



Visual Analytics: the View From Vancouver

“A Grand Challenge in Science:

*Turning Information Overload into the
Opportunity of the Decade”*

Visual Analytics Concept

“ The science of analytical reasoning supported by interactive visual interfaces ”

“How can we develop, through technology and science, the tools to analyze masses of data in different formats and types, from different sources, with highly varying degrees of confidence levels, within the time frames needed for decision making”

Jim Thomas, NVAC head





VA Research Fields

- Mathematics & statistics
 - Models are accurate and appropriate
- Computer science & engineering
 - Program runs, implements functionality
- **Cognitive & perceptual sciences**
 - Situation supports human analysis, decision-making and execution

Comprehensive VA R&D Capability

**Cognitive
Science**

**Information
Systems**



**Visual
Analytics**

**Graphic &
Interaction
Design**

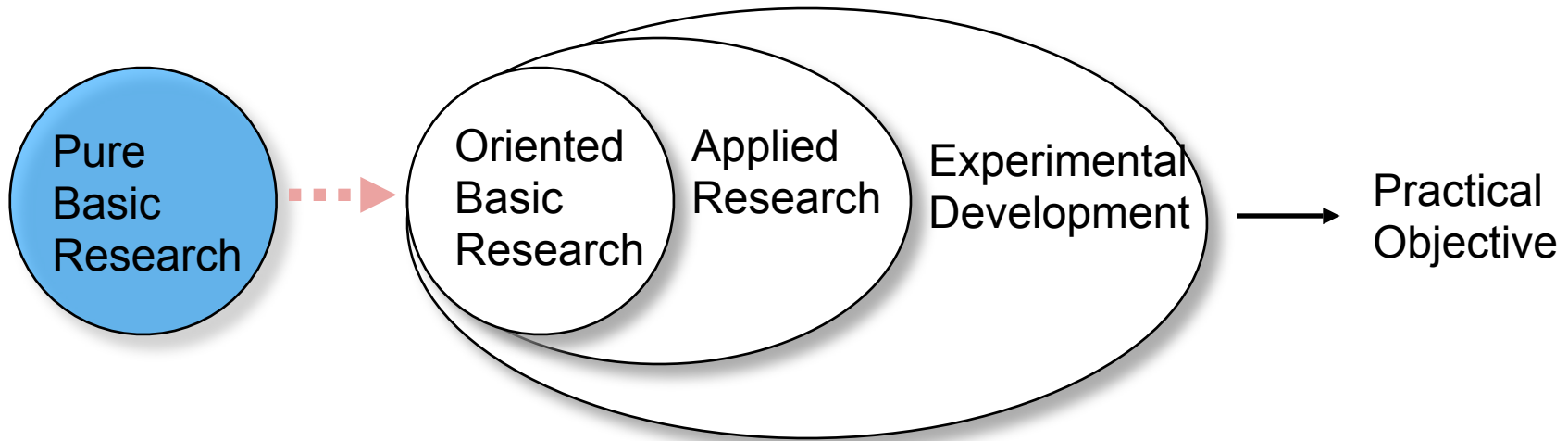
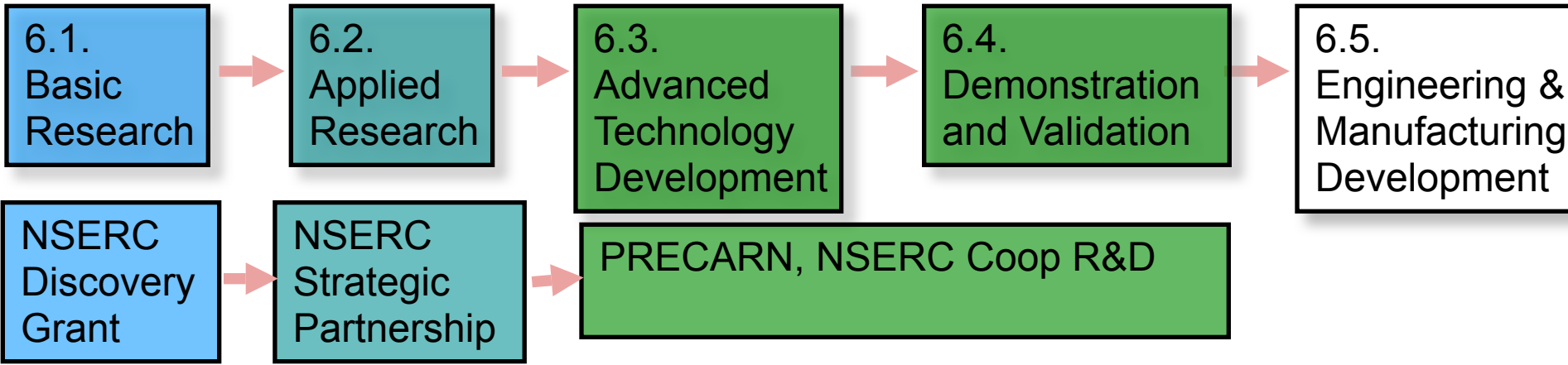
**Mathematical &
Statistical Methods**

