Enabling participation through rehabilitation engineering

Waterloo Smarter Health Seminar Series

November 24, 2004

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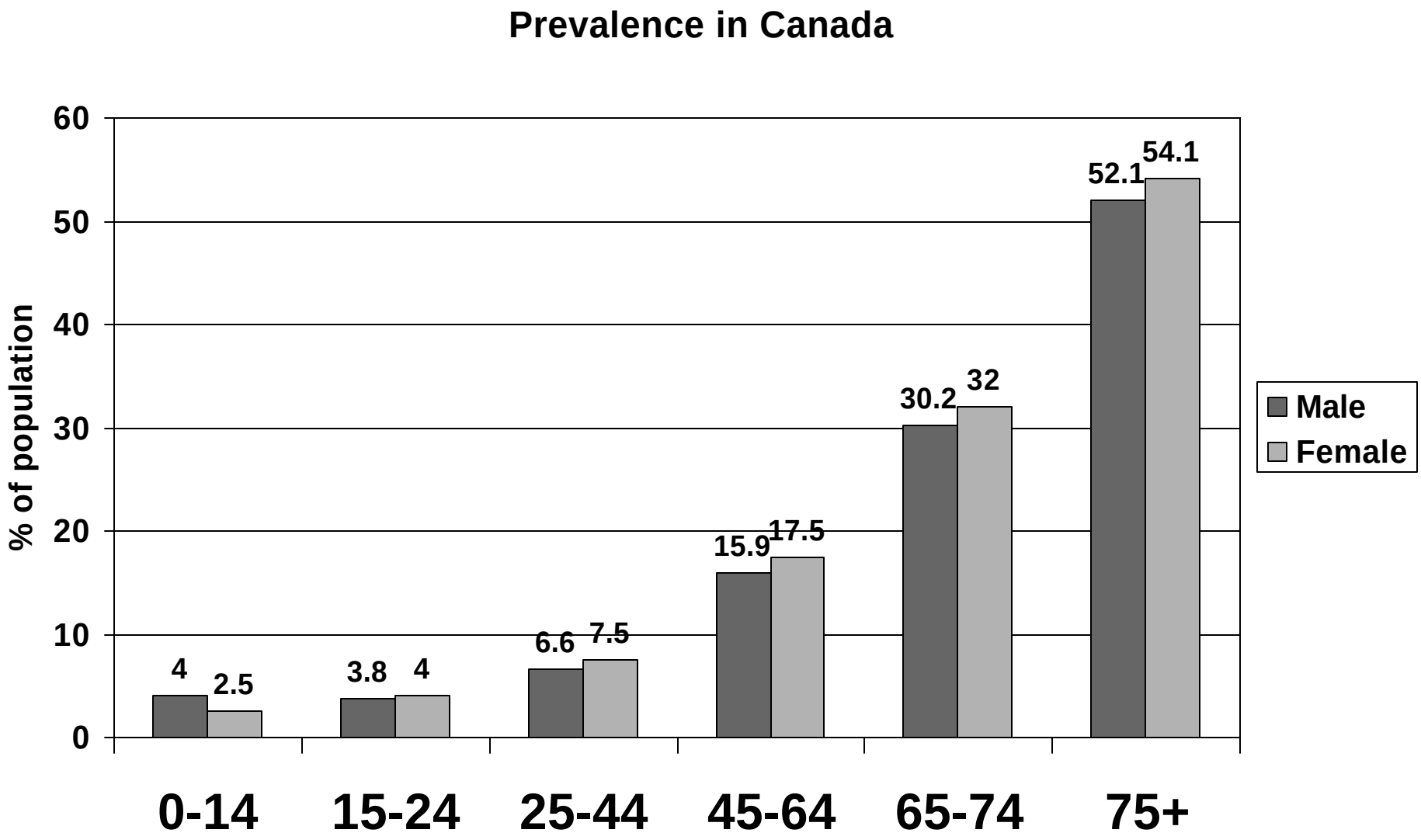
Bloorview MacMillan Children’s Centre
Faculty of Medicine
University of Toronto

What we will talk about

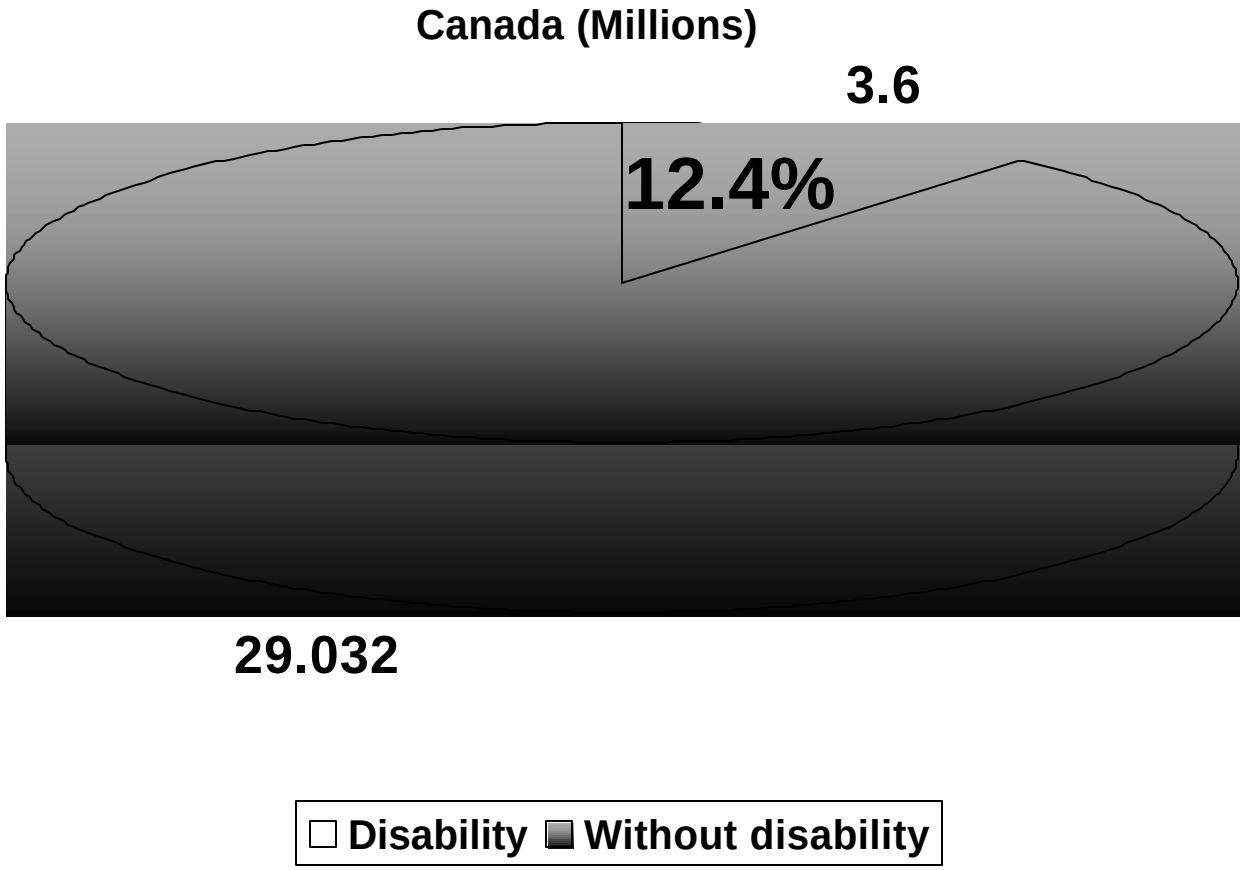
- Magnitude of disability
- Biopsychosocial model of disability
- Implications for rehab engineering
- Examples from Bloorview MacMillan

Magnitude of disability



A profile of disability in Canada, Statistics Canada, 2001

Magnitude of disability



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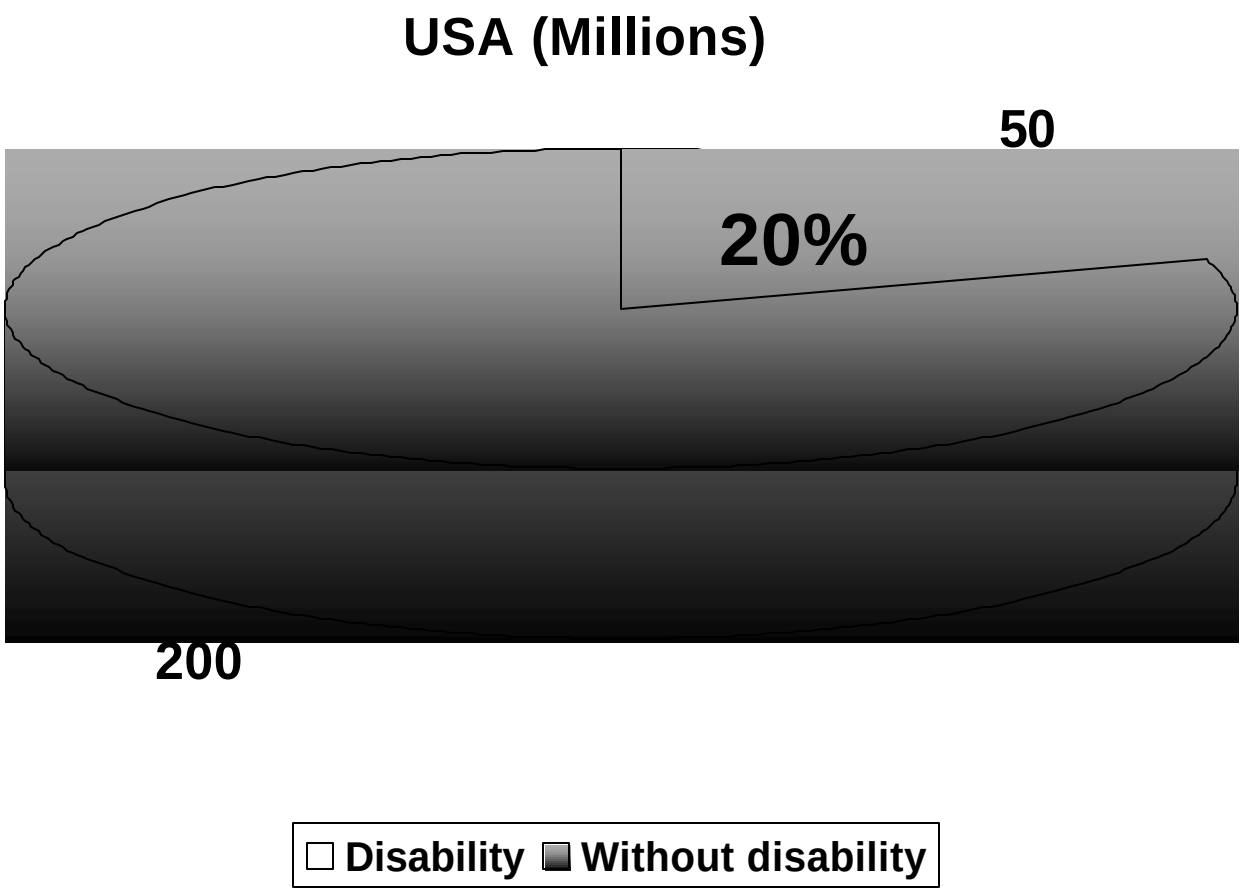
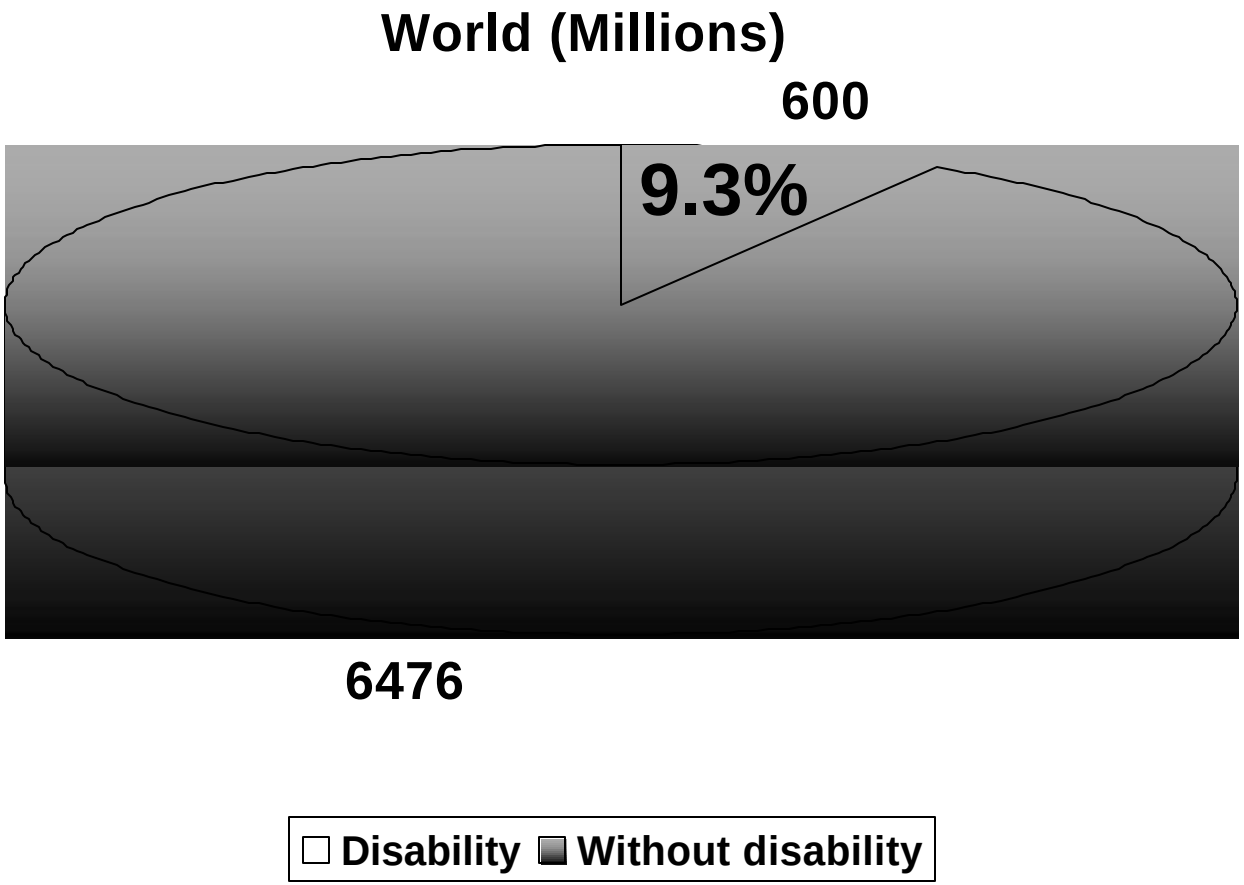


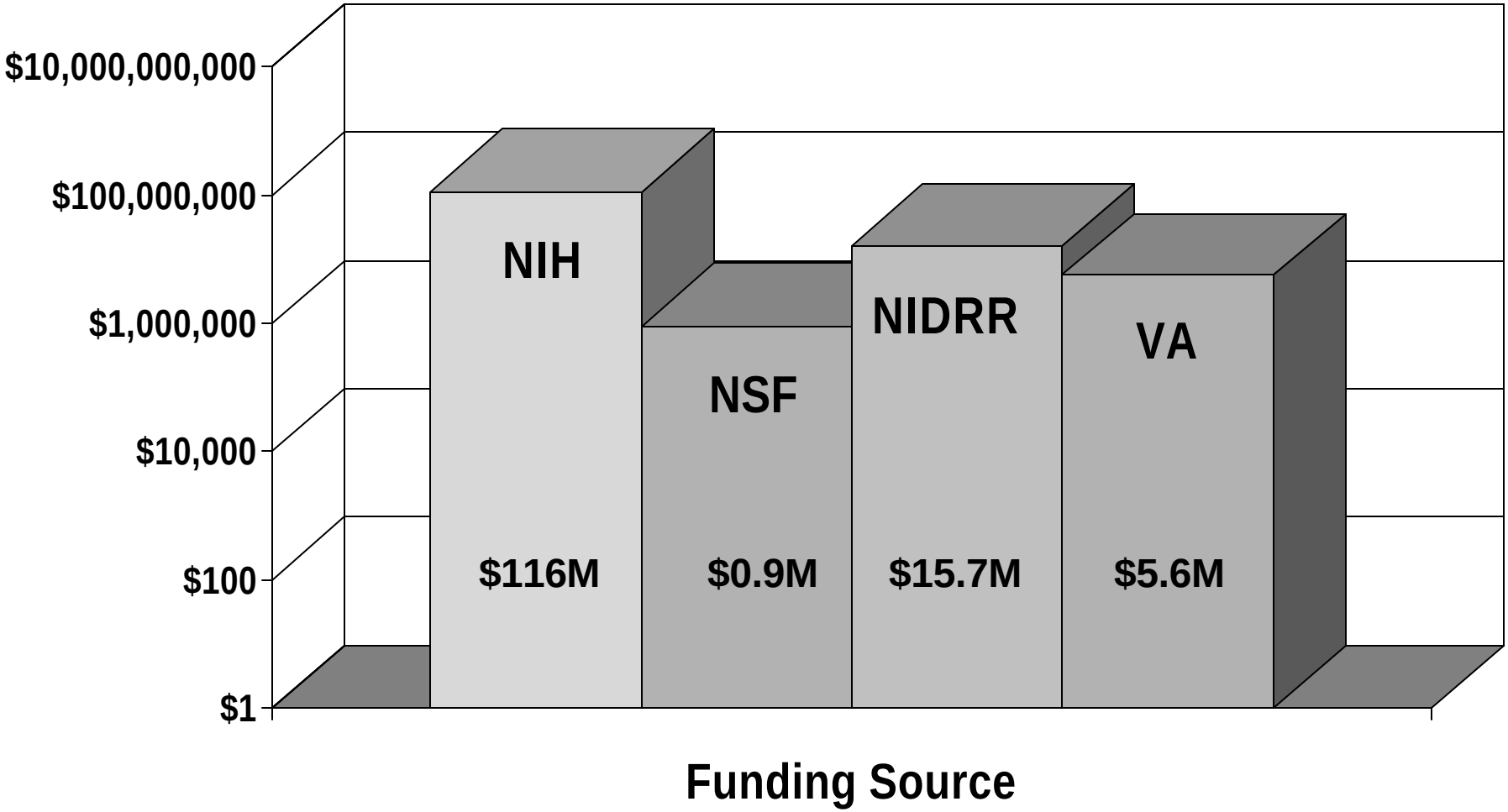
US Census Bureau, 2003

Magnitude of disability



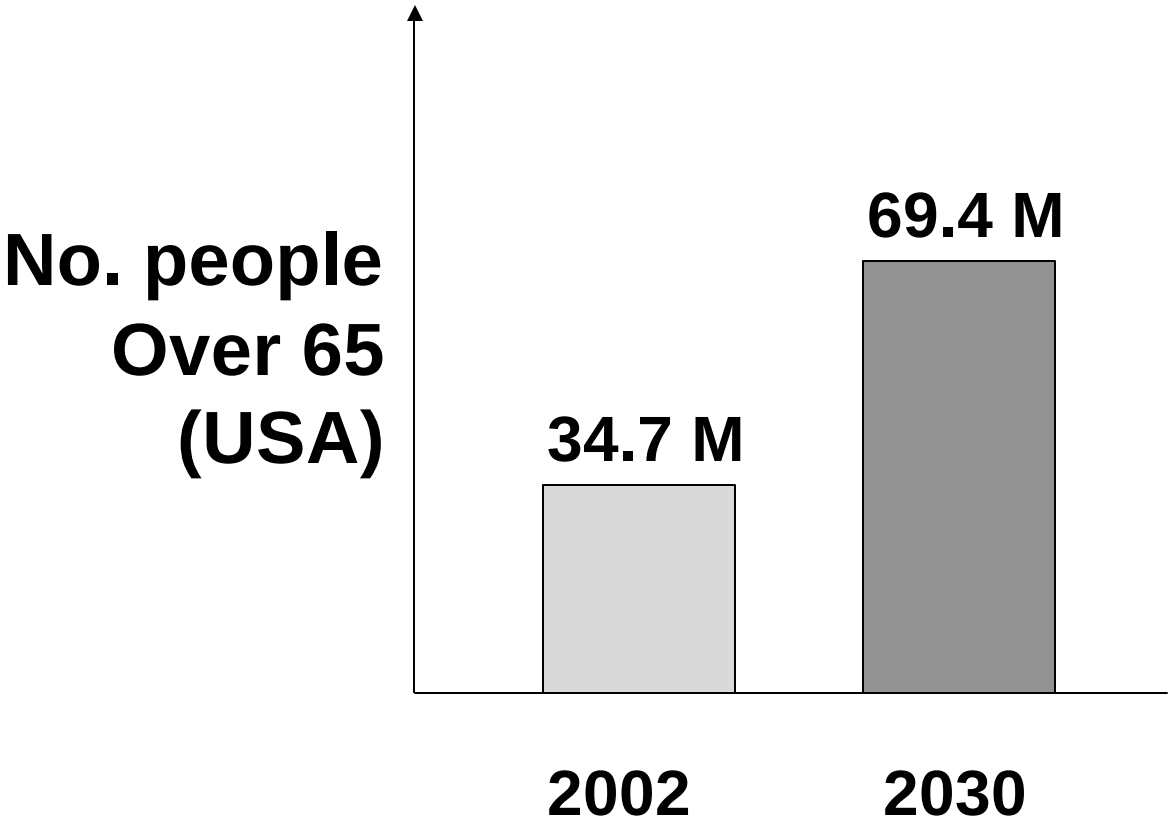
United Nations, 2004

Assistive Technology R&D (US)



