MAI4CAREU

Master programmes in Artificial Intelligence 4 Careers in Europe

University of Cyprus

HUMAN-CENTERED INTELLIGENT USER INTERFACES - MAI648

Marios Belk

2022

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CONTENT 4

Human Cognitive Factors in Intelligent Interactive Systems

CONTENTS

- Importance of Human Cognitive Factors
- Human Memory
- Visual Perception
- Visual Search
- Visual Attention
- Cognitive Styles and Abilities
- Learning Styles
- How to Elicit Human Cognitive Factors

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CONTENT 4

Learning Outcomes

- Understand the importance of human cognitive differences in the design of intelligent interactive systems
- Know the underlying theories of human cognition
- List the characteristics of human cognitive factor models
- Analyze an individuals' cognitive characteristics based on state-of-the-art theories and models

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Personalization based on Human Factors

- Human-computer interactions are processed on a cognitive and emotional level
  - Users respond to various stimuli through the use of logical and rational thinking in cognitive processing that has also a certain degree of emotional influence

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CONTENT 4

Personalization based on Human Factors

Human cognitive and emotional characteristics should be investigated and integrated in the user interface design process of interactive systems

- Personalize the visual and interaction design to the individuals' preferred cognitive processing characteristics and emotional states

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Challenges

- Which human factors are important for personalizing interactive systems?
  - How to elicit and model these factors?
  - What are the effects of human factors on the design characteristics?

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Challenges

- What visible aspects could be adapted for improving the usability and user experience?
  - How to adapt the content?
  - How to adapt the navigation?

- How to design, develop and integrate all the entities under an extensible interoperable system?

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CONTENT 4

Core Human Cognitive Factors

- Human Memory
- Visual Perception
- Visual Search
- Visual Attention
- Cognitive Styles and Abilities
- Learning Styles

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Human Memory

- Researchers have worked on understanding human cognitive processes, proposing various models, definitions and interpretations on the structure of an internal information processing system
- Describe the basic architecture of this system, defining as ‘information’, any stimulus that is newly processed or is already exploited by the human mind to comprehend objects, events and situations (Anderson 1990)
- Memory is the part of the brain in which information is encoded, stored, and retrieved when needed