Science in Visual Analytics

“This science must be built on integrated perceptual and cognitive theories that embrace the dynamic interaction between cognition, perception, and action. It must provide insight on fundamental cognitive concepts such as attention and memory. It must build basic knowledge about the psychological foundations of concepts such as ‘meaning,’ ‘flow,’ ‘confidence,’ and ‘abstraction.’ “

“Illuminating the Path” (IEEE Press)

Linear Model of Research



Applied research always drives out basic research: Vannevar Bush

Pasteur's Quadrant (Stokes)



Quest for Fundamental Understanding?	Yes	Pure basic research (Bohr)	Use-inspired basic research (Pasteur)
	No		Pure applied research (Edison)
		No	Yes
		Considerations of Use?	

"Il n'existe pas une catégorie de sciences auxquelles on puisse donner le nom de sciences appliquées. Il y a la science et les applications de la science, liées entre elles comme le fruit à l'arbre qui l'a porté"

Pasteur's science

BASIC SCIENCE

- crystal studies
 - life left-handed

- micro-organisms cause fermentation

- germ theory of disease

USE

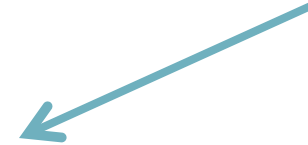
alcohol fermentation problems

- micro-organisms cause beer, wine, silkworm problems

- pasteurization

- hospital hygiene

- childbed fever, operations



Science of visual analytics

Use-inspired...

- Questions from users & infosystem designers
- Study fluent interaction w. visually rich interfaces for timely & accurate cognition & communication by particular set of users

... basic research

- Uses scientific method: experiments & field studies
- Goal is **knowledge**: to make predictions about what will occur in a given set of situations
- Method is **falsification**: disprove a hypothesis, reject an approach

New questions from industry

- Diversity of users (D.Kasik, Boeing)

“We want to derive more value for 3D model data outside engineering... Examples: 3D for assembly instructions, animation for maintenance procedures, bids from suppliers.”

- Individual differences (R.Smith, GM)

“For a smaller number of individuals.. some features are seen to be inappropriately large or small, they may appear at the wrong distance, the three-dimensional space inside the vehicle may appear distorted...”

- Problems with perceptual abilities of more diverse user population

Research focus: The Back Half



- Transistor density doubles every 24 months
- Disk density doubles every 12 months
- Brain volume doubles every 3×10^7 months

“Visual Analytics provides the last 12 inches between the masses of information and the human mind to make decisions”

Interaction science themes

- Spatial cognition & action w. large screens
 - Wayfinding in VR (Boeing)
 - Space constancy in display environs (AFOSR)
 - Multimodal interaction (AFOSR)
 - Gesture & voice control (NSERC)
- Item tracking in projected 3D displays (HRL)
- Depth judgments w. stereo displays (GMR)
 - Psychophysical methods (Fechner)

Focus on visual & spatial cognition in complex displays, how “changes in the rules” affect human performance

Research approach

- Decompose task based on cognitive architecture
- Identify interaction challenges to cognitive processing modules
- Devise “toy world” test of that module’s robustness to challenge
 - Use-inspired basic research
 - Research interaction, not the mind
- Model data for quantitative prediction