Department of Commerce, US, 2000

Aging population



US Department of Health and Human Services, Administration on Aging, 2002

Economic numbers

$29 Billion loss per year
(industry & businesses)

Time away to care for aging parents

MIT Age Lab, 2004

Economic numbers

Assistive technology industry

$2.87 Billion

Bureau of industry and security, US Department of Commerce, 2003

Biopsychosocial model of disability

WHO ICF 2001

WHO ICF: Goals

- ***scientific basis*** for consequences of health conditions
- ***common language*** to improve communications
- ***comparison of data*** across:
  - countries
  - health care disciplines
  - services
  - time
- ***systematic coding scheme*** for health information systems

Principles of ICF

Human Functioning	- <u>not</u>	*merely disability*
Universal Model	- <u>not</u>	*a minority model*
Integrative Model	- <u>not</u>	*merely medical or social*
Interactive Model	- <u>not</u>	*linear progressive*
Parity	- <u>not</u>	*etiological causality*
Context - inclusive	- <u>not</u>	*person alone*
Cultural applicability	- <u>not</u>	*western concepts*
Operational	- <u>not</u>	*theory driven alone*
Life span coverage	- <u>not</u>	*adult driven*

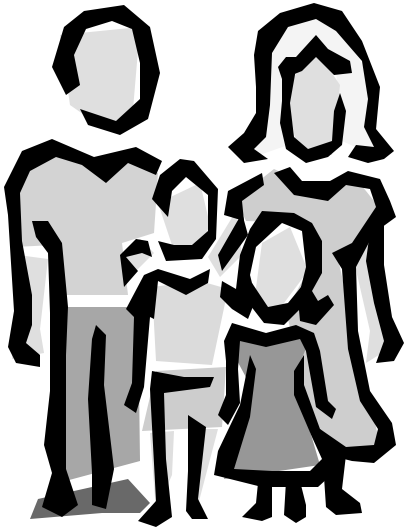
Principles of ICF

Human Functioning **disability**

- **Body functions & structures** —— impairments
- **Activities** —— limitation
- **Participation** —— restriction

Principles of ICF

Universal Model vs. Minority Model



Everyone may have disability
Continuum
Multi-dimensional

Certain impairment groups
Categorical
Uni-dimensional

“LABELS”

Principles of ICF

Universality

How far you go in life depends on you being tender with the young, compassionate with the aged, sympathetic with the striving and tolerant of the weak and the strong. Because someday in life you will have been all of these.

George Washington Carver (1864-1943)

Principles of ICF

Dr. Gregor Wolbring

“I refuse to see myself within a defective framework. I don’t accept the defect label because I have no legs. I see myself as a person with a non-mainstream body function.”

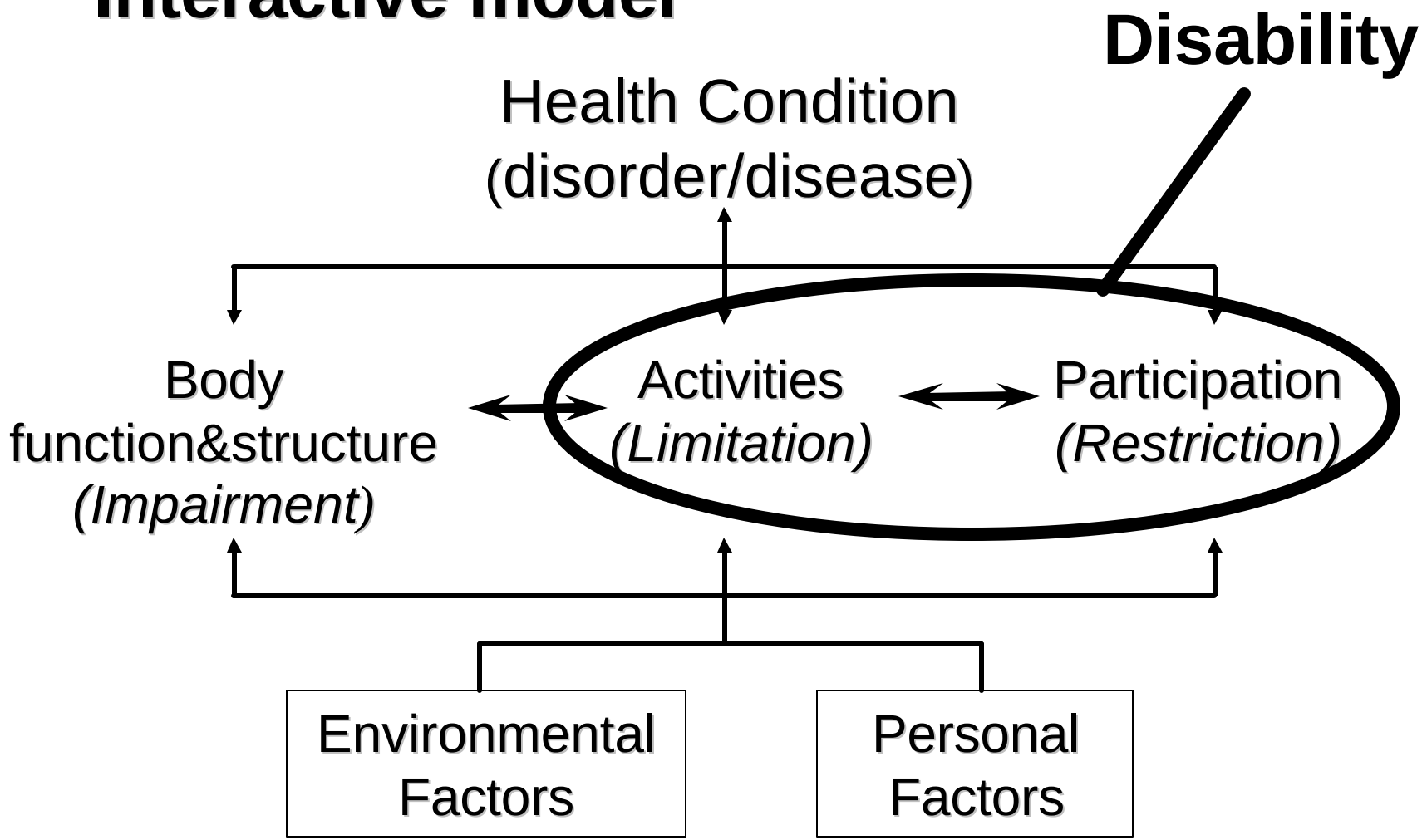
Principles of ICF

Medical *versus* Social Model

• PERSONAL problem	vs	SOCIAL problem
• personal adjustment	vs	environmental manipulation
• behaviour	vs	attitude
• individual adaptation	vs	social change

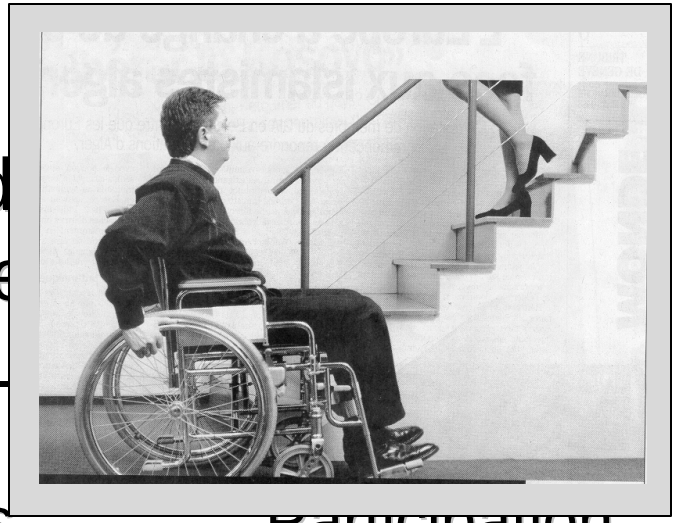
Principles of ICF

Interactive model



Principles of ICF

- Products
- Close milieu
- Institutions
- Social Norms
- Culture
- Built-environment
- Political factors
- Nature



Cond
er/dise

ctivities
(Limitation)

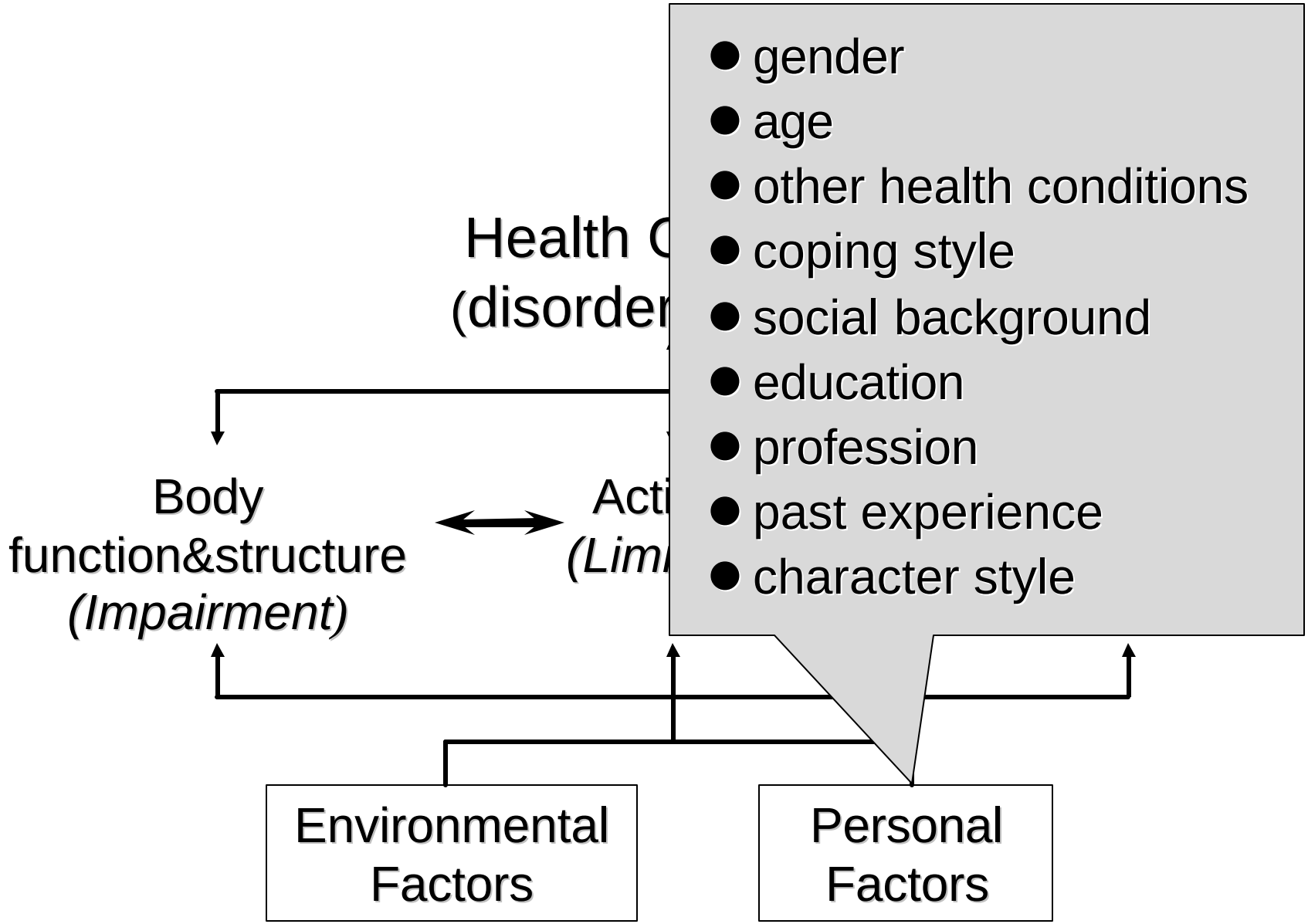
Participation
(Restriction)

(Impairment)

Environmental Factors

Personal Factors

Principles of ICF

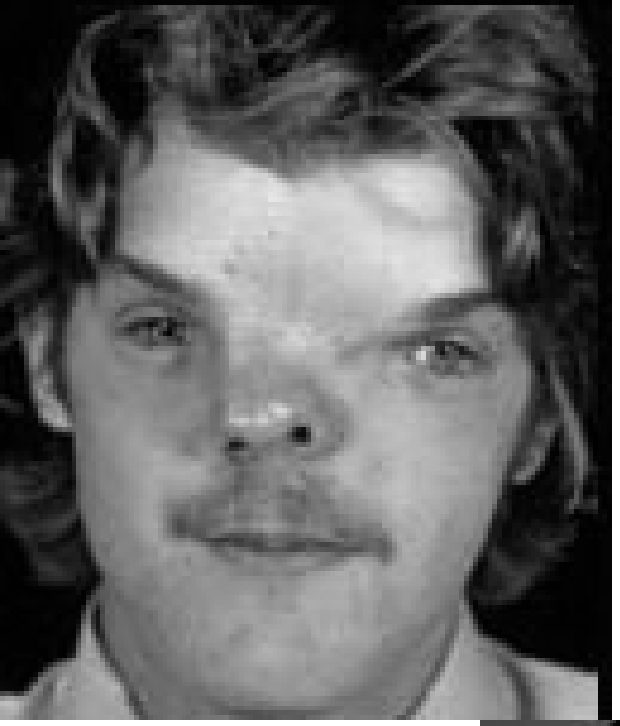


Principles of ICF

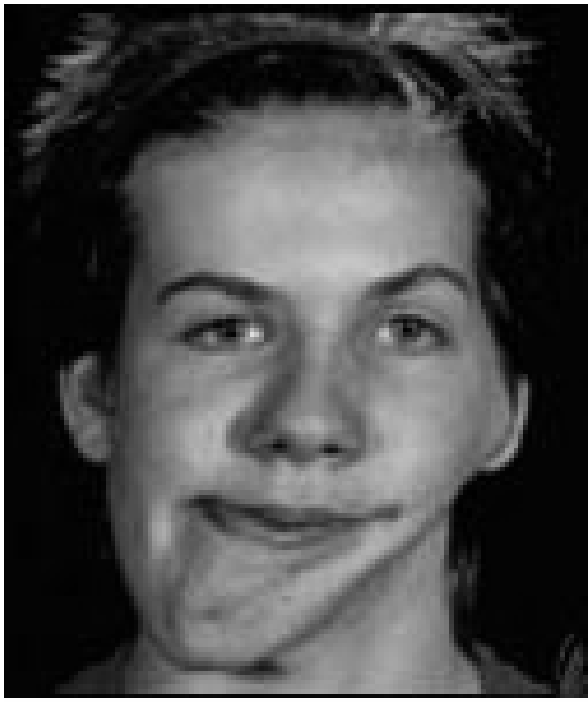
“If I had to say that there is one most difficult thing about being a teen in a wheelchair, it would be that I still feel there is a constant battle to "belong." By belong, I mean to feel that I am a part of my community, my school, to have a feeling of being welcome, and to never ever again feel the need to question my own self value, worth, or ability. As a teen, this is one of the most complicated and painful parts of being in a wheelchair.”

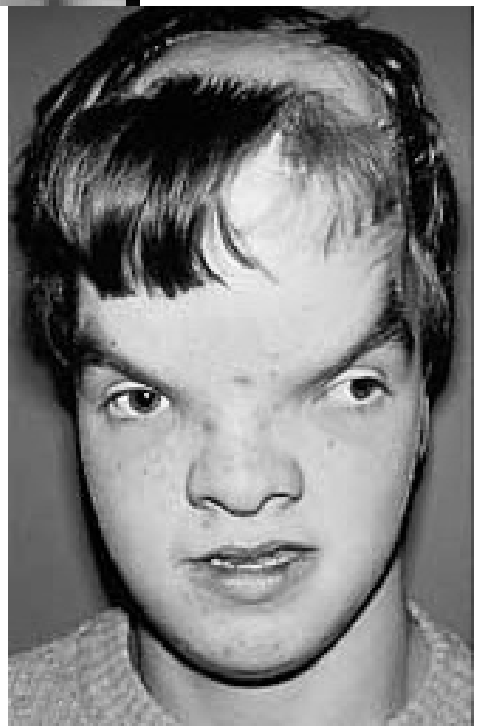
- Eileen, seventeen year old high school senior living with a spinal cord injury

Principles of ICF



Principles of ICF





Implications for rehabilitation engineering

Embracing a biopsychosocial model

Rehabilitation Engineering

“… is the application of science and technology to improving the quality of life for people with disabilities.“

James Reswick, 1st RESNA President

Assistive Technology

"Any item, piece of equipment, or product system, whether acquired commercially off the shelf, modified, or customized, that is used to increase, maintain, or improve functional capabilities of individuals with disabilities.