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Multi Store Model of Memory

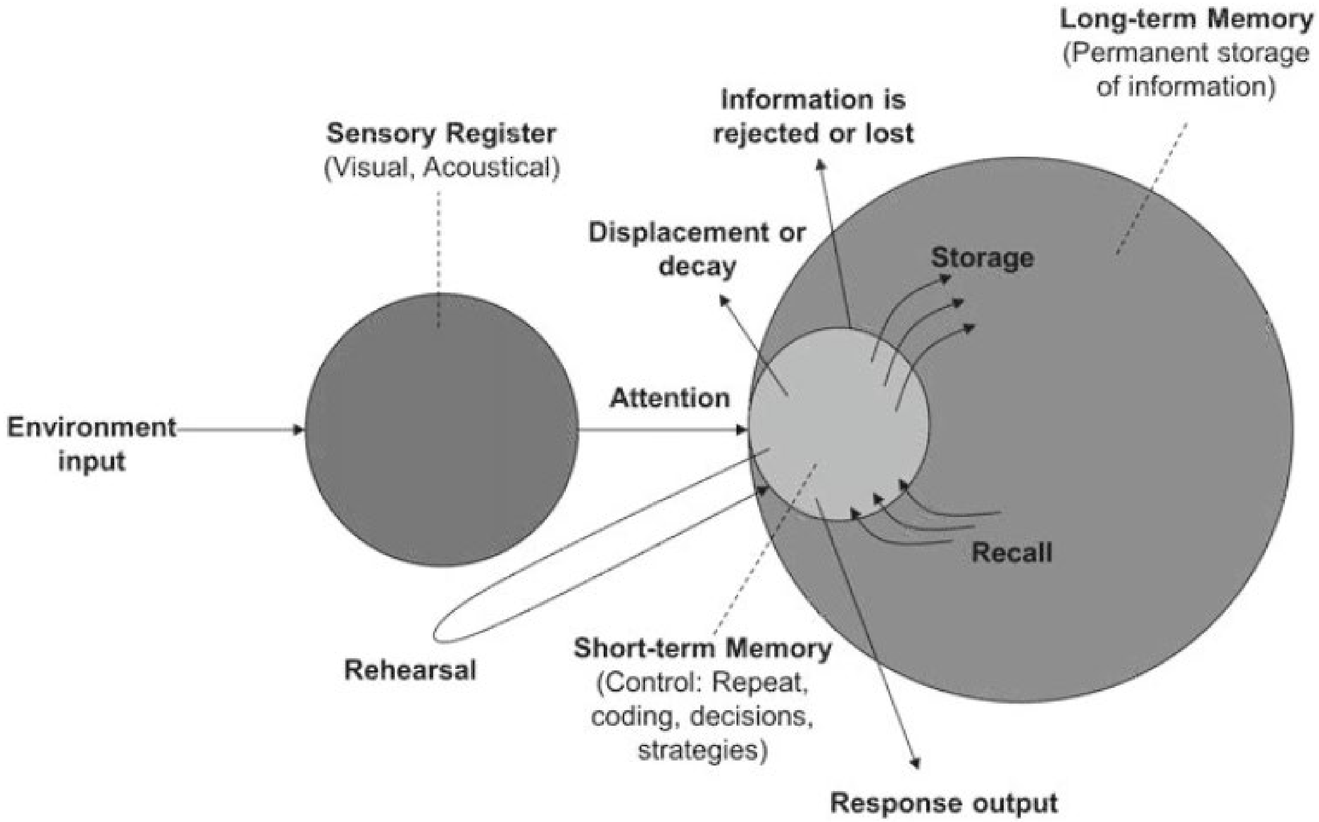

Fig. 2.1 Representation of the multi store model of memory (Atkinson and Shiffrin 1968)

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Multi Store Model of Memory

- A number of research works have criticized its simplicity since it ignored the functional dynamic aspect of information processing for the sake of a structural, linear description (Baddeley 1990)

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Multi Store Model of Memory

- Recent research models and methods suggested replacement of these weaknesses, enriching the original memory model with statements about the quality and depth of processing in which the information is submitted in each area of the cognitive system (Craik and Lockhart 1972), or highlighting explicitly the importance of a particular area, the working memory for the current information process (Baddeley and Hitch 1974; Baddeley 1986)
- Nevertheless, the three main components of the model, in the form of treatment and nature of the information they process are in general widely accepted

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Sensory Memory

- Any stimulus that is coming from the individual's surrounding environment and detected by the human senses is briefly available in sensory memory

- This temporary retention of information as they enter the brain is also called **sensory buffer**, because it concerns information detected by the senses and not yet processed further in the human brain for processing and interpretation

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Short-term Memory

- Due to the high number of sensory input from the environment, much of the information in sensory memory decays and is forgotten

- Once information is attended, it is transferred to the short-term memory

- In short-term memory the time and capacity is limited
  - According to Miller (1956), short-term memory might contain from 5 to 9 objects active at the same time (7 ± 2)

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Working Memory

- The conception of working memory grew out of the literature on short-term memory (Baddeley 1992, 2012) as an empirical model of cognitive functions used for temporarily storing and manipulating information

- Although short-term memory and working memory are used interchangeably in many occasions
  - short-term memory could be referred as the simple temporary storage of information
  - working memory as the combination of storage and information manipulation (Baddeley 2012)

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Multi-component Model of Working Memory

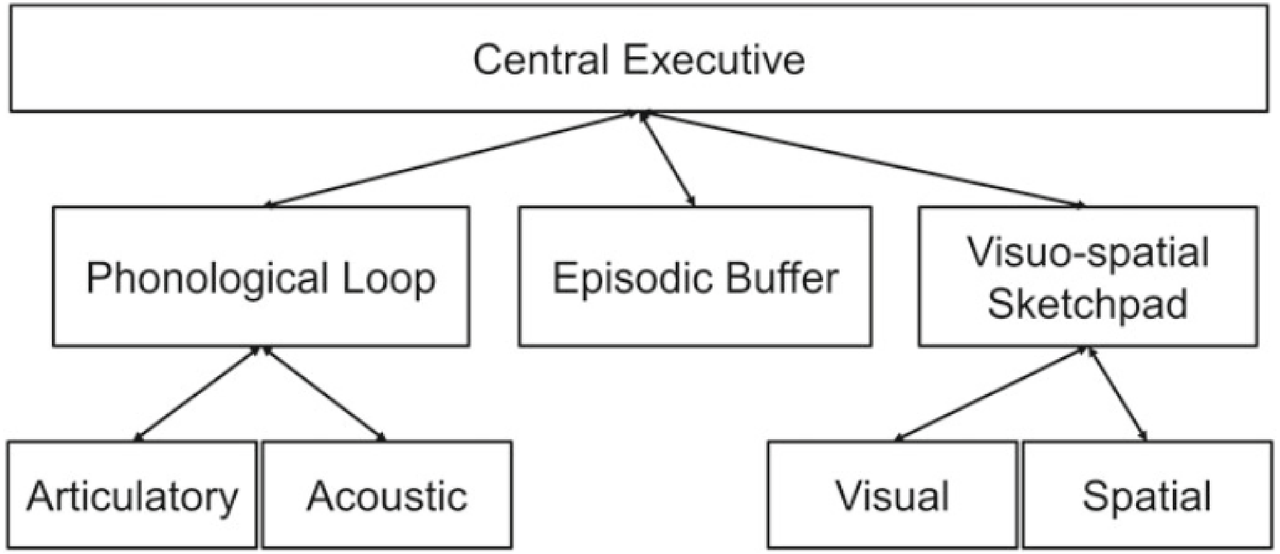

Fig. 2.2 Baddeley and Hitch's working memory model (1974)