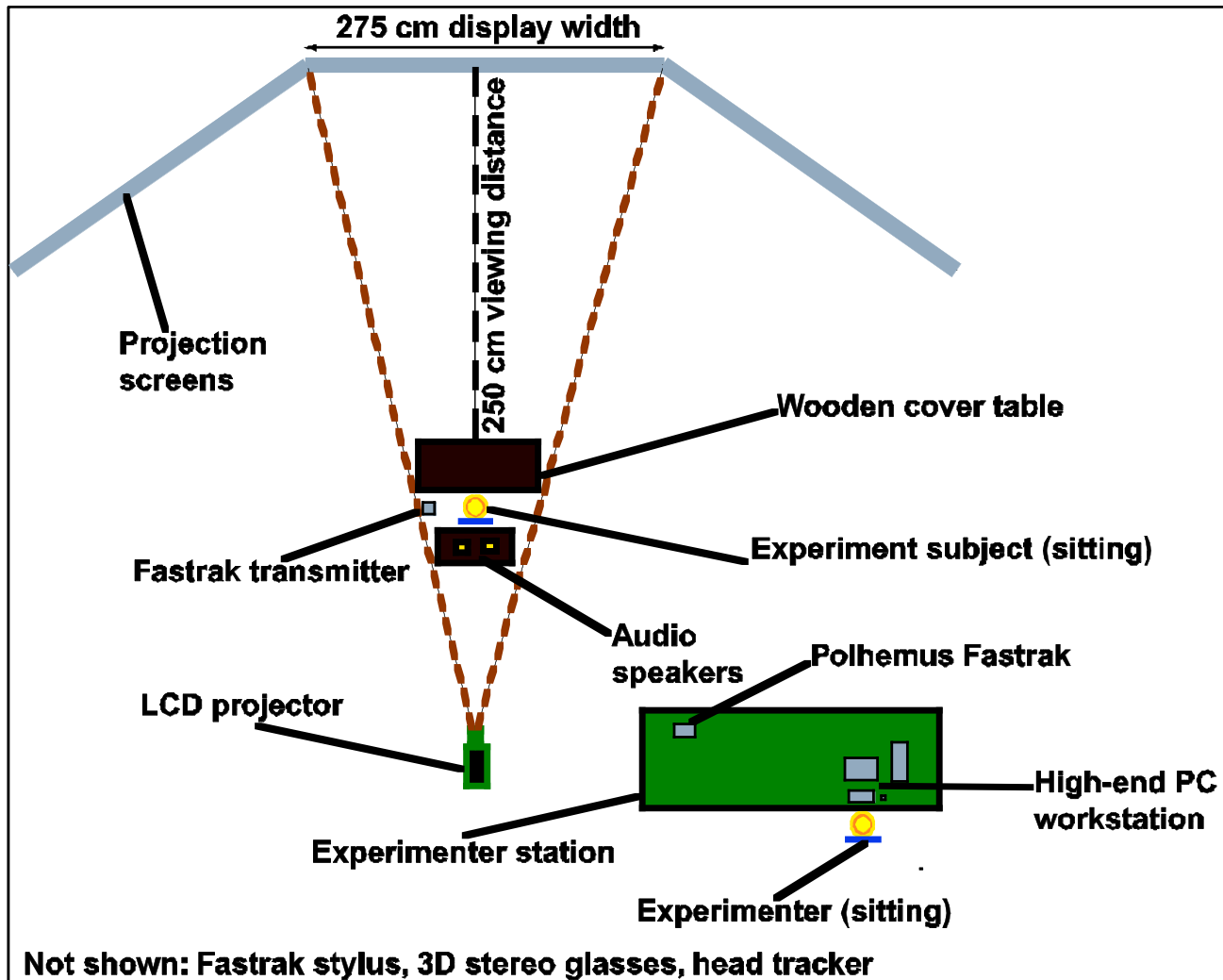
Some 2 visual system illusions

stimuli	deficits	spared abilities
Tichner circles	Size report	Grip scaling
Target displacement during saccade	Detection of displacement, location report	Pointing
Moving or off-centre frame	Induced motion, location report	Pointing
Sound with displaced visual distractor	Pointing	Apparent location of sound