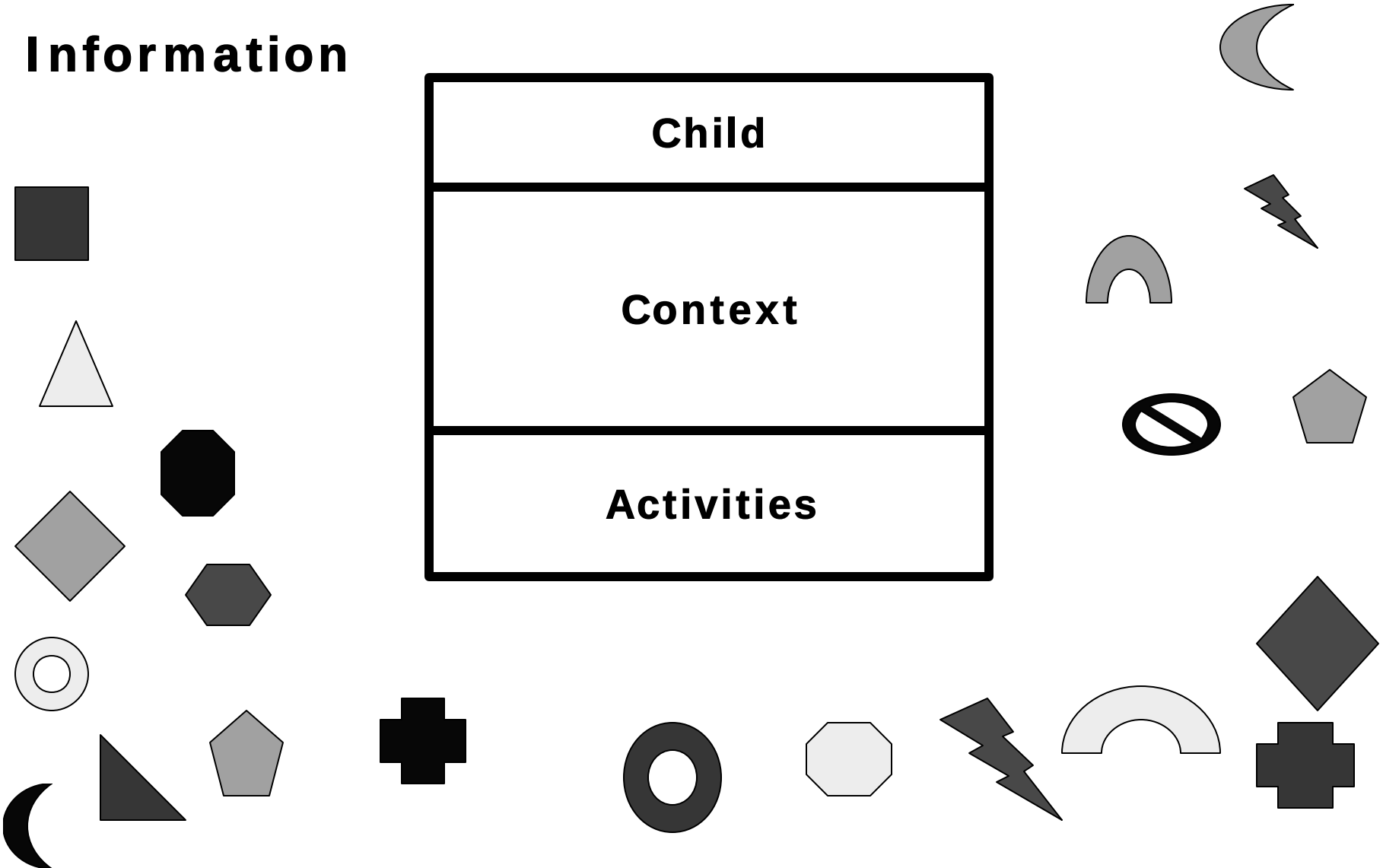
Source: The US technology-related assistance for individuals with disabilities act of 1988, Section 3.1. Public Law 100-407, August 9, 1988 (renewed in 1998 in the Clinton Assistive Technology Act)

Embracing a biopsychosocial model of disability

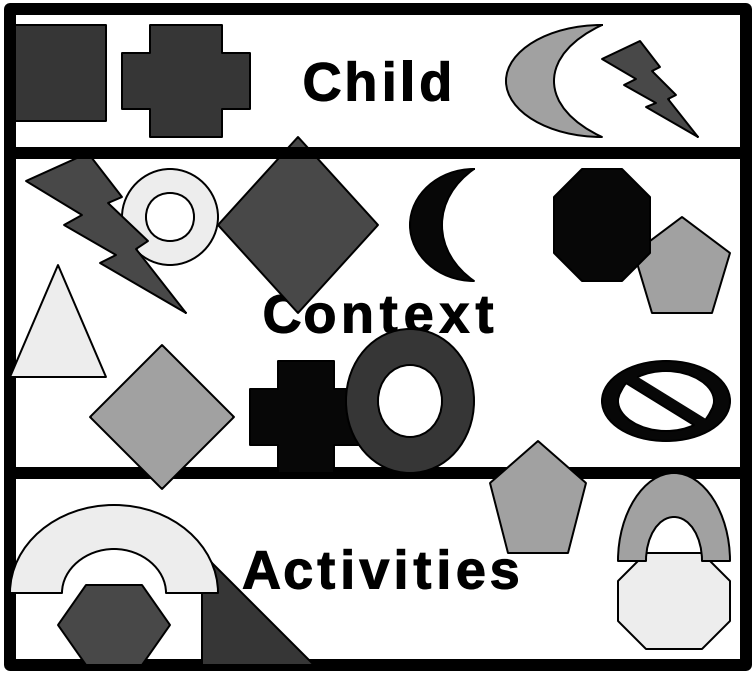
Intelligent systems

Intelligent system

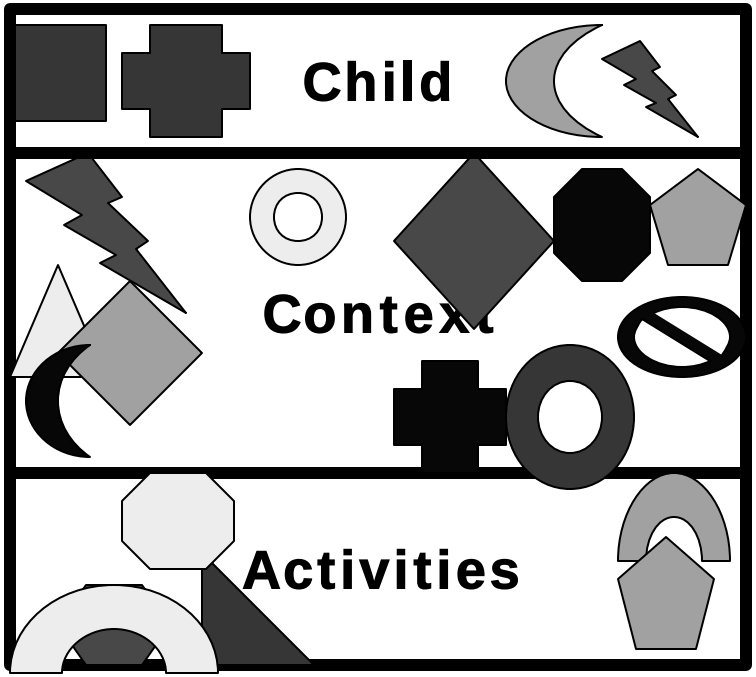
Information



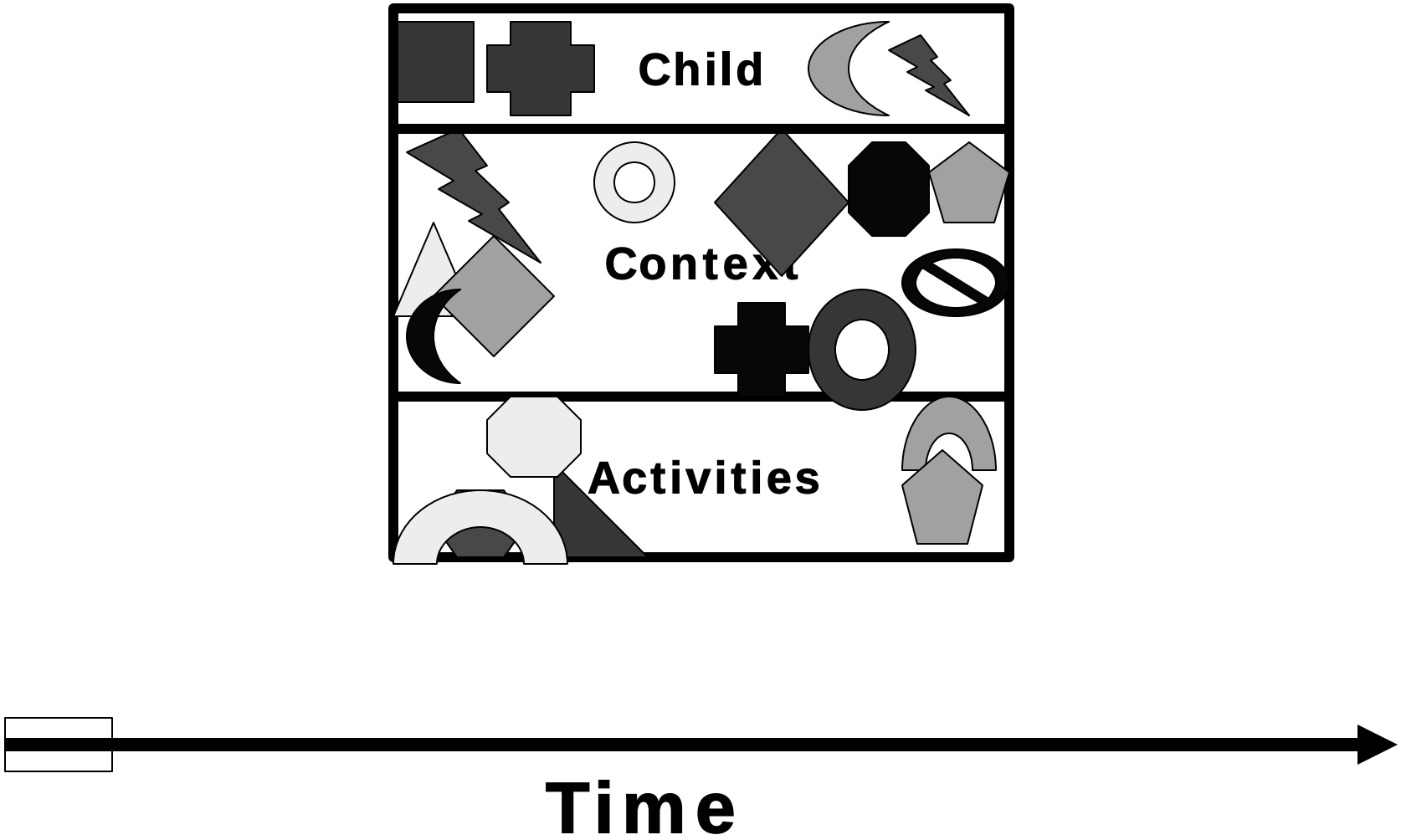
Intelligent system



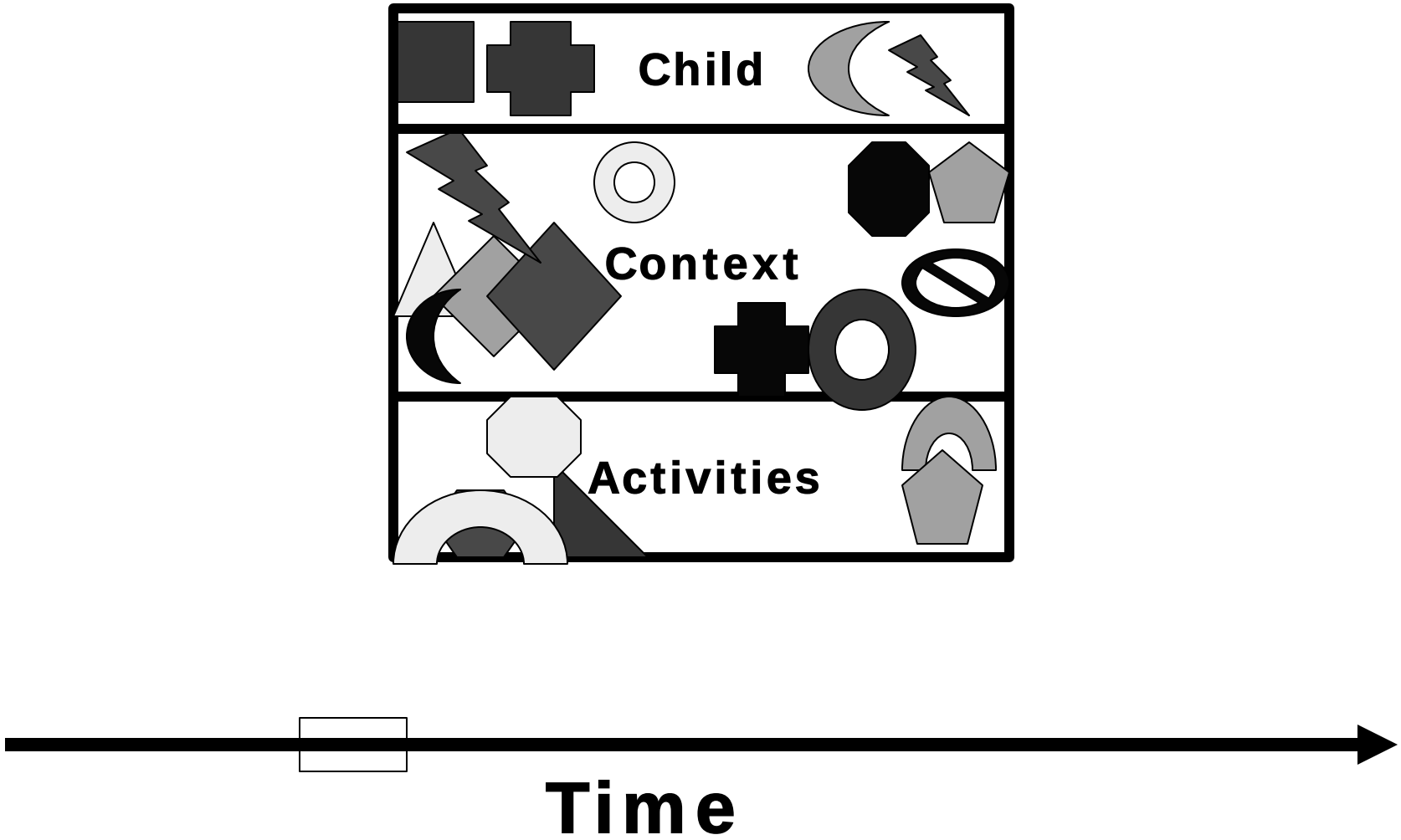
Intelligent system



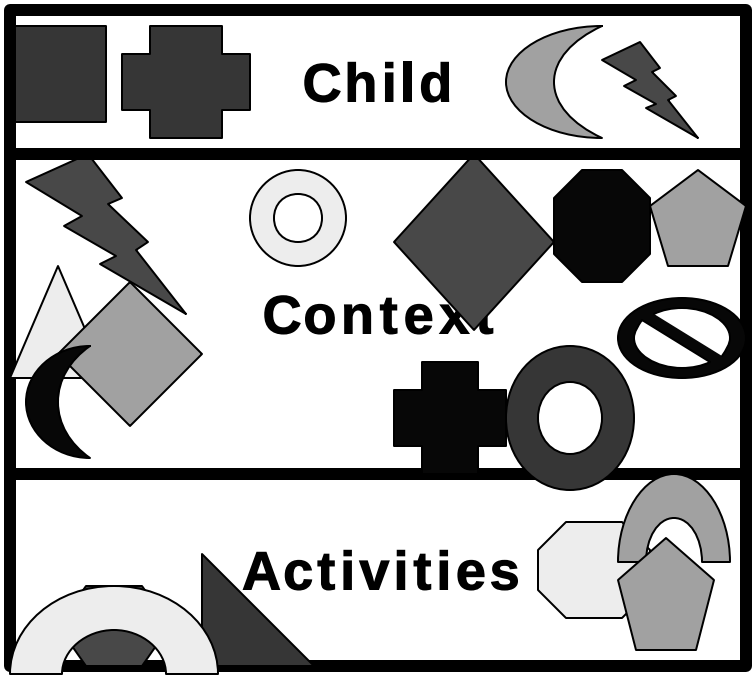
Dynamic intelligent system



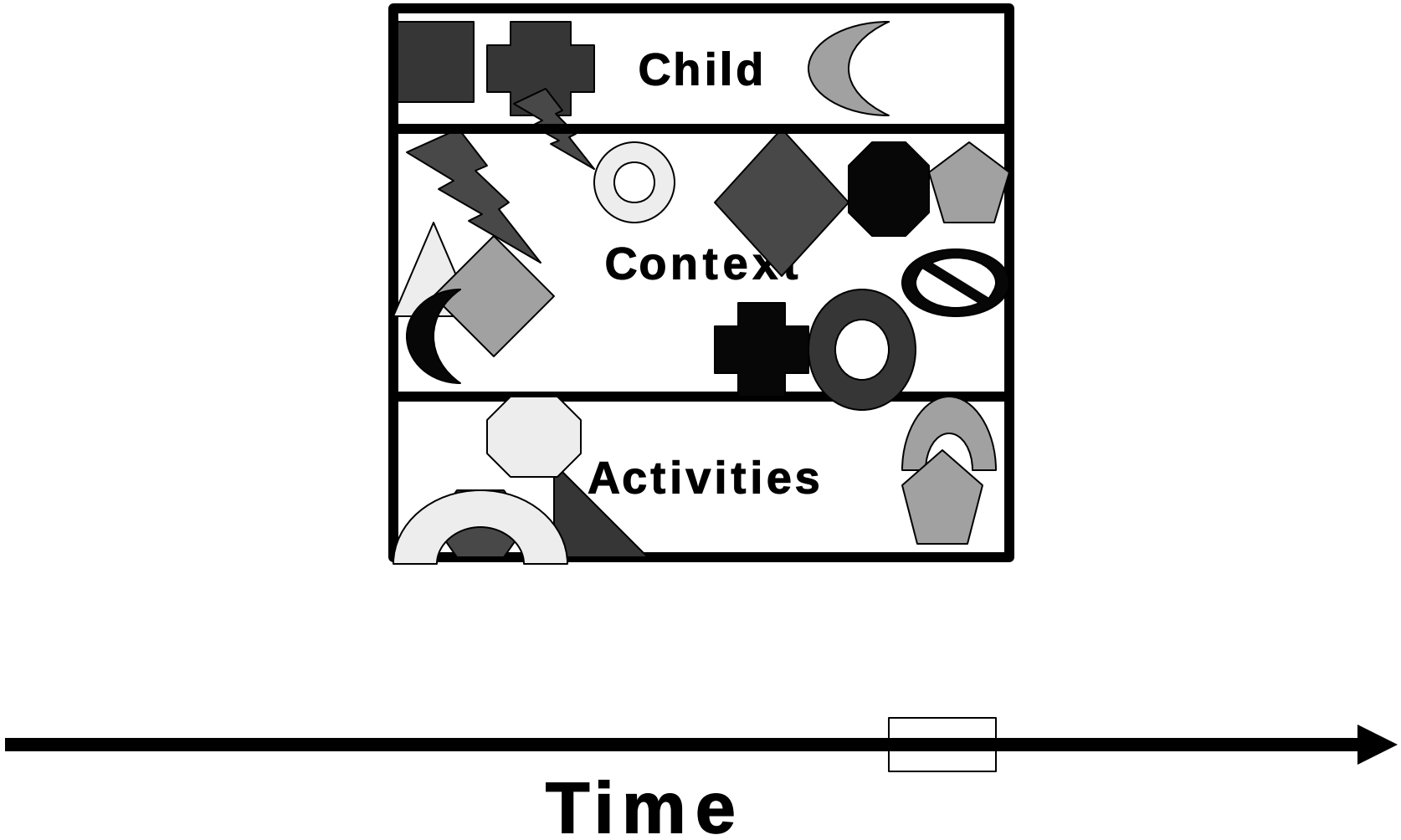
Dynamic intelligent system



Dynamic intelligent system



Dynamic intelligent system



Dynamic intelligent system

Outputs **Inputs** **Time**

$$y = f(q, x, t)$$

Free parameters

Intelligent system

Transfer onus of learning human-machine interface from child to machine

Human functioning

Intelligent system

Individual is ok

Depart from minority model

Accommodate any user ability

Psychosocial model

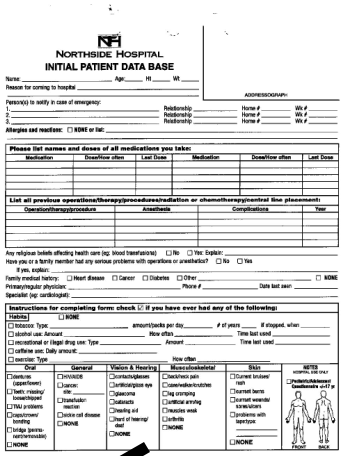
Intelligent system

Context-aware

Personal factors

Environmental factors

Intelligent system



NORTHSIDE HOSPITAL
INITIAL PATIENT DATA BASE

Name _____ Age_____ Ht _____ Wt _____
Reason for coming to hospital _____
ADDRESSOGRAPH

Person(s) to notify in case of emergency:
1. _____ Relationship _____ Home # _____ Wk # _____
2. _____ Relationship _____ Home # _____ Wk # _____
3. _____ Relationship _____ Home # _____ Wk # _____

Allergies and reactions: ☐ NONE or list: _____

Please list names and doses of all medications you take:

Medication	Dose/How often	Last Dose	Medication	Dose/How often	Last Dose

List all previous operations/therapy/procedures/radiation or chemotherapy/mental line placement:

Operation/therapy/procedure	Anesthesia	Complications	Year

Any religious beliefs affecting health care (eg: blood transfusions) ☐ No ☐ Yes: Explain: _____
Have you or a family member had any serious problems with operations or anesthetics? ☐ No ☐ Yes
If yes, explain: _____
Family medical history: ☐ Heart disease ☐ Cancer ☐ Diabetes ☐ Other _____ ☐ NONE
Primary/regular physician: _____ Phone # _____ Date last seen: _____
Specialist (eg: cardiologist): _____

Instructions for completing form: check ☑ if you have ever had any of the following:

Habits ☐ NONE
☐ tobacco: Type _____ amount/packs per day_____ # of years _____ if stopped, when _____
☐ alcohol use: Amount _____ How often _____ Time last used _____
☐ recreational or illegal drug use: Type _____ Amount _____ Time last used _____
☐ caffeine use: Daily amount: _____ How often _____
☐ exercise: Type _____

Oral	General	Vision & Hearing	Musculoskeletal	Skin	AGE/SEX (CENTRAL USE ONLY)
☐ dentures (upper/lower) ☐ teeth: missing/ loose/chipped ☐ TMJ problems ☐ caps/crowns/ bonding ☐ bridge (perma-nent/removable) ☐ NONE	☐ HIV/AIDS ☐ cancer: site _____ ☐ transfusion/ reaction ☐ sickle cell disease ☐ NONE	☐ contacts/glasses ☐ artificial/glass eye ☐ glaucoma ☐ cataracts ☐ hearing aid ☐ hard of hearing/ deaf ☐ NONE	☐ back/neck pain ☐ bone/weak/brittle ☐ leg cramping ☐ artificial arm/leg ☐ muscles weak ☐ arthritis ☐ NONE	☐ current bruises/ rash ☐ current burns ☐ current wounds/ sores/ulcers ☐ problems with tan/tyx ☐ NONE	☐ Pediatric/Adolescent Sexual/Immotive <=17 yr FRONT 18 19 BACK