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Long-term Memory

- Long-term memory is the final stage of Atkinson and Shiffrin's human memory model (Atkinson and Shiffrin 1968). In this stage, information remains for a long period of time or indefinitely

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Long-term Memory

- Explicit memory (declarative memory) refers to information that is consciously available
  - Episodic memory that refers to memory for specific events in time (e.g., remembering a person's name and incidence of interaction with that person)
  - Semantic memory that refers to factual information (e.g., the meaning of words)
  - Autobiographical memory that refers to information regarding events and experiences of an individual
- Implicit memory refers to procedural information about the body of the person, e.g., how to brush the teeth, how to swim, etc.

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Visual Perception

- *“the acquisition and processing of sensory information in order to see, hear, taste, or feel objects in the world; also guides an organism’s actions with respect to those objects” - Sekuler and Blake (2002, p. 621)*

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CONTENT 4

Visual Perception

- Visual perception is of vital importance in our everyday lives
- It enables individuals to move around freely, to recognize other people or objects, to read books, to identify depth and proximity or to watch videos and movies
- Some of the most important factors that influence the area of HCI

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Gestalt Psychology

- The Gestalt psychology has influenced significantly the study of how individuals perceive visual components and how they are organizing them
- Direct application in IUI and HCI

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Gestalt Principles

- Principle of *proximity*, objects that are close to each other are formulating groups
- Principle of *similarity*, objects which are similar with respect to their shape or color belong to the same group
- Principle of *closure*, objects (or regular figures) that are not complete tend to be perceived as a whole by individuals (our mind fills in the visual gap)

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Gestalt Principles

- Principle of *continuity*, the elements of objects that are aligned within an object tend to be grouped together perceived as an integrated whole
- Principle of *common fate*, the elements that move towards one (the same) direction or in the same speed are perceived as elements of a common group that moves towards that directional line or path
- Principle of *symmetry*, the elements (or areas) of objects contained between symmetrical limits appear (or perceived) to create solid coherent shapes

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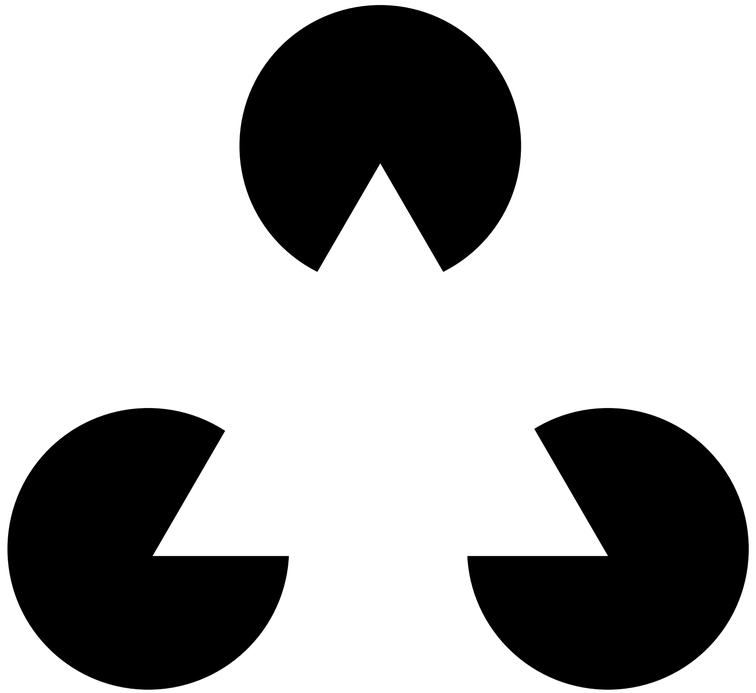
Gestalt Principle - Closure