Applying 2 visual systems to VR

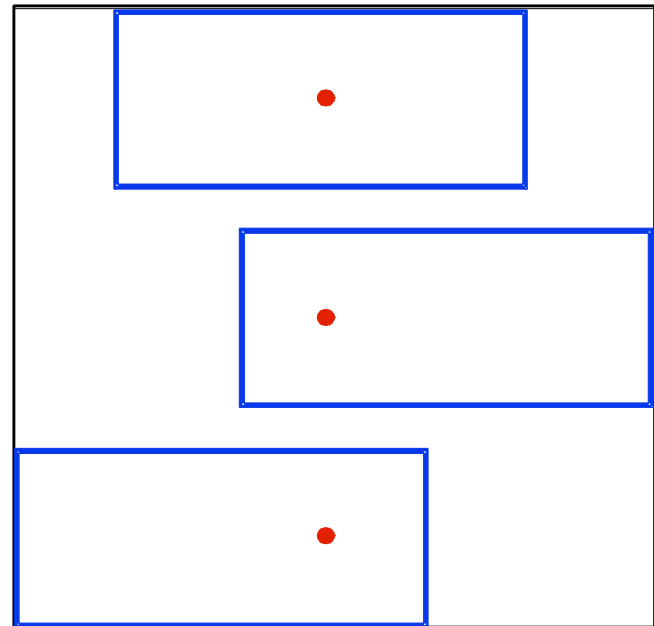
- Graphical content vs. world
 - Object and scene onsets (cuts) common
 - Point of view pans, zooms etc.
 - Conflict between multimodal cues common
 - Conflict between acceleration and vision
 - Conflict between synthetic cues (e.g. depth)
- Does immersion magnify these effects?
- Do they differ between the 2 visual systems?

Apparatus



2VS & interaction in the large

- Task: Localize target with voice (far left, near left centre etc.) or pointing
- Induced Roeloffs Effect: displaced frame should cause ventral system errors (ASC), but not dorsal (FSC)



Experimental protocol

- Display appears, then disappears
- Verbal report & pointing tasks
 - 1 block of verbal report
 - 1 block pointing with no visual feedback
 - 1 block pointing with visible pointer
 - 1 block pointing with 1/2 second lagged pointer
- Within subject psychophysical analysis
- Meta-analysis of proportion of subjects exhibiting effects

Findings

1. Can you tell if a target is on the left or right?
 - 3 out of 7 males, 7 out of 7 females made errors
2. Can you point to it without seeing your hand?
 - 6 out of 10 who failed #1 were correct
3. Are you better with a (simulated) laser pointer?
 - Out of 6 who point accurately in 2, all fail
4. Will pointing accuracy be affected if visible pointer lags pointing?
 - 3 of the 6 who failed #3 succeed

Subject data for pointing study

- *Independent factor: Frame position (3 levels)*
- *Dependent factor: Subject response (continuous, x-coordinate)*
 - One for each subject, one for each response condition (classic analysis)