Sensors

Intelligent system

Sensors

Interface

Dynamic intelligent system

Disability is dynamic

Disease progression

Environmental change

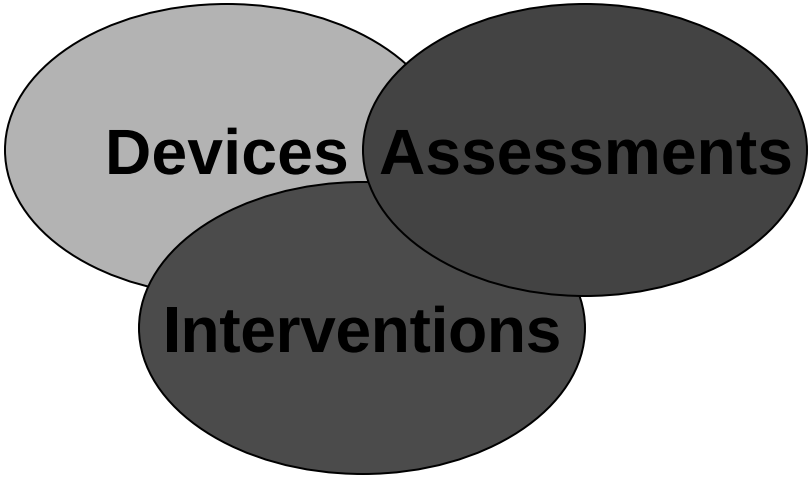
Developmental change

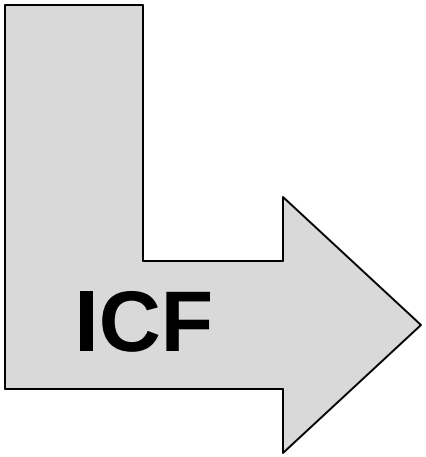
Interactive model

Life span coverage

Dynamic intelligent systems

1. Transfer onus of learning
2. Individual is ok
3. Look at context
4. Disability is dynamic





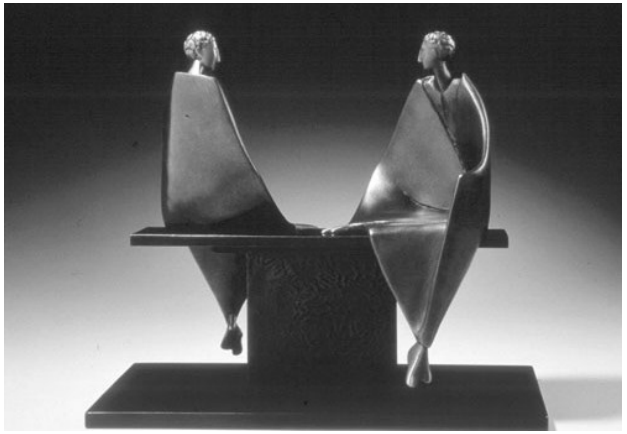
Developmental

Ecological relevance

Body – Activity - Participation

Examples from paediatric rehabilitation

- Non-contact communication aid
- Aspirometer
- Augmented environments
- Mechanomyography
- Fractal gait

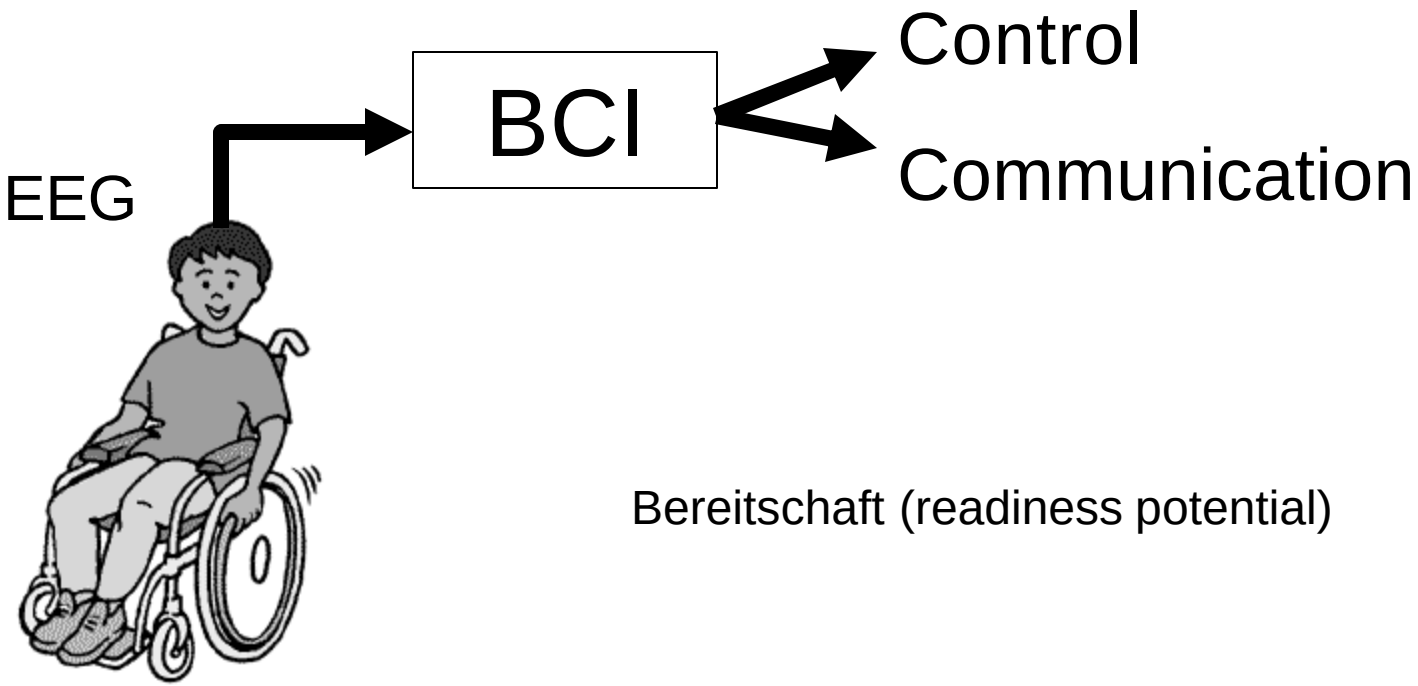


Non-contact communication

- Brain computer interface
- Gesture interface

Brain-computer interfaces

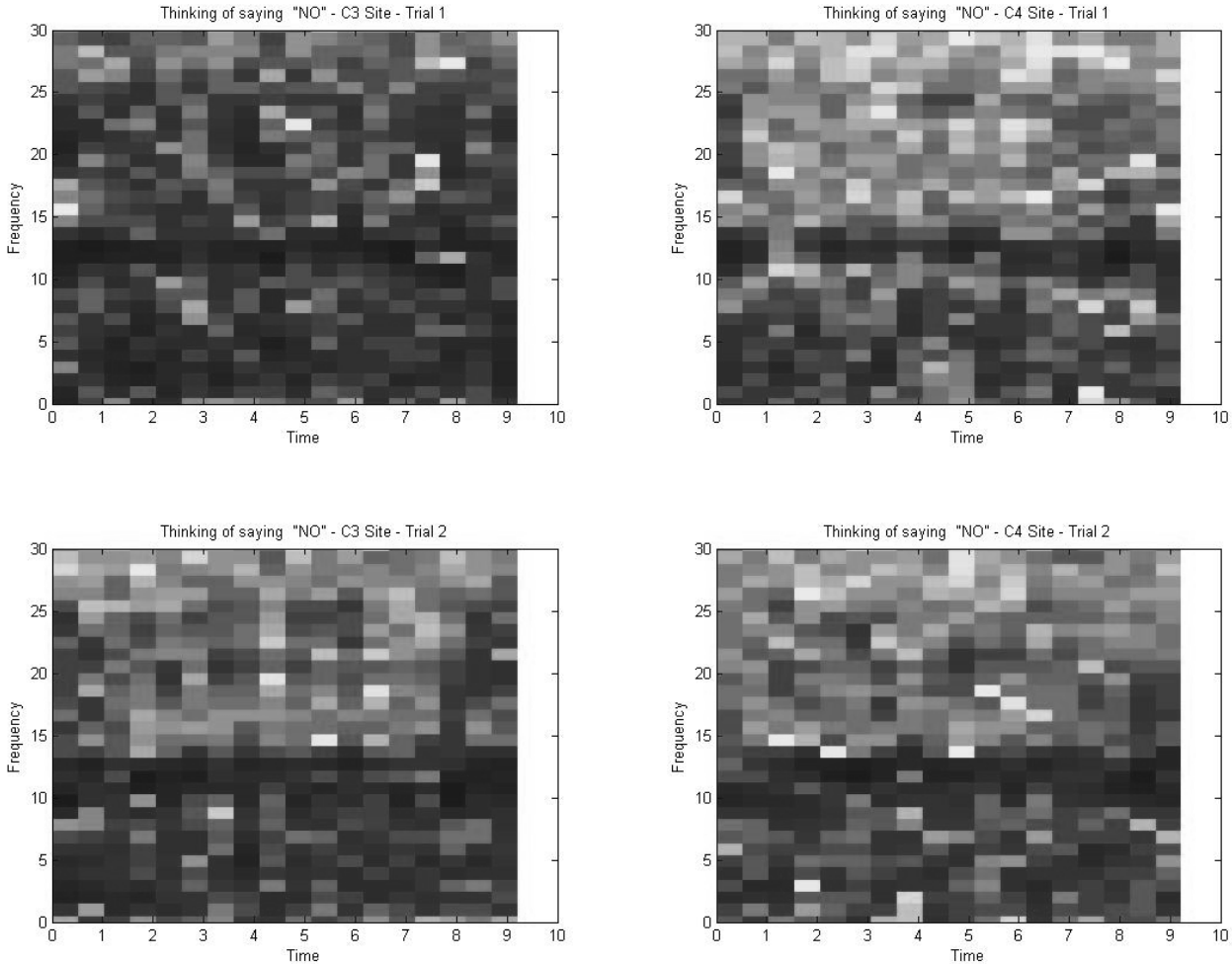
Brain-computer interfaces



Bereitschaft (readiness potential)

Brain-computer interfaces

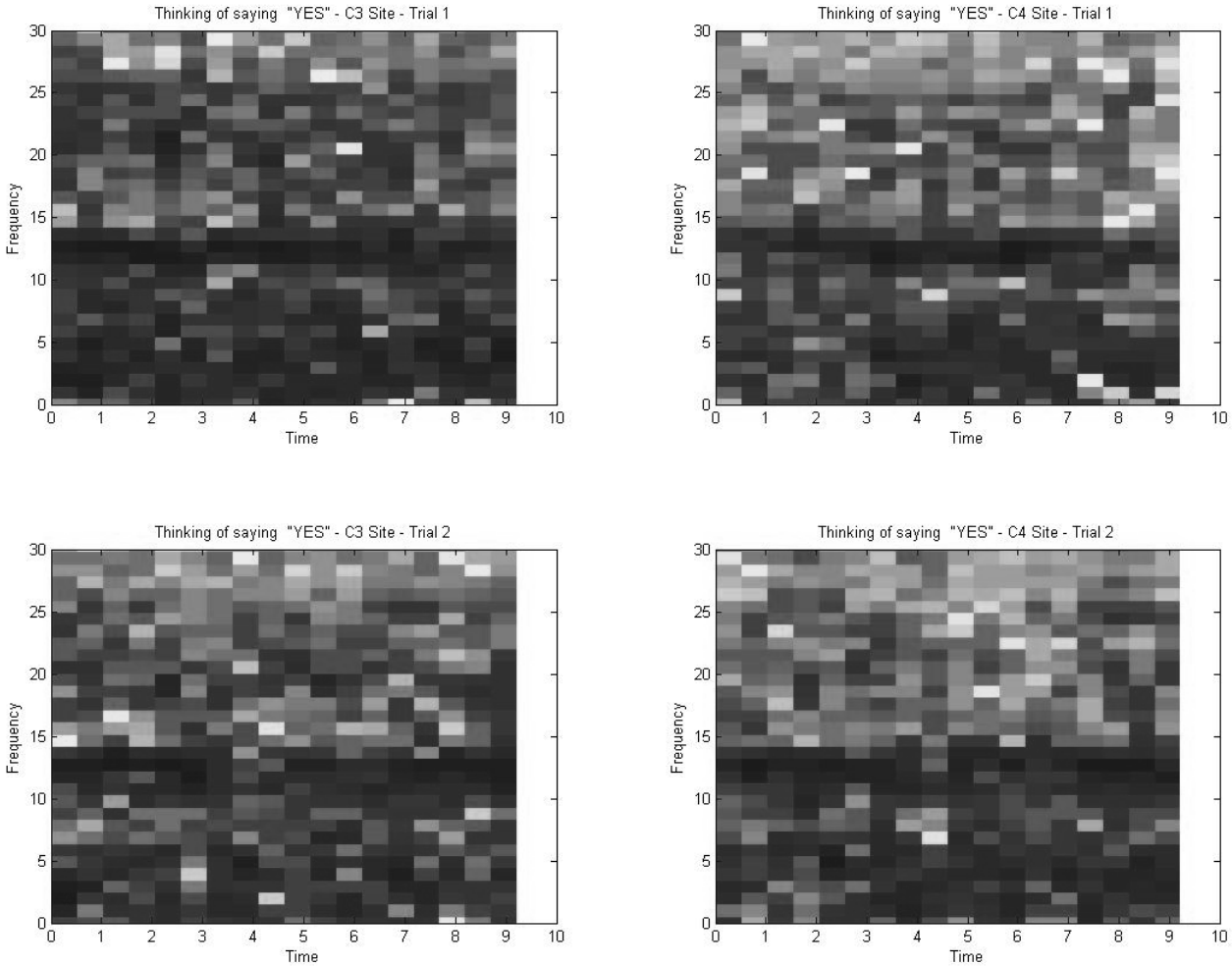
Expressions of preference



“No”

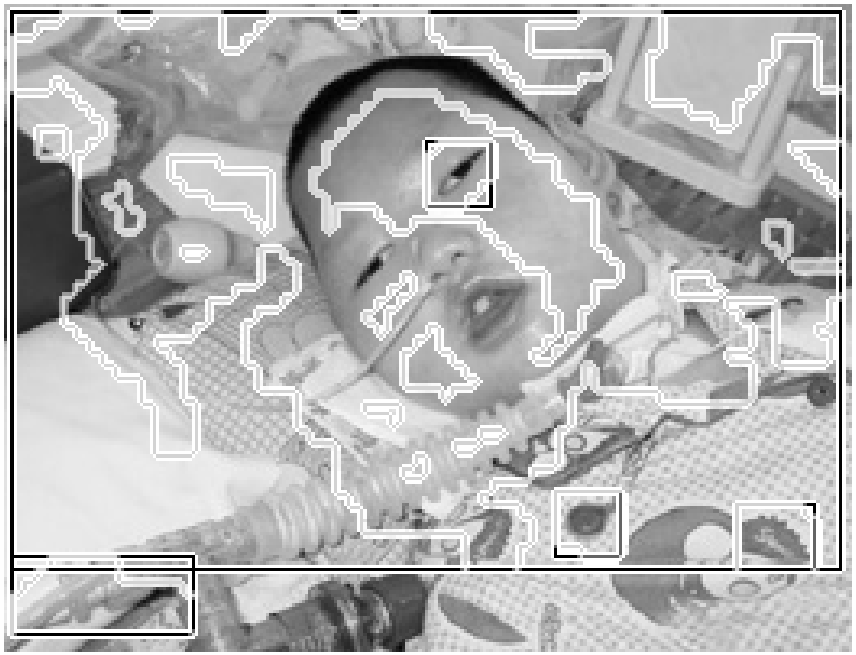
Brain-computer interfaces

Expressions of preference

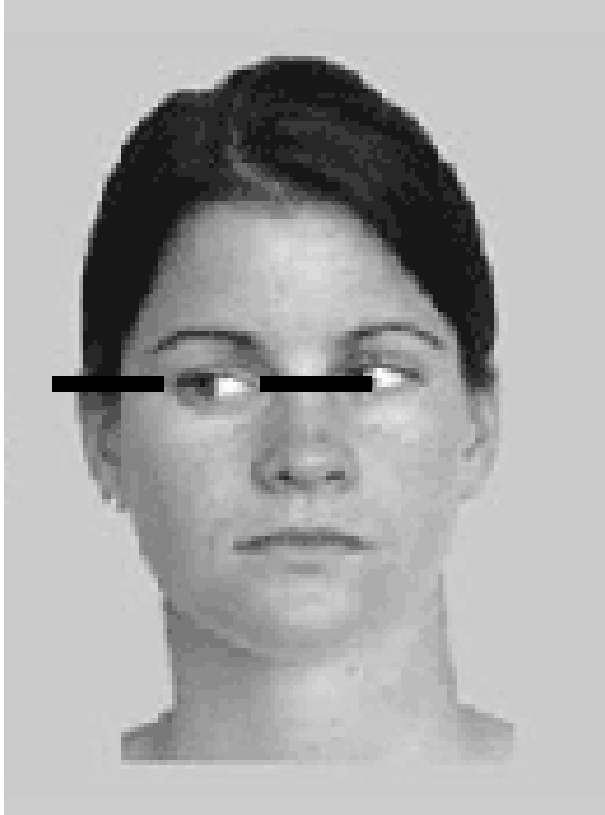


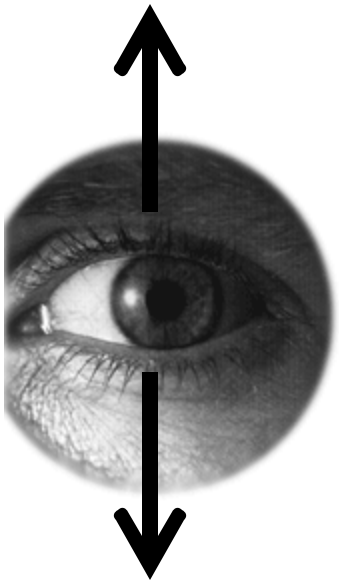
“Yes”