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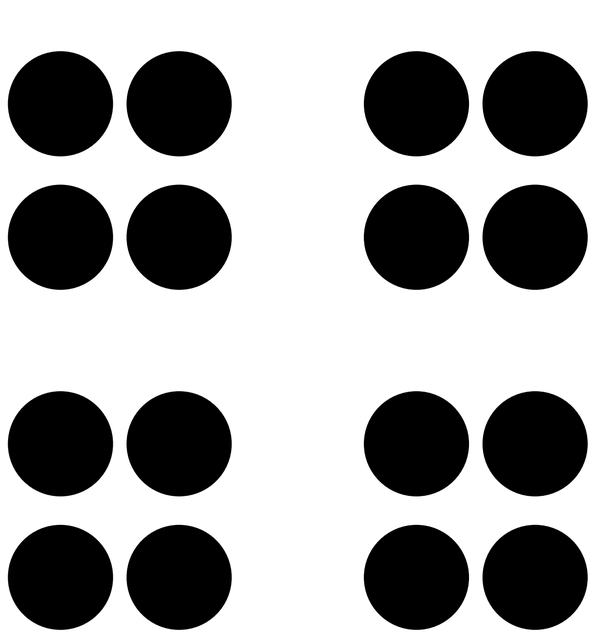
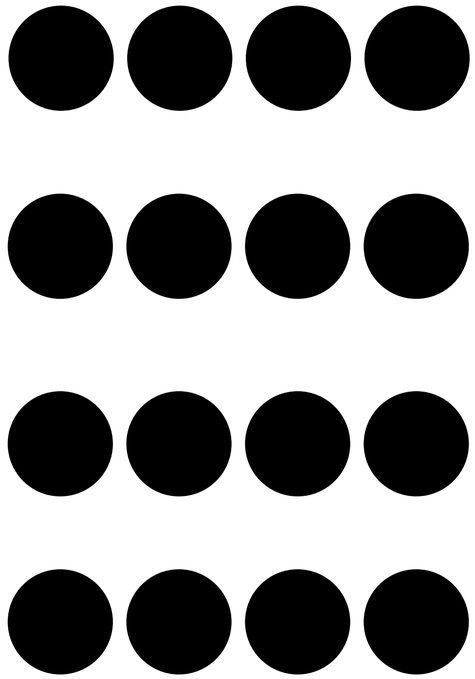
Gestalt Principle - Group





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Visual Search

- *“From the time we wake in the morning until we go to bed at night, we spend a good deal of each day searching the environment. For example, as we drive from home to work, we scan the roadway for other automobiles, pedestrians, and bicyclists. In the office, we may look for a coffee cup, the manuscript we were working on several days ago, or a phone number of a colleague that we wrote down on a scrap of paper. In short, much of our life is spent searching for information relevant to the task at hand ”* - Peterson et al. (2001)
- The processes included in these activities have been studied under the light of *visual search*

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Visual Attention

- *Visual attention* is defined as a process of concentrating on a discrete aspect of information (visual or auditory)

- *Pre-attentive attributes:* The brain processes the information prior to focusing attention on anything

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Pre-attentive Attributes

12345678

1234**5**678 size

12345678 color

1234ƽ678 orientation

12345678 texture

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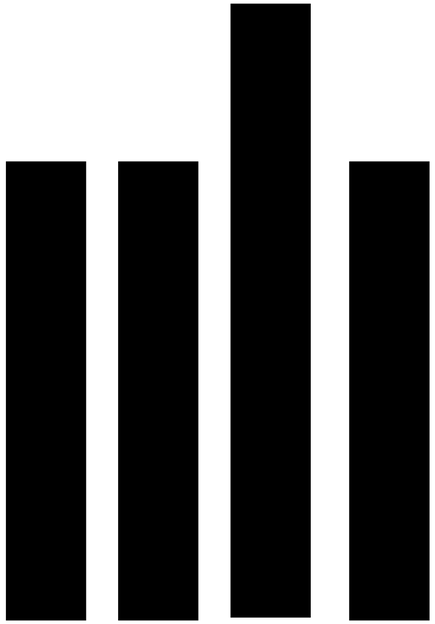
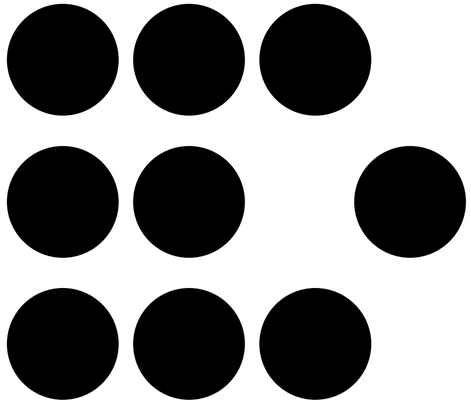
Pre-attentive Attributes





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Individual Differences in Cognitive Styles

- **Cognitive Styles:** A person's preferred way of processing information using cognitive brain-based mechanisms and structures [Peterson et al., 2009]

- Reflects how individuals process, organize and structure information
- Related to mental behaviors, habitually applied by an individual to problem solving

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Individual Differences in Cognitive Styles

- Riding and Cheema [1991] surveyed thirty different cognitive styles, among others:
- According to the descriptions, correlations, methods of assessment, and effect on behavior, they concluded these may be grouped into two groups
  - Verbal/Imager – Wholist/Analyst

- **Verbal/