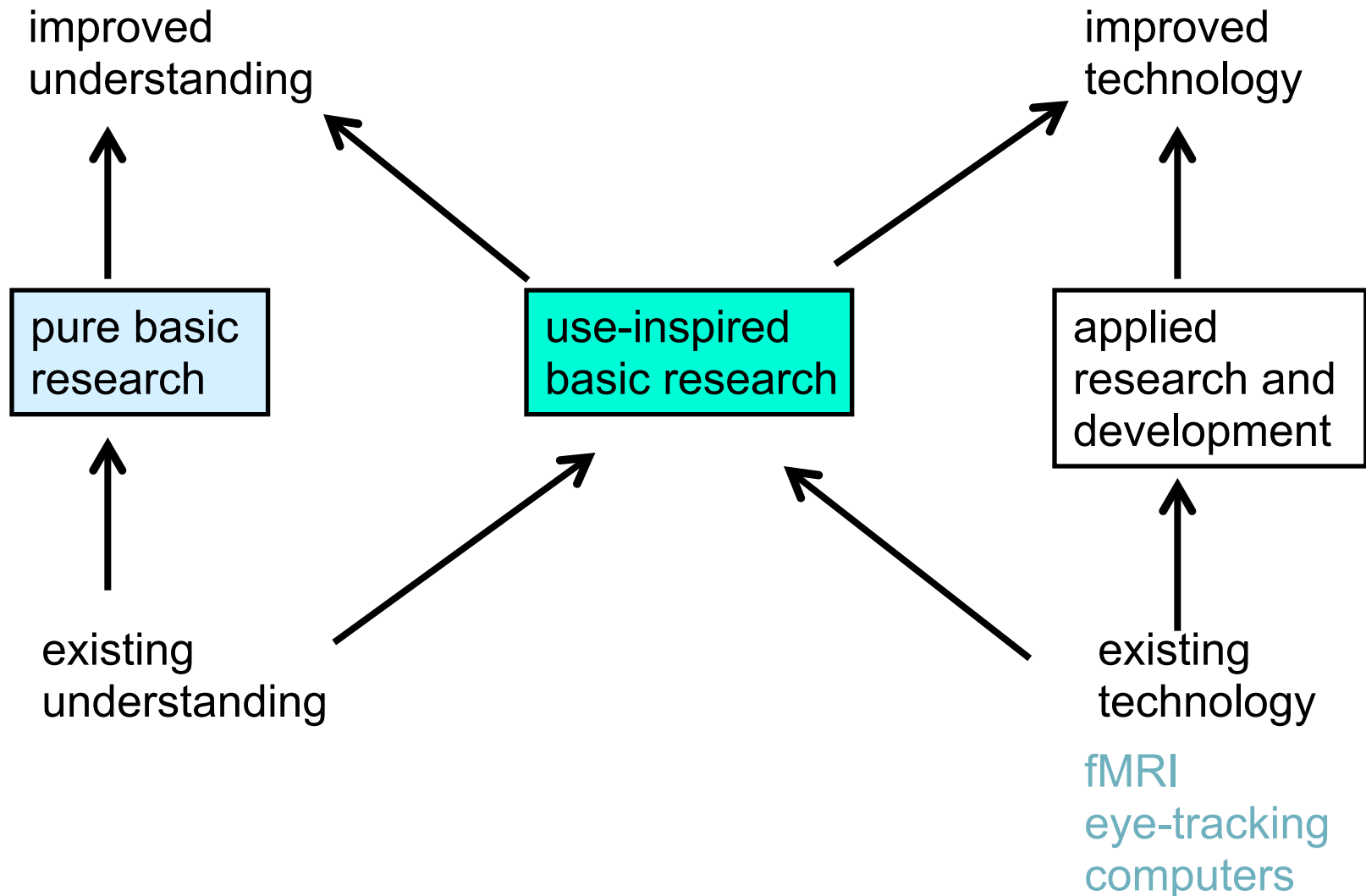
Subject Number	Cognitive Report (Vocal Interaction)	Open Loop Pointing (No Feedback)	Closed Loop Pointing (Lag-Free Feedback)	Closed Loop Pointing (Lagged Feedback)
1	YES (p < 0.001)	NO (p = 0.707)	YES (p < 0.001)	NO (p = 0.951)
2	YES (p < 0.001)	NO (p = 0.985)	NO (p = 0.484)	NO (p = 0.843)
3	YES (p < 0.001)	NO (p = 0.975)	YES (p < 0.001)	NO (p = 0.952)
4	YES (p < 0.001)	NO (p = 0.950)	NO (p = 0.955)	NO (p = 0.697)
5	NO (p = 0.765)	NO (p = 0.968)	NO (p = 0.636)	NO (p = 0.988)
6	YES (p < 0.001)	NO (p = 0.572)	YES (p = 0.034)	NO (p = 0.752)
7	NO (p = 0.537)	NO (p = 0.800)	NO (p = 0.093)	NO (p = 0.939)
8	YES (p < 0.001)	NO (p = 0.963)	NO (p = 0.789)	NO (p = 0.846)
9	YES (p < 0.001)	NO (p = 0.933)	YES (p = 0.012)	NO (p = 0.358)
10	YES (p < 0.001)	NO (p = 0.428)	YES (p = 0.027)	NO (p = 0.834)
11	NO (p = 0.285)	NO (p = 0.932)	YES (p = 0.006)	NO (p = 0.675)
12	NO (p = 0.899)	NO (p = 0.964)	NO (p = 0.856)	NO (p = 0.940)
13	YES (p = 0.049)	NO (p = 0.954)	NO (p = 0.451)	NO (p = 0.971)


Results

- Displaced frame leads to verbal errors (ASC)
- Most subjects who made verbal errors did not make pointing errors (FSC) w/o cursor.
- Visual feedback hurts (FSC -> ASC)
- Time lagged feedback (>FSC) helps
- Fits predictions of 2 visual systems theory:
 - Pointing (dorsal) more robust against illusion
 - Feedback shifts to ventral, increases illusion