Gestural interface

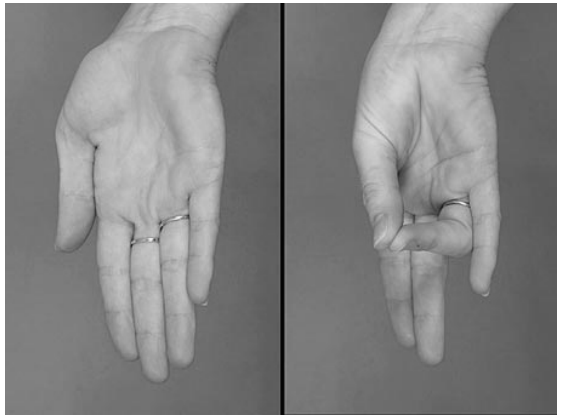


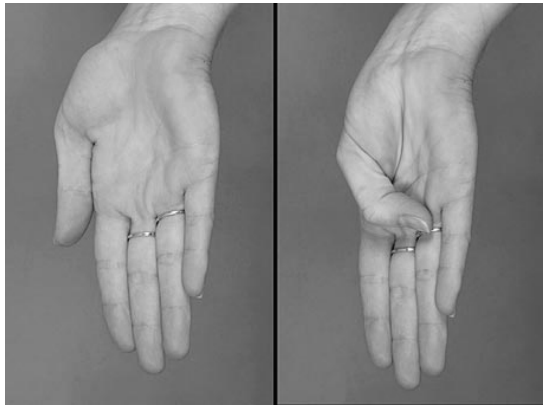
Gestural interface



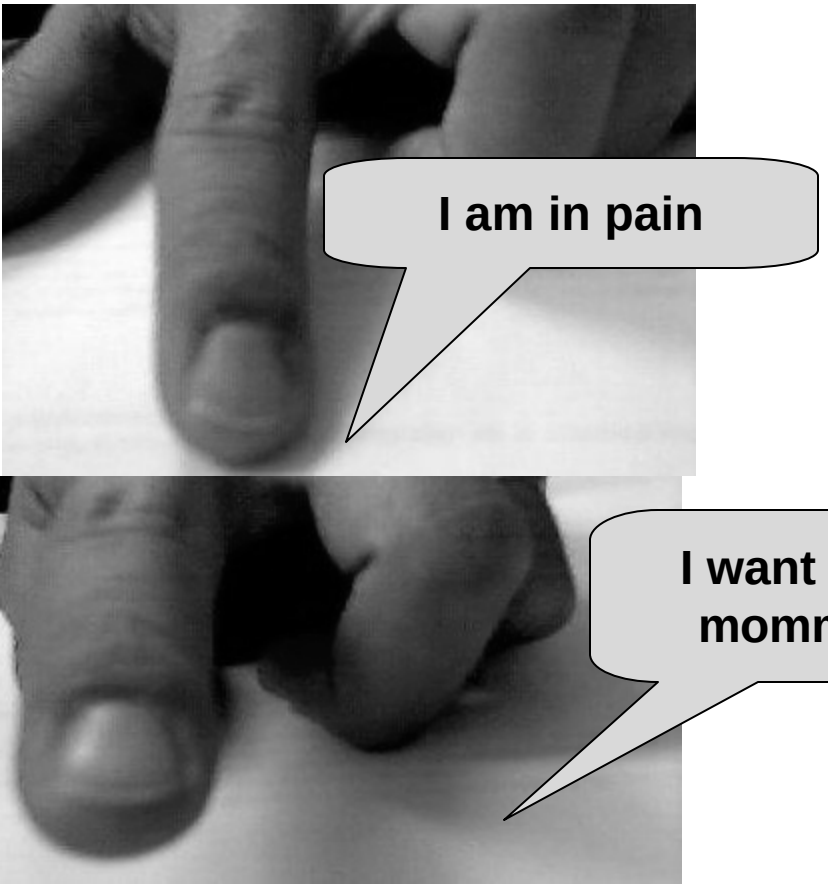


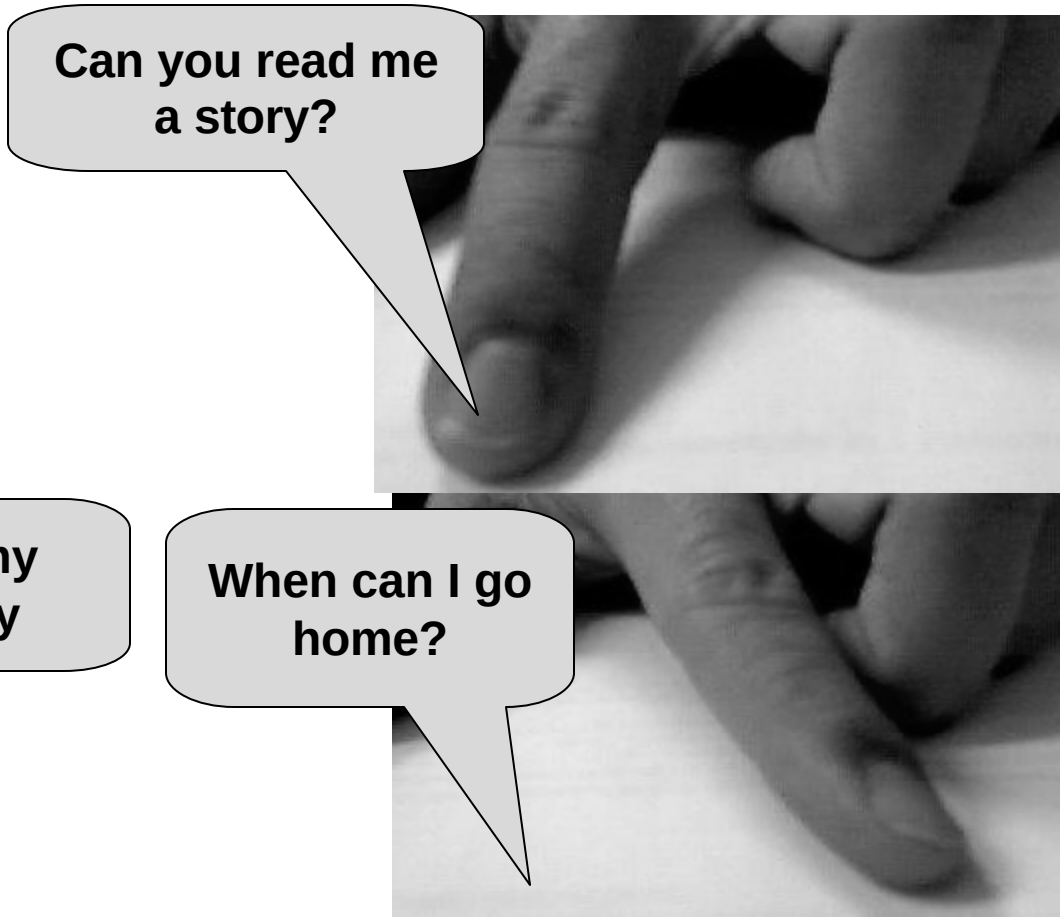
Gestural interface



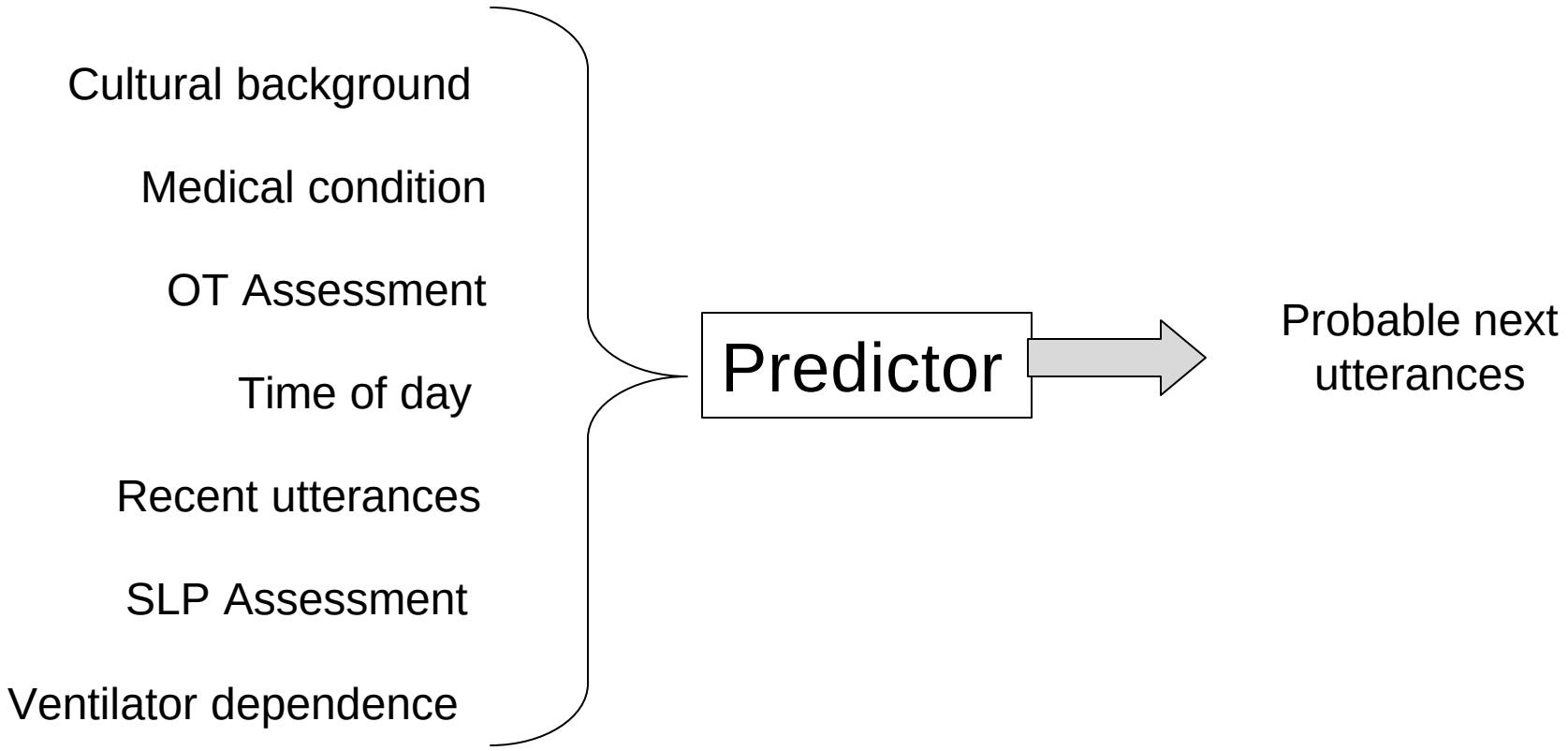


Gestural interface

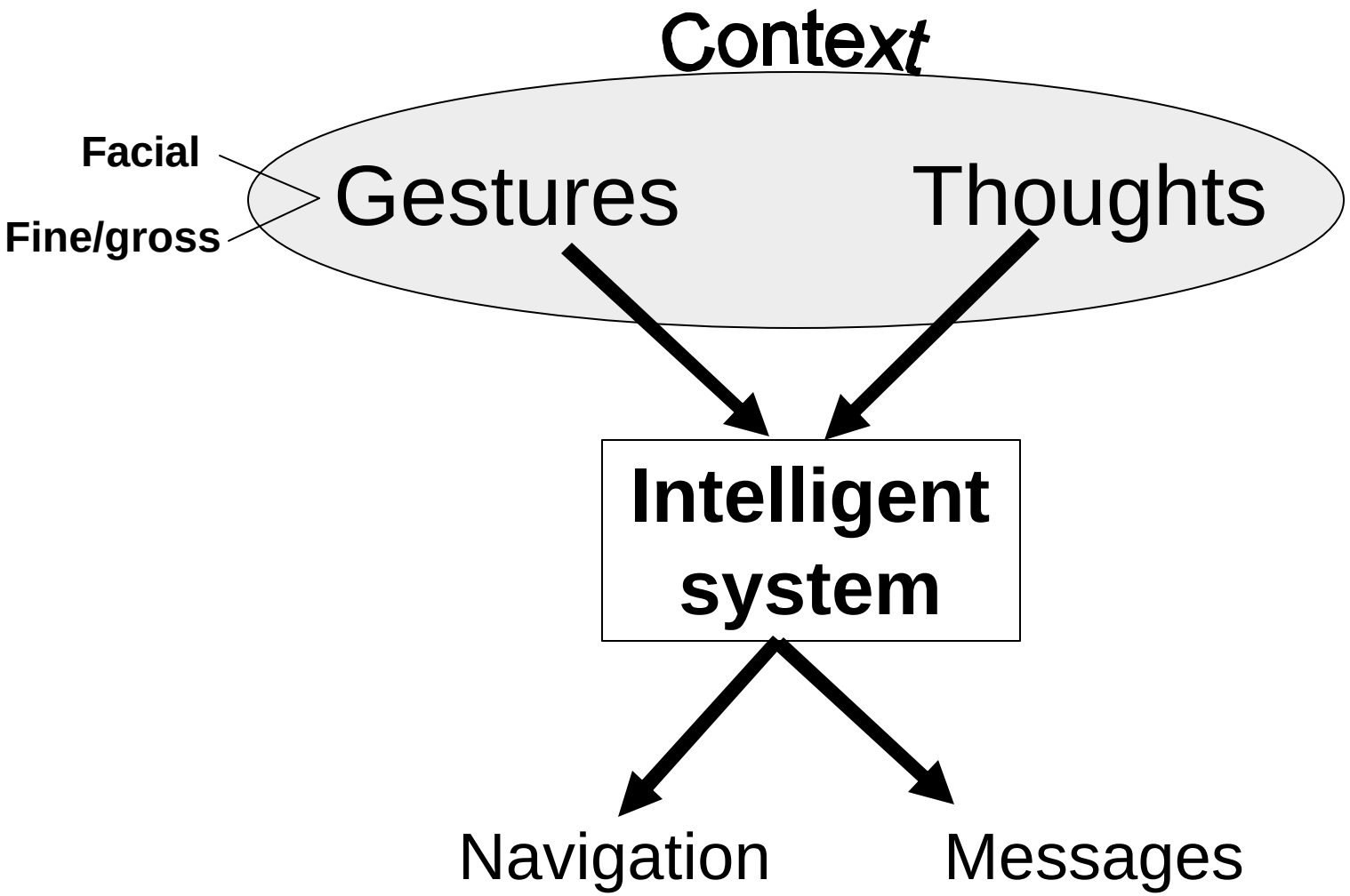




Context – speech act prediction



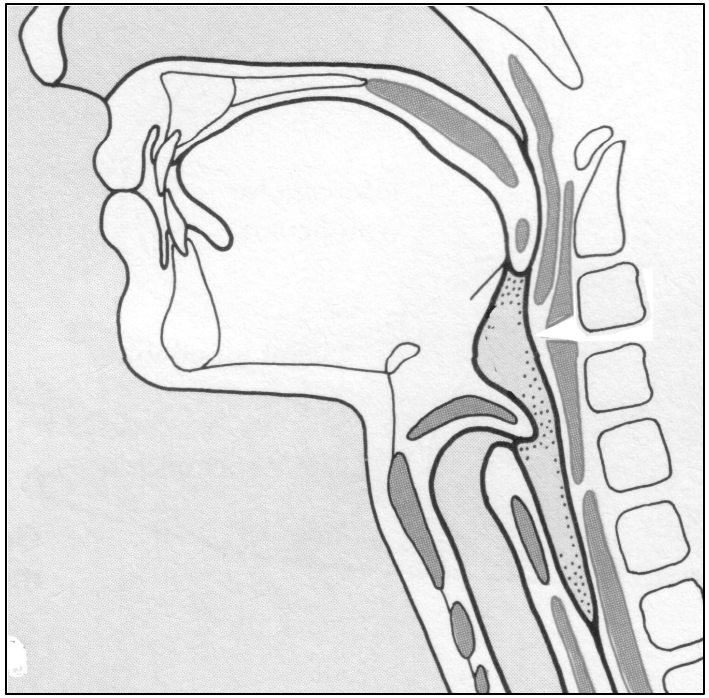
Noncontact communication

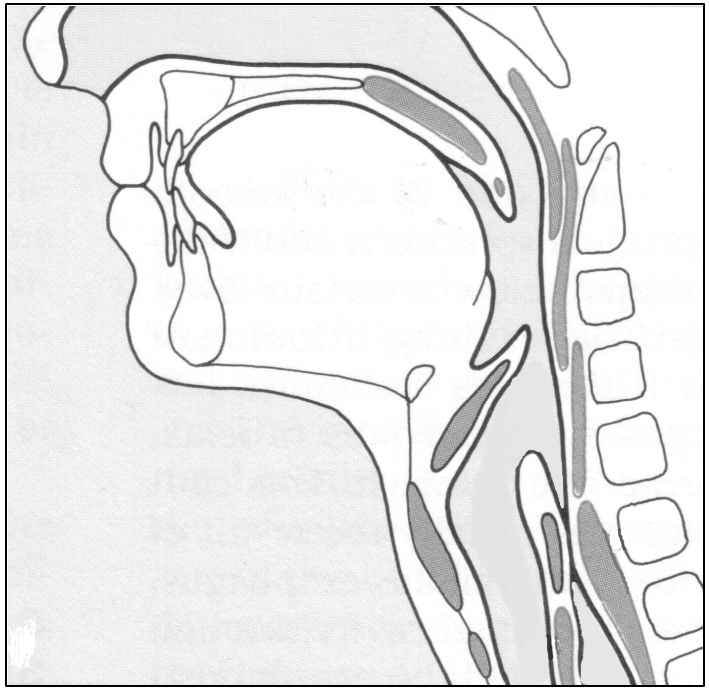


Examples from paediatric rehabilitation

- Non-contact communication aid
- Aspirometer
- Augmented environments
- Mechanomyography
- Fractal gait

Detection of aspiration



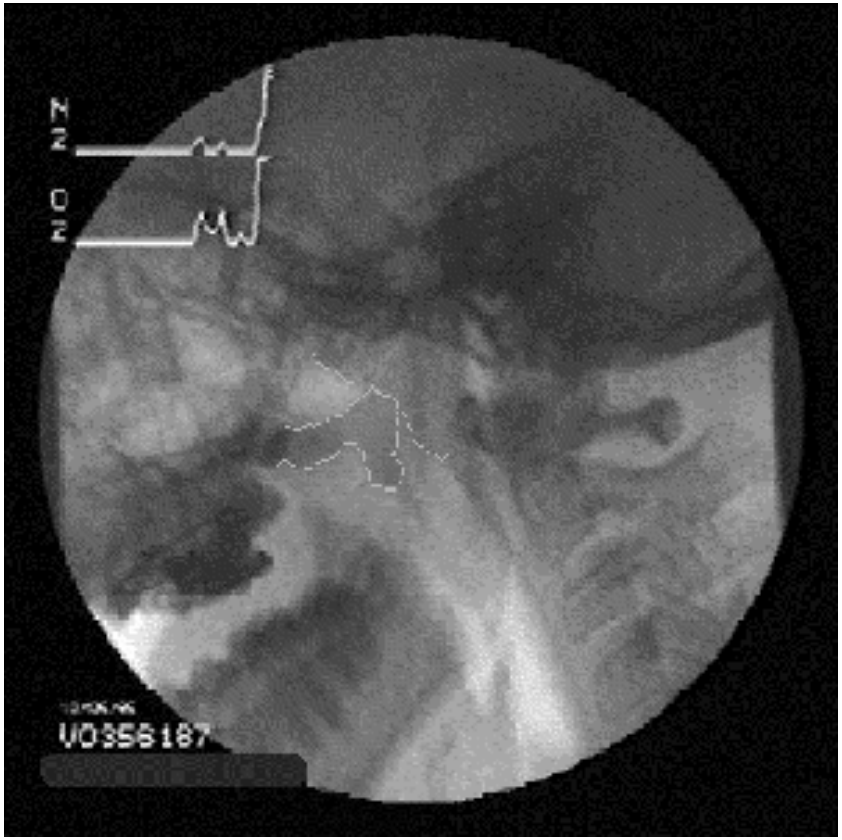


Detection of aspiration

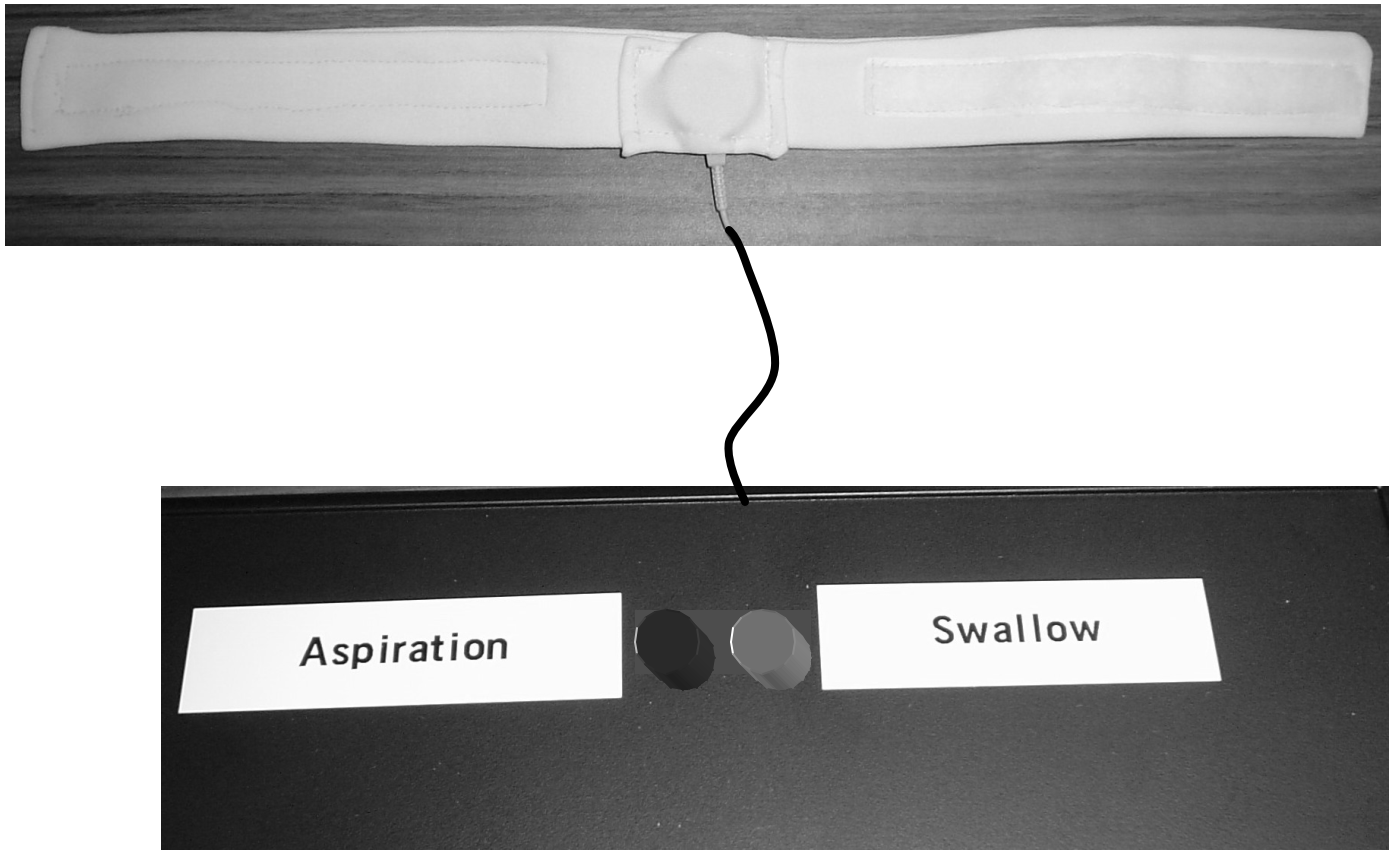
Vibration sensor

Synchronized (time stamped) X-ray video & accelerometry

Videofluoroscopy



Detection of aspiration



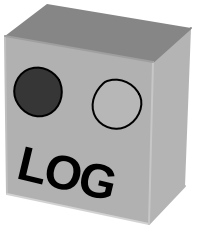
Chau T., Chau, D., Casas M., Berall G. & Kenny D. (*In Press*). “On the stationarity of paediatric aspiration signals”, IEEE Transactions on Neural and Rehabilitation Engineering.

Chau T., Kenny DJ, Casas M, Berall G, Apparatus and method for detecting swallowing activity, (US 10/869,024 filed June 17, 2004).

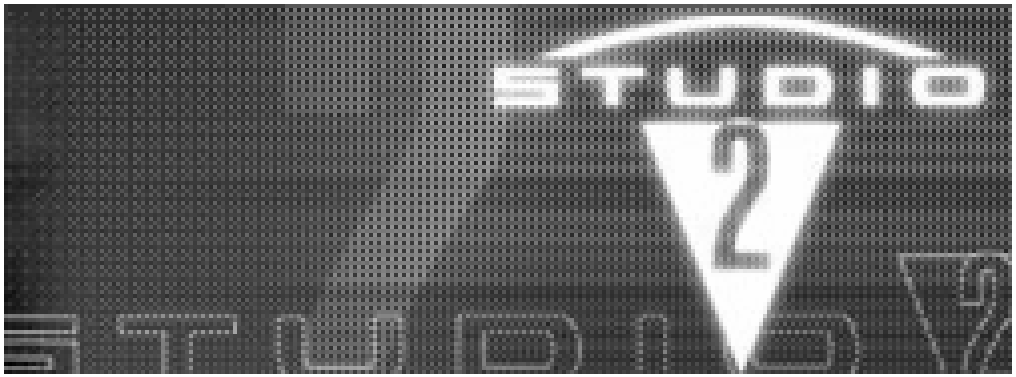
Detection of aspiration

- 3 Features: stationarity, normality, dispersion

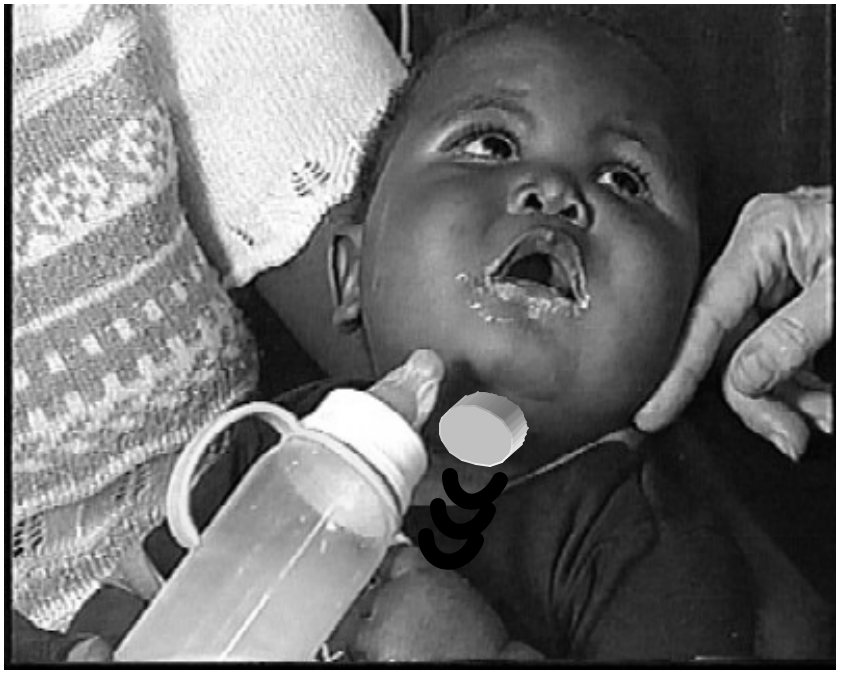
+ve predictive value	93%
-ve predictive value	58%
Sensitivity	83%
Specificity	81%

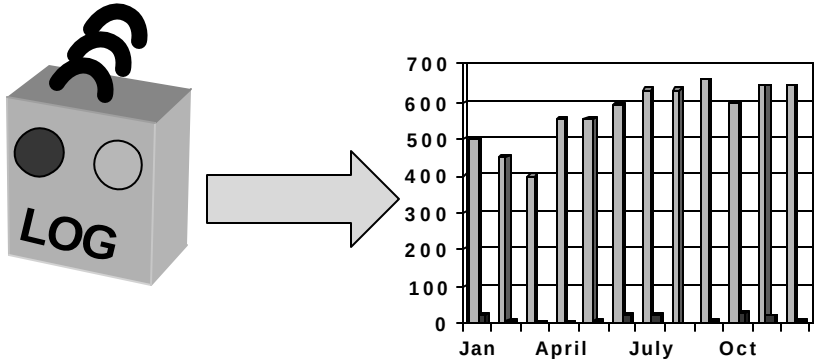


Aspirometer



Aspirometer





Examples from paediatric rehabilitation

- Non-contact communication aid
- Aspirometer
- Augmented environments
- Mechanomyography
- Fractal gait

Augmented environments

Real, physical environment

+

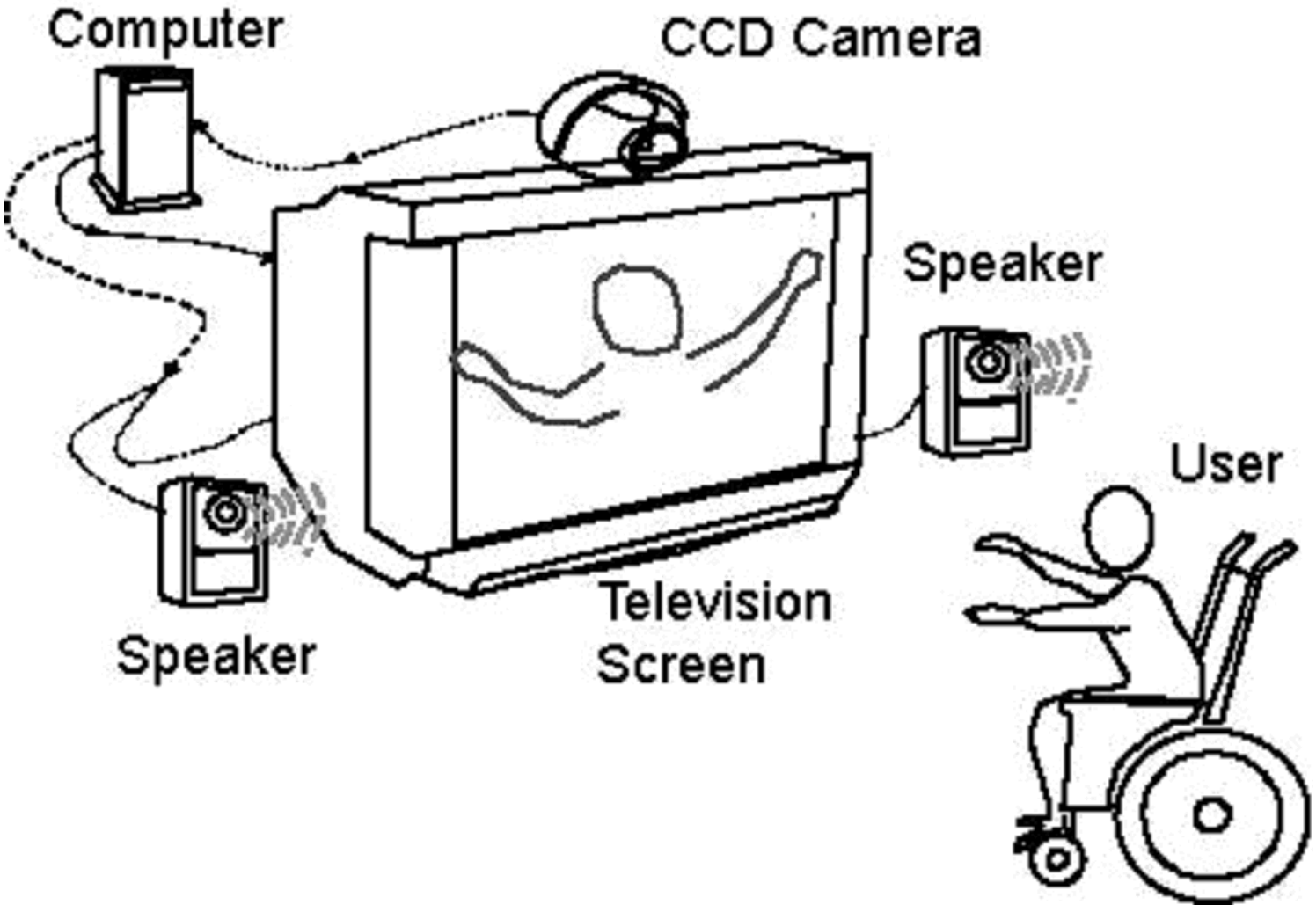
Virtual objects

Information (cues)

Enhanced properties

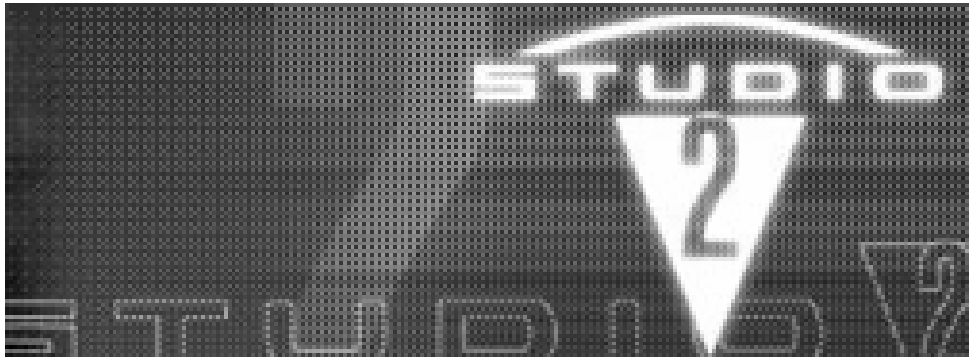
Augmented environments

Virtual music instrument



Augmented environments

Virtual music instrument



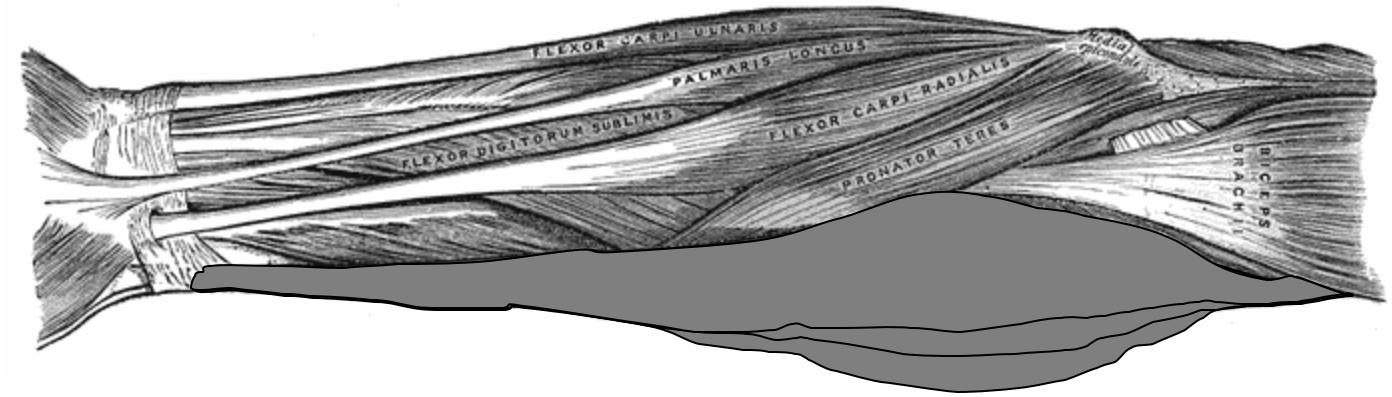
Augmented environments

Virtual music instrument

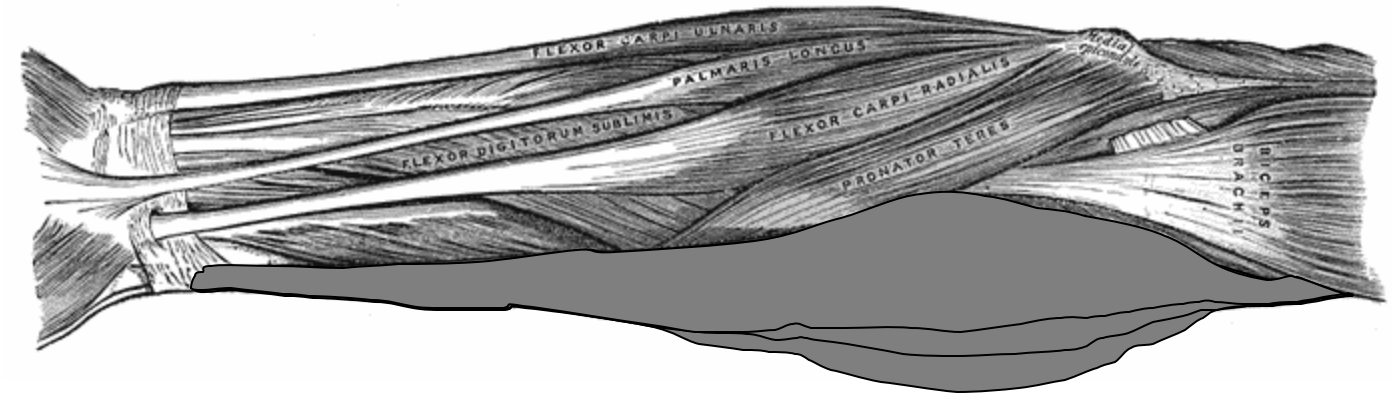
Examples from paediatric rehabilitation

- Non-contact communication aid
- Aspirometer
- Augmented environments
- Mechanomyography
- Fractal gait

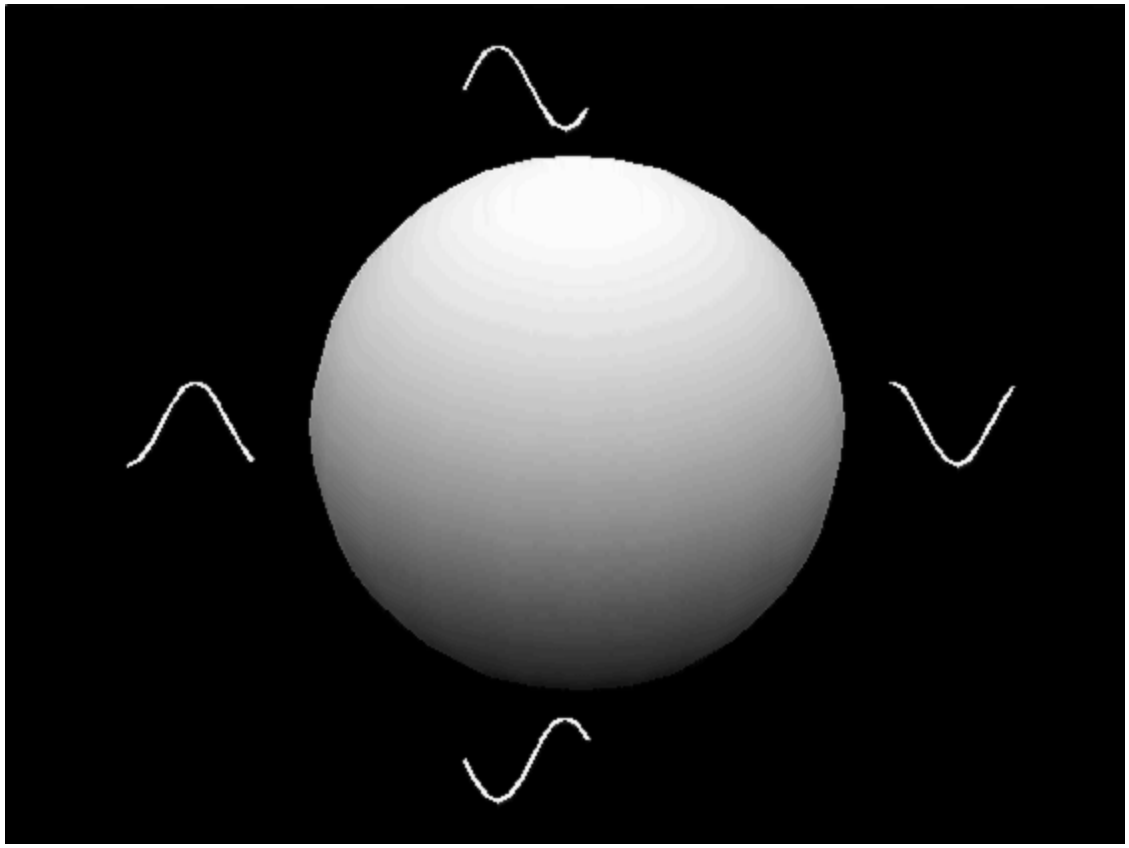
Mechanomyography



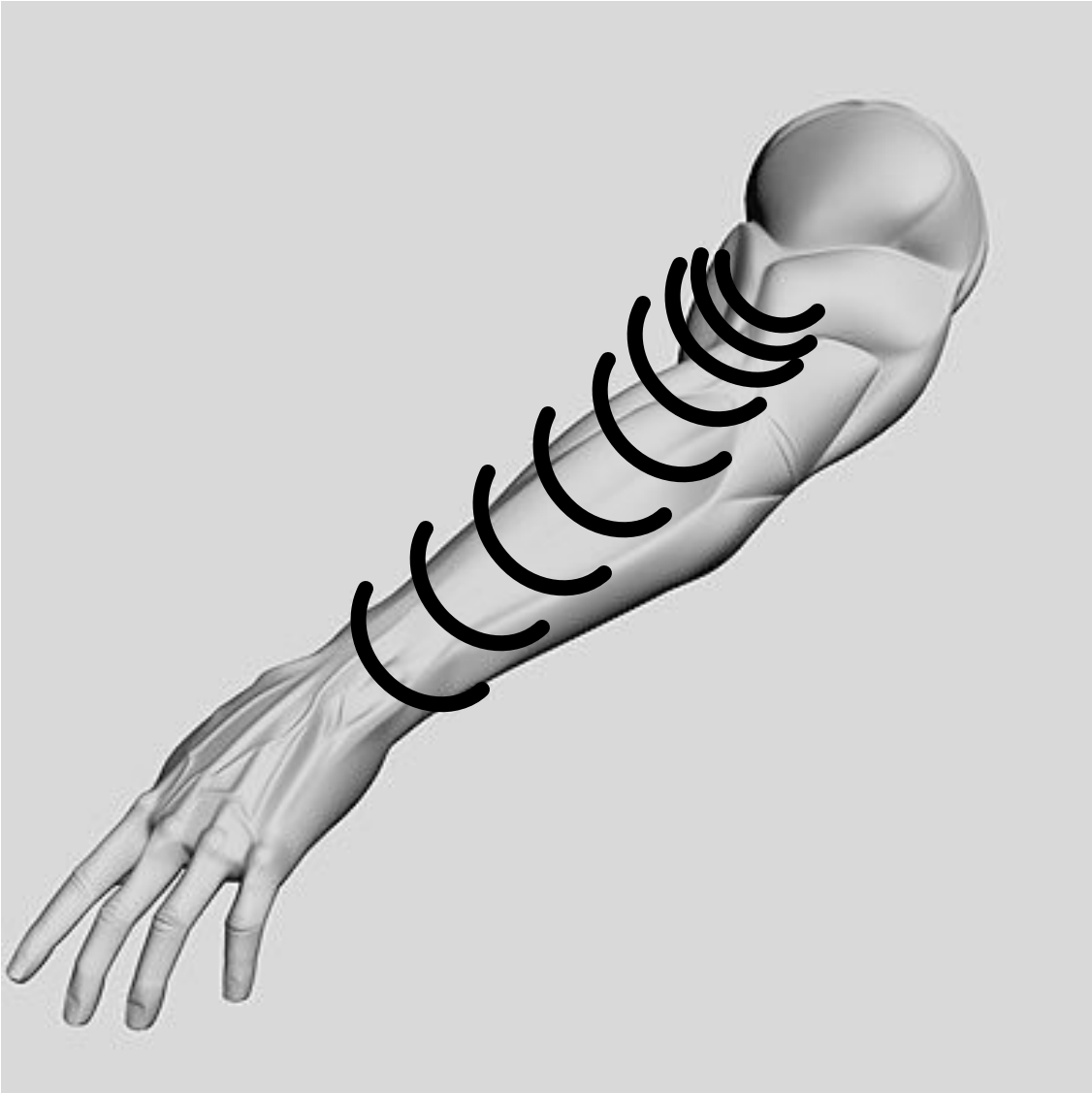
Mechanomyography



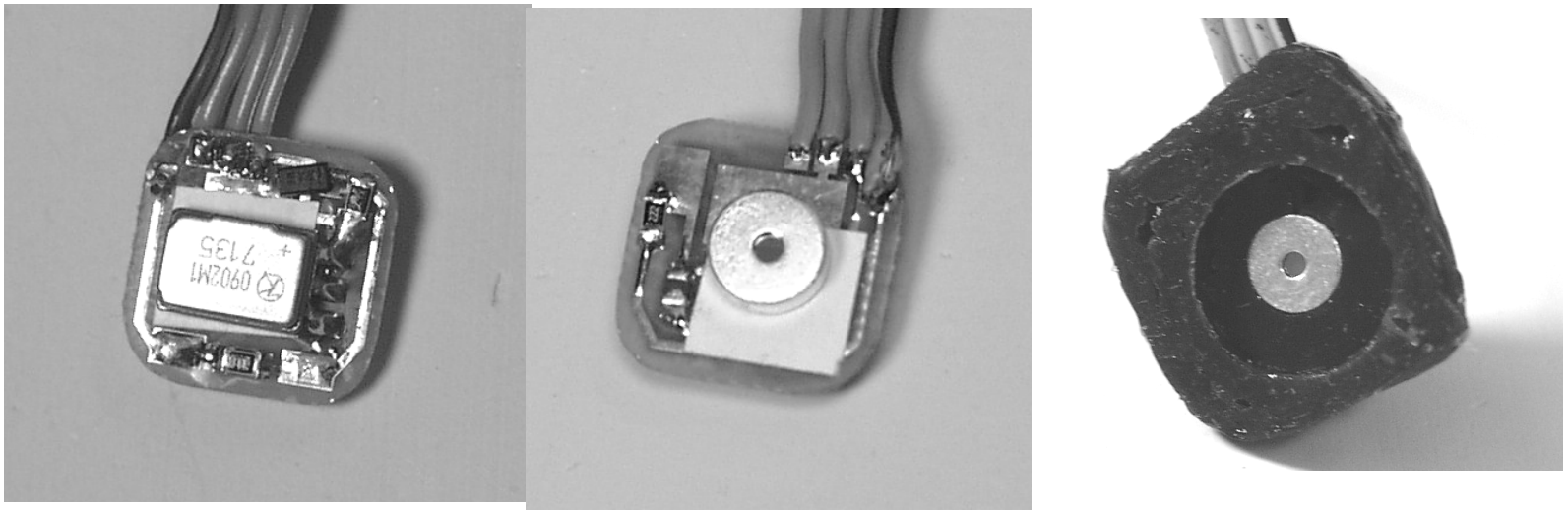
Mechanomyography

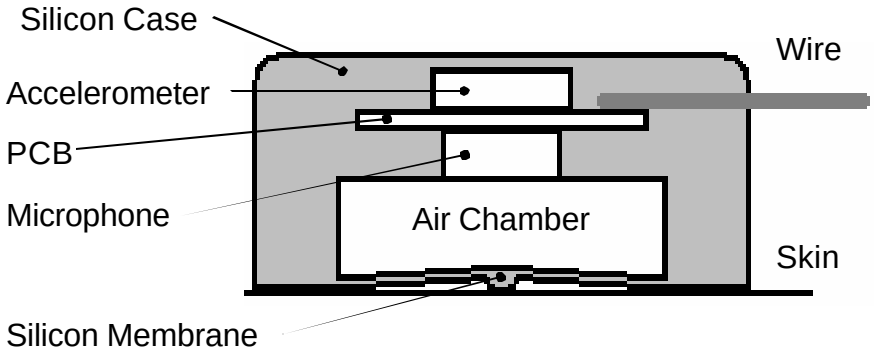


Mechanomyography



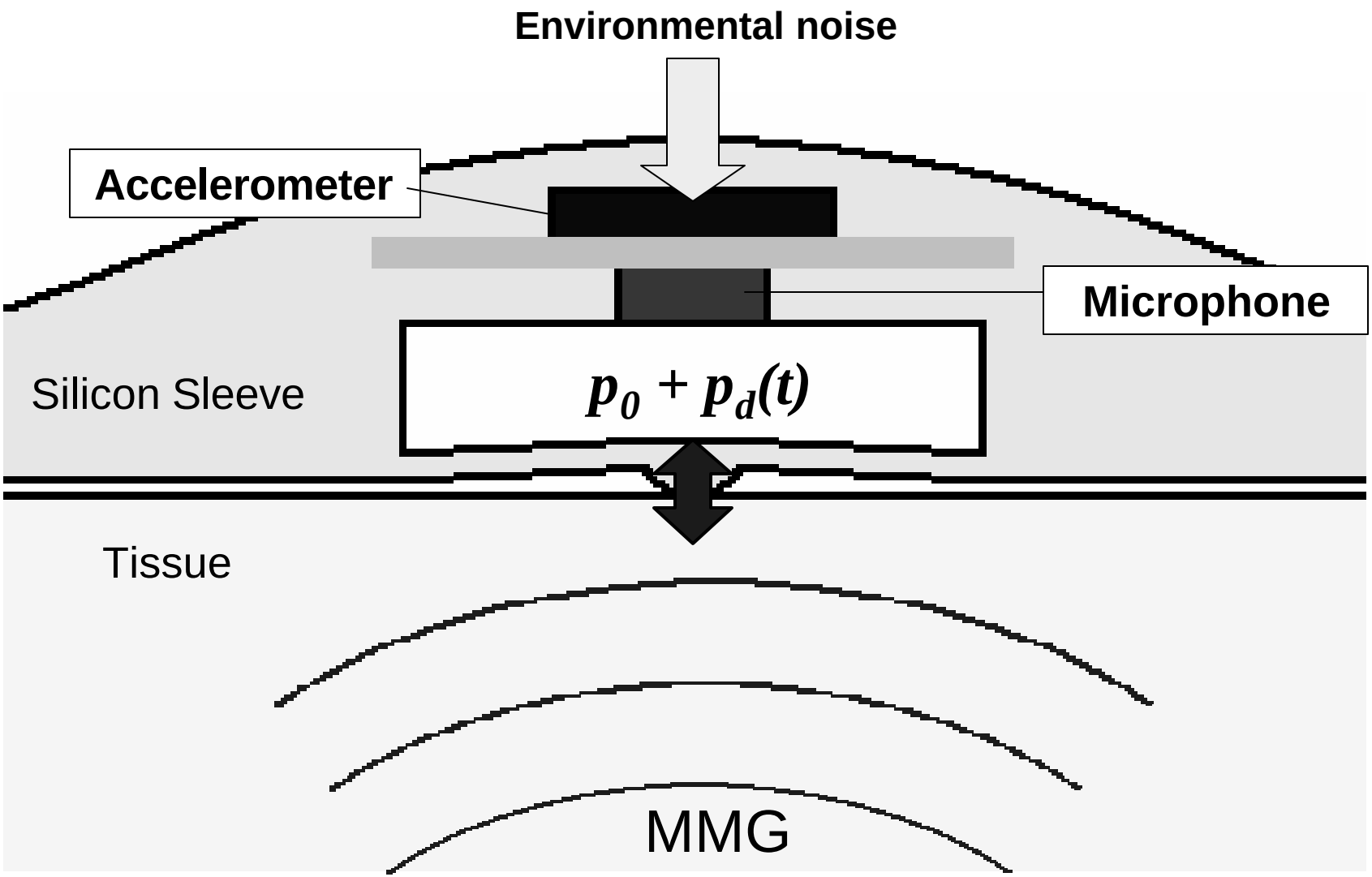
Mechanomyography





Silva J. & Chau T. (2003). “Coupled microphone-accelerometer sensor pair for dynamic noise reduction in mechanomyography signal recording”, Electronics Letters, 39(21) 1496-1498.

Mechanomyography



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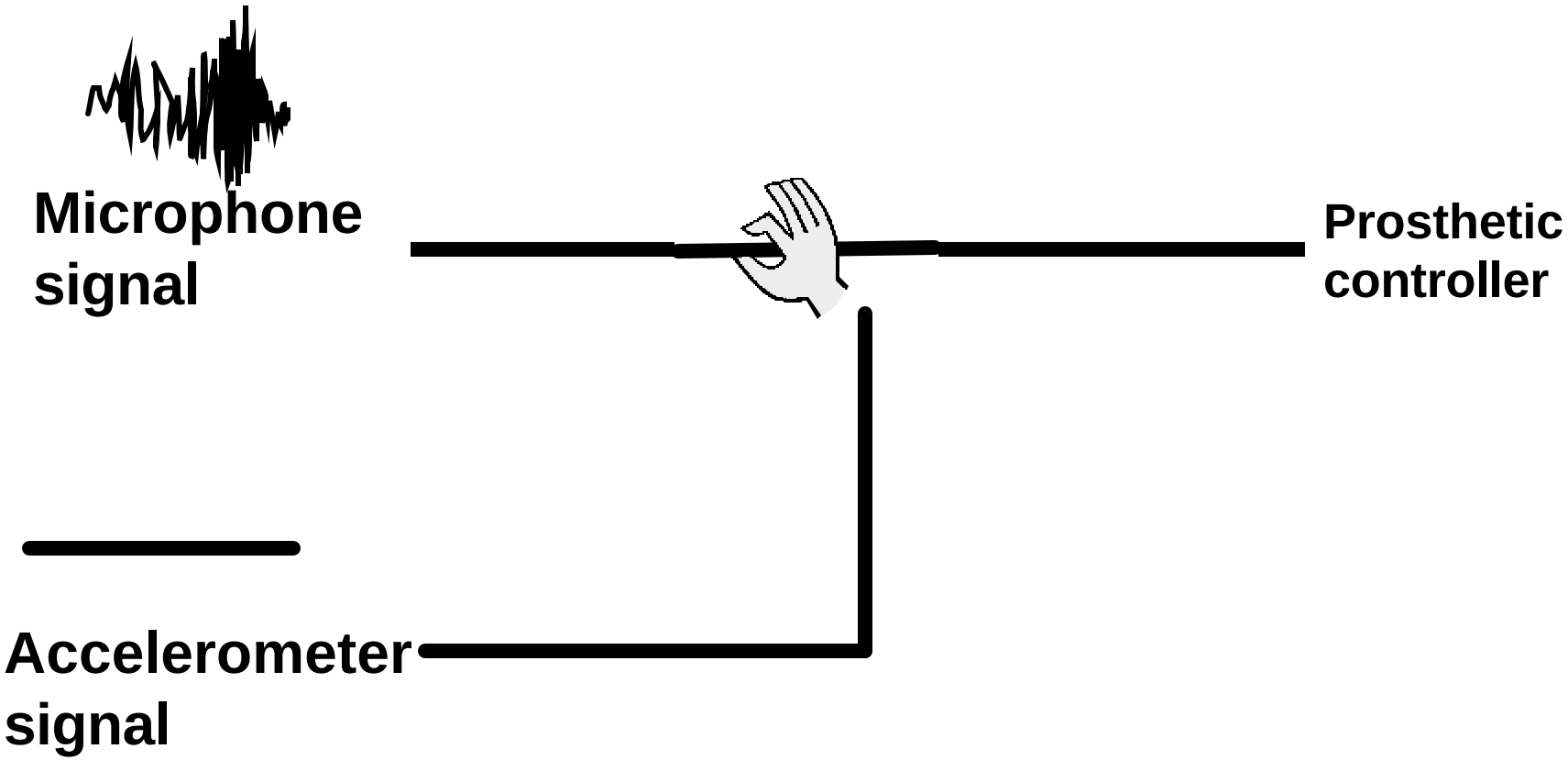

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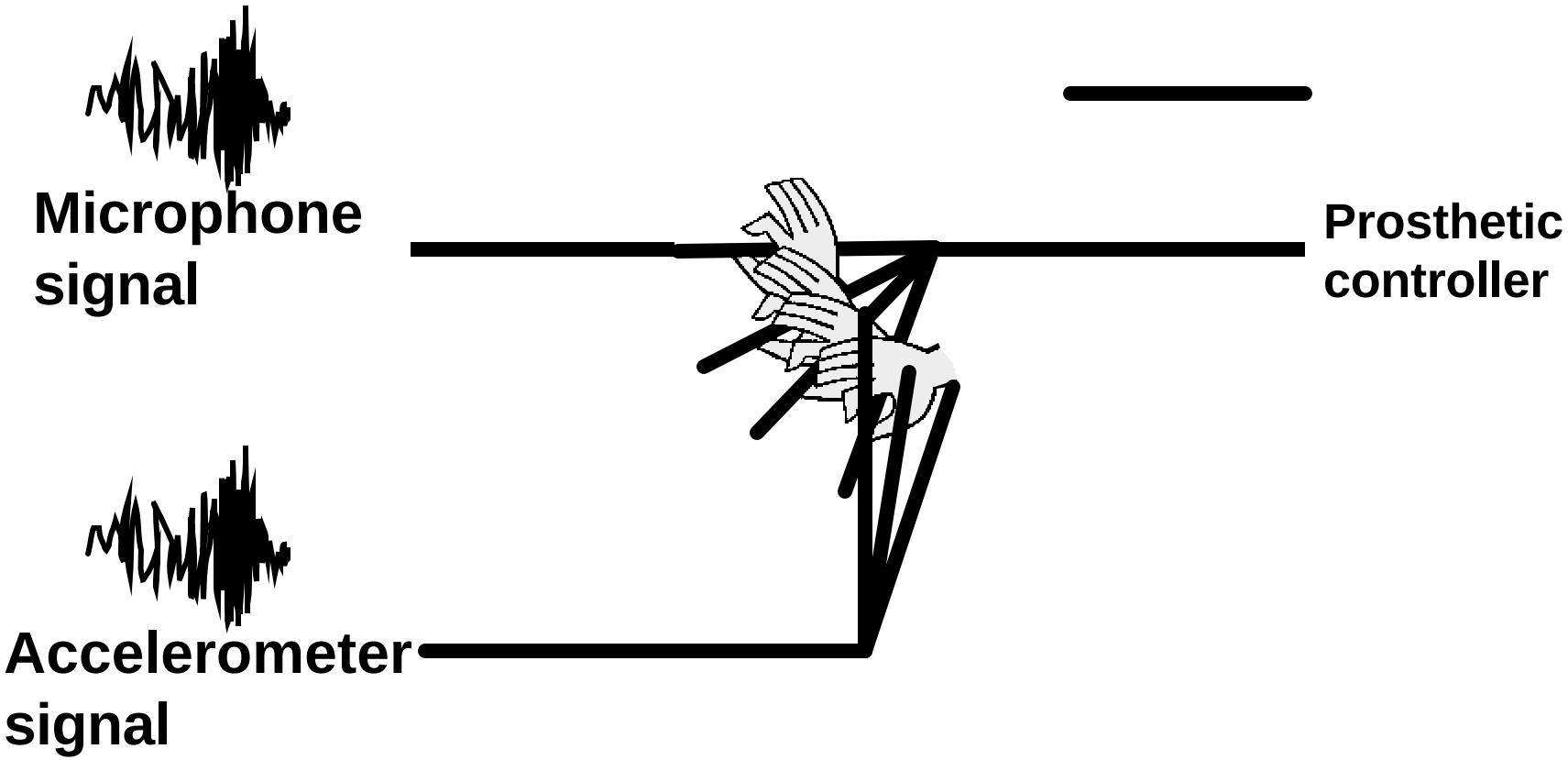

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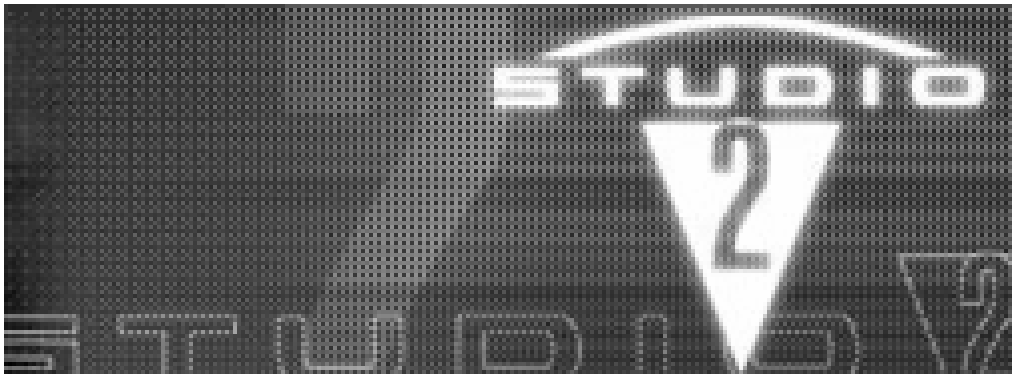
Mechanomyography



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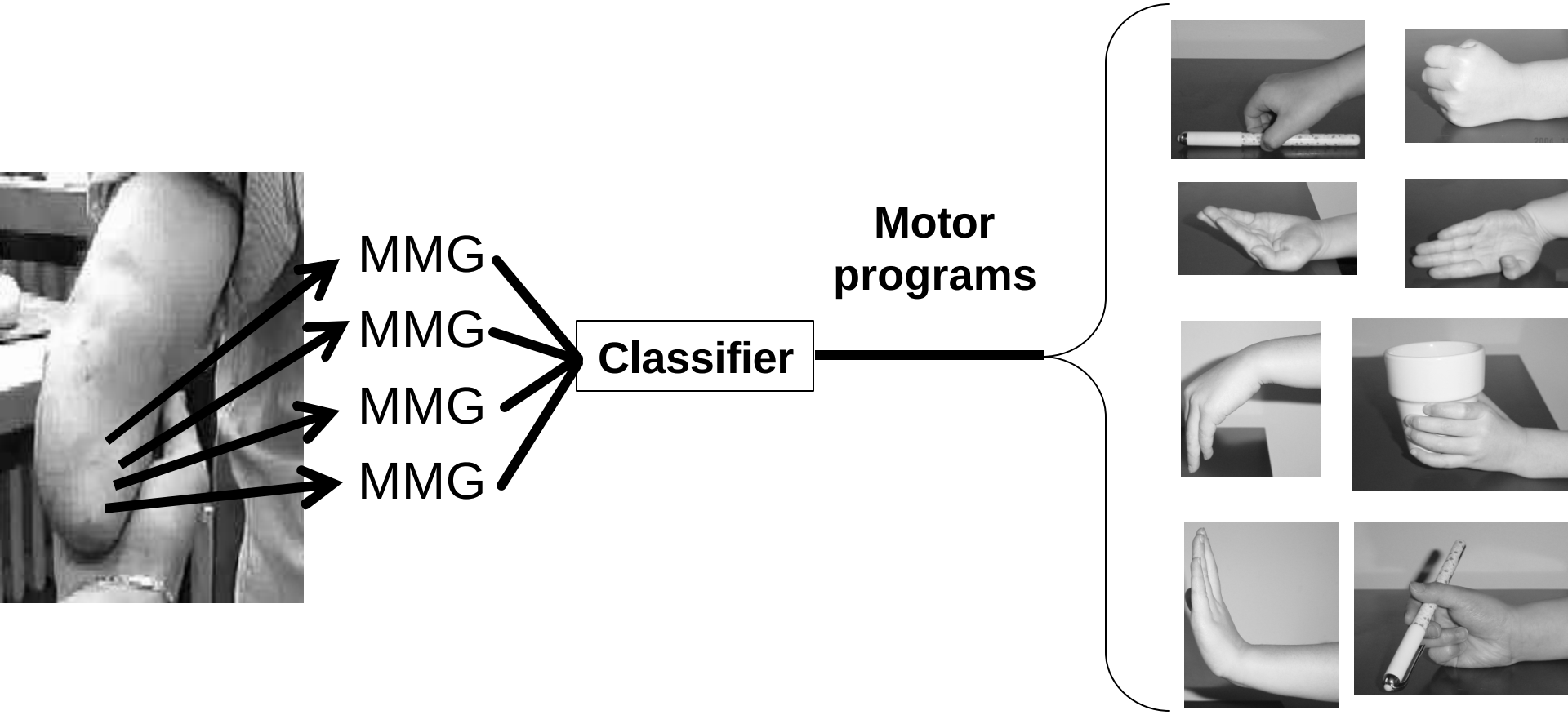
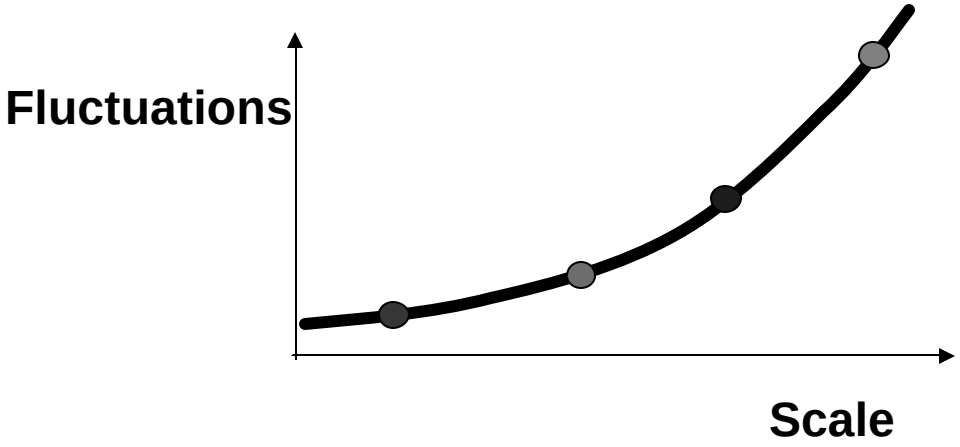
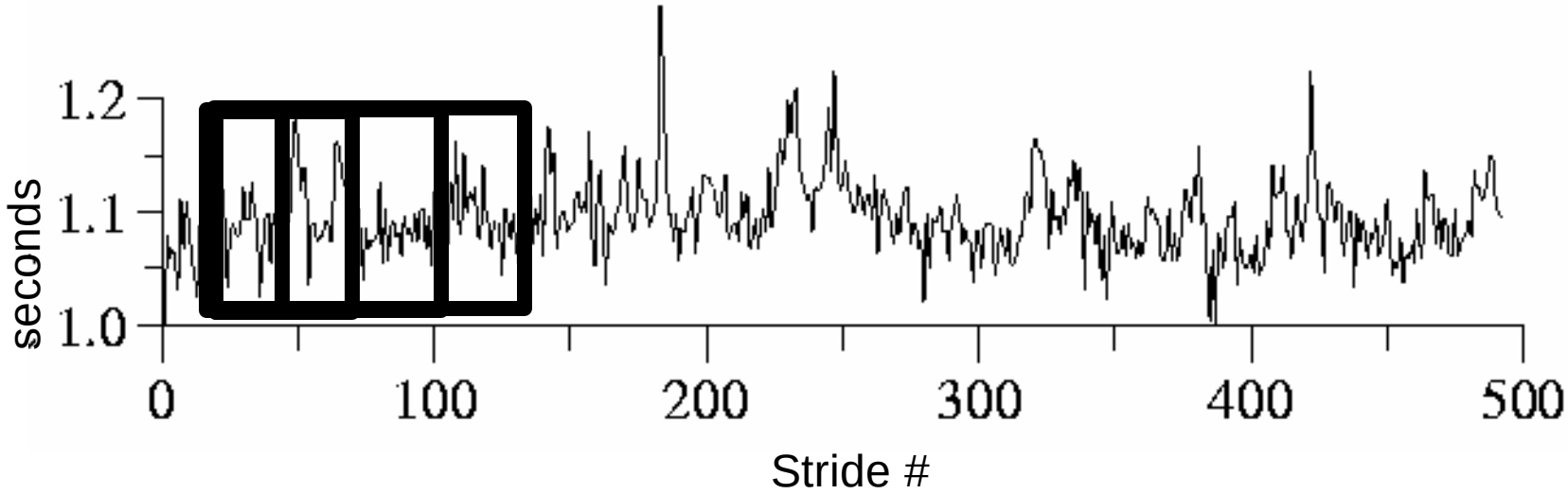


Examples from paediatric rehabilitation

- Non-contact communication aid
- Aspirometer
- Augmented environments
- Mechanomyography
- Fractal gait

Temporal fractals





Measurement

- Any time-varying, quasi-periodic gait variable

Measurement

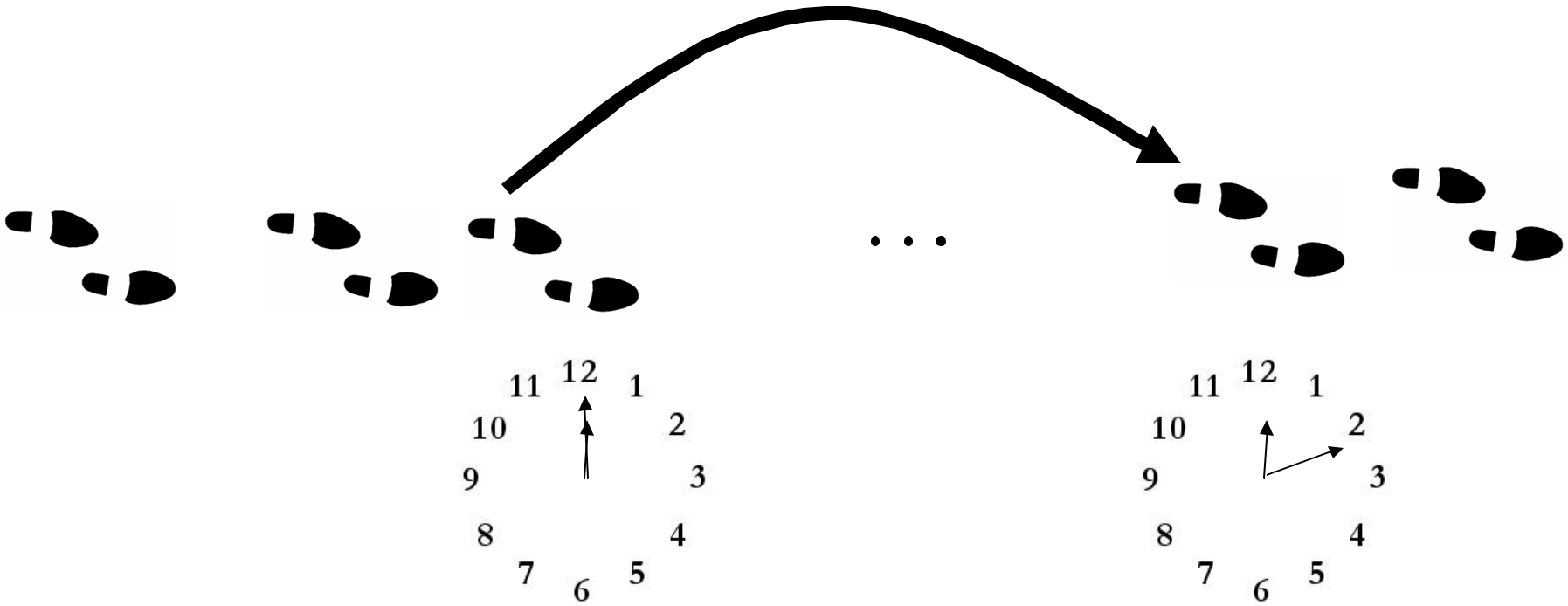
Period of measurement: = 10 minutes

Number of strides: = 500

Context: outside of laboratory

Healthy gait

- Scaling exponent – close to 1.0
  - What does this mean?



Healthy gait

- **Robust dynamics**
  - Speed
  - 1000+ strides
  - 1 hour of walking

- **Obliterate dynamics**
  - Scramble time series
  - Walk to metronome
  - Walk on a treadmill

Physiological hypotheses

1. Efficiency - energy expenditure
2. Stability/balance
3. Adaptability – response to perturbations
4. Hierarchical synthesis of multiscale input -> multiscale control output

Physiological hypotheses

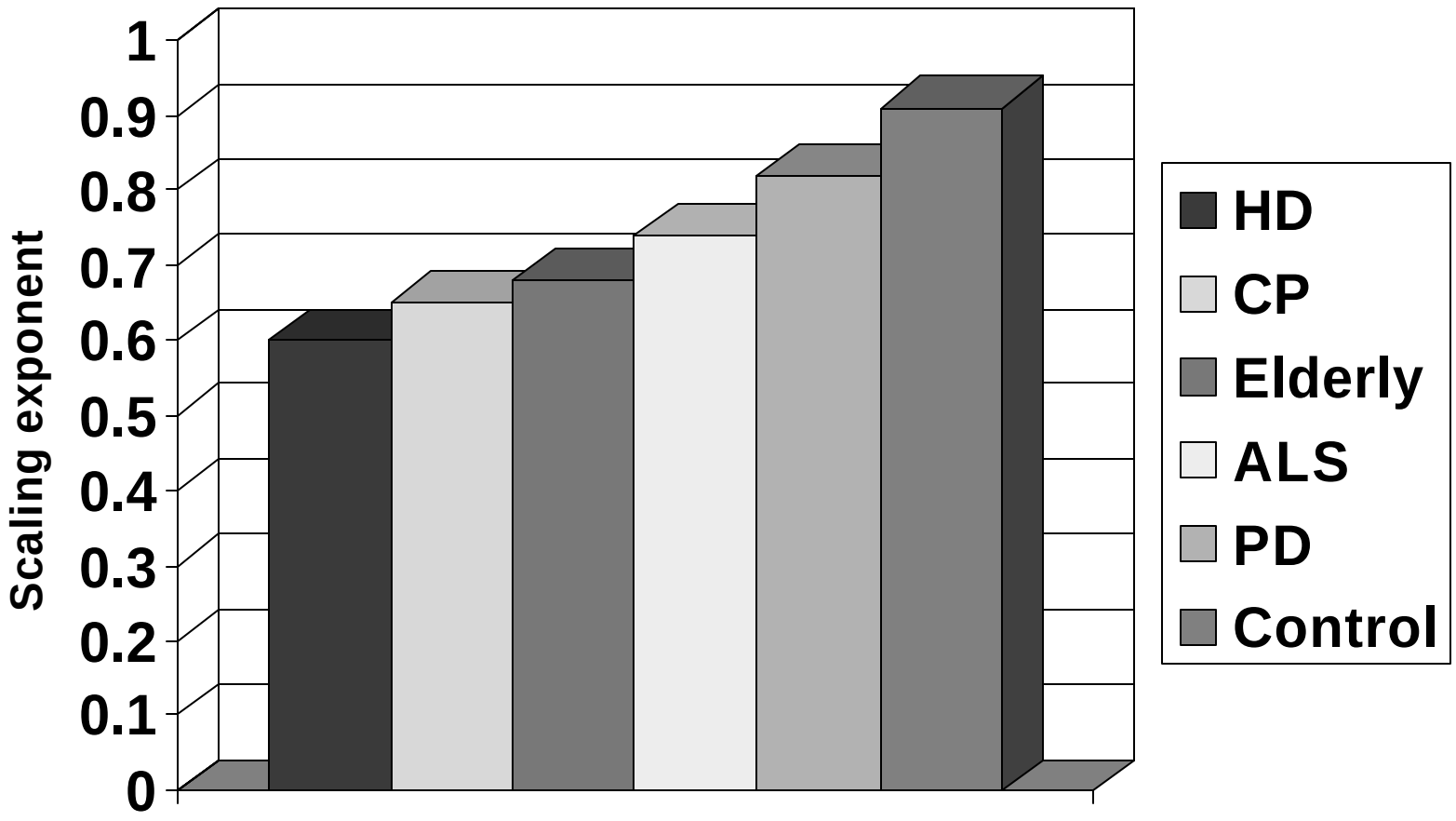
Proprioceptive

Visual

Auditory

Vestibular

Pathological gait



Pathological gait

- Diminished dynamics – implications
  - Less stable
  - Less energy efficient
  - Prone to falls
  - Less adaptable
  - More periodic

Chau T. & Parker K. (2004). “On the robustness of stride frequency estimation”. IEEE Transactions on Biomedical Engineering, 51(2), 294-303.

Chau T. & Rizvi S. (2002). “Automatic stride interval extraction from long, highly variable and noisy gait timing signals”. Human Movement Science, 21(4), 495-514.

Chau, T. (2001). “A Review of Analytical Techniques for Gait Data. Part 1: Fuzzy, Statistical and Fractal Methods”. Gait & Posture, 13(1), 49-66.

Fractal vs. conventional thinking

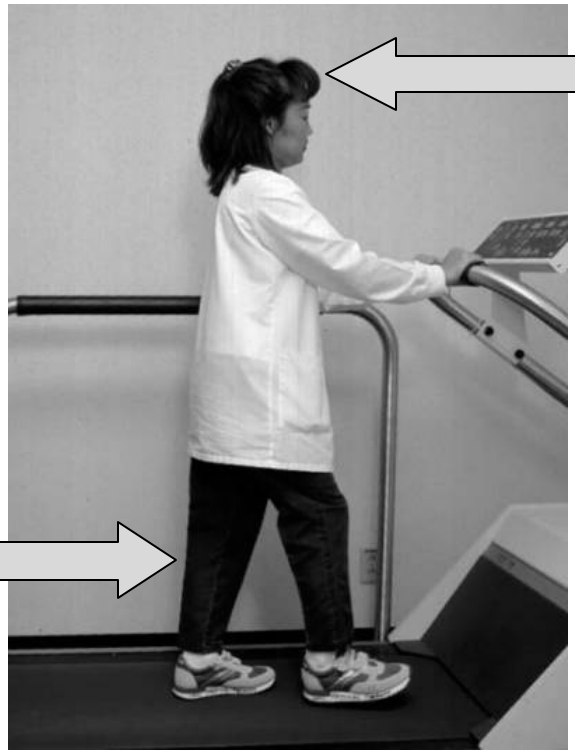
Topic	**Fractal**	**Conventional**
Information	Fluctuations	Absolute values
Fluctuations	“ordered”	Random
Periodicity	Bad!	Good
Data	100’s strides	<10 strides
Analysis	Temporal dynamics	Summary statistics
Perspective	System	Localized

Interventions

- **Implications**
  - Repetitive, periodic training (e.g. treadmill) – not good!
  - Walking while listening to computer generated music – bad?
  - Need to consider CONTEXT of walking
  - Intervention: Entrain healthy dynamics?

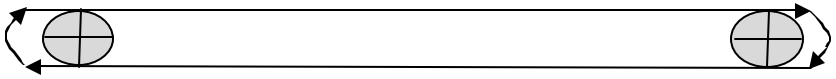
Interventions

- Fractal gait training



Entrained dynamics?

Fractal timing



Fractal velocity pattern

Interventions

- Walking in context

Sensory stimuli

Collective vs. individual walking

Other cognitive processes (e.g. talking)

Other PRISM Lab Projects

- Evidence-based approach to written productivity
- Electroactive polymers
- In-place health care & remote activity monitoring
- Self-selected expressions of functional intent

What we have talked about

- Magnitude of disability
- Biopsychosocial model of disability
- Implications for rehab engineering
- Examples from Bloorview MacMillan

The Future

- “Developmental” technology – dynamic
- Context-aware, context-dependent solutions (in-place health monitoring)
- Novel actuation/sensing materials

The Future

- Fractal rehabilitation – outcomes and interventions
- Intersection of micro- and macroscopic biomedical engineering
- Evidence-based medicine & policy

Body Functions and Structures

Mental functions	Structures of the nervous system
Sensory functions and pain	The eye, ear and related structures
Voice and speech functions	Structures involved in voice and speech
Functions of the cardiovascular, haematological, immunological and respiratory systems	Structures of the cardiovascular, immunological and respiratory systems
Functions of the digestive, metabolic and endocrine systems	Structures related to the digestive, metabolic and endocrine systems
Genitourinary and reproductive functions	Structures related to the genitourinary and reproductive systems
Neuromusculoskeletal and movement-related functions	Structures related to movement
Functions of the skin and related structures	Skin and related structures

Activities and Participation

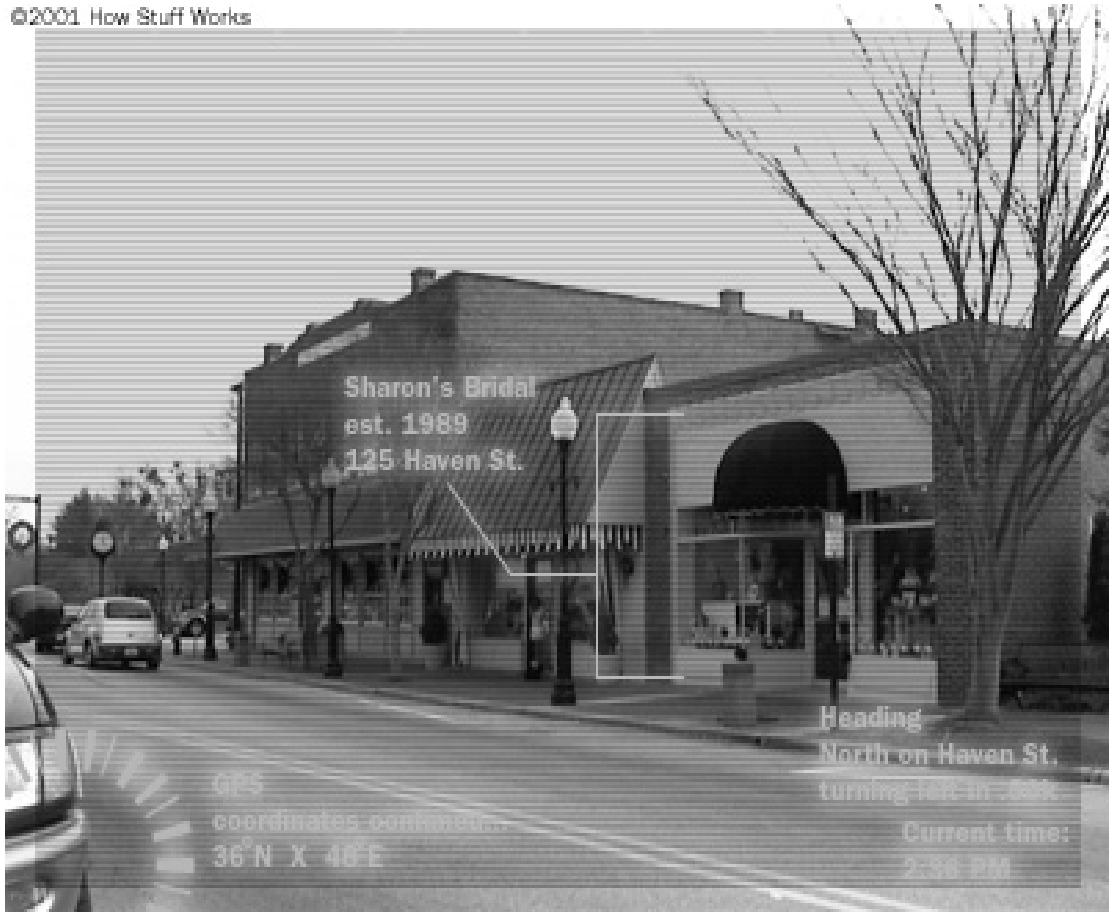
1 **Learning &Applying Knowledge**
2 **General Tasks and Demands**
3 **Communication**
4 **Movement**
5 **Self Care**
6 **Domestic Life Areas**
7 **Interpersonal Interactions**
8 **Major Life Areas**
9 **Community, Social & Civic Life**

Environmental Factors

1. Products and technology
2. Natural environment and human-made changes to the environment
3. Support and relationships
4. Attitudes
5. Services, systems and policies

Augmented environments

Community mobility rehabilitation



Augmented environments

Community mobility rehabilitation