wednesday lab:
 - Idea generation for AT solution, staff feedback
- Reading for next week
 - C&H Ch. 3

Terminology

- Proprioceptive sense
 - Relation of body parts, strength of effort
- Exteroceptive sense
 - Sensation of the world external to the body
- Interoceptive sense
 - Sensation of pain, hunger, movement of organs
- Kinesthetic sense
 - Sensation of motion of the body parts
- Vestibular sense
 - Sensation of balance and spatial orientation