Less information = better performance

Goal is integrated VA R&D

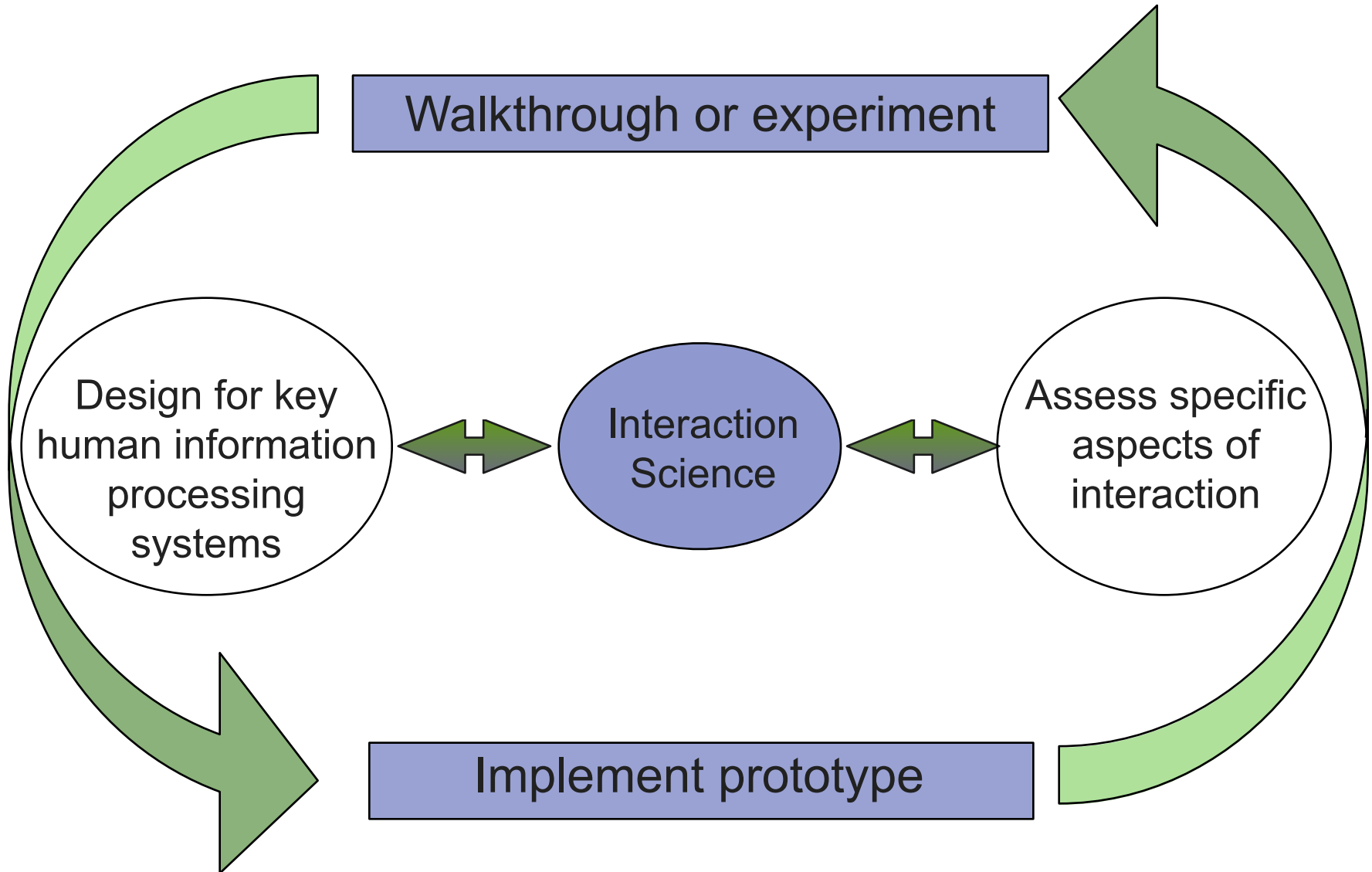




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Louis Pasteur

Science in the development process



Interaction science & design



■ Paul Ehrlich

- Knew chemistry, but not biochem
- Used science to reduce design space to 900
- Had animal model for testing
- Number 606 = Salvarsan
- Advance science and treatment

■ Today

- Medical science is distributed cognition
- Clinicians, physiologists biochem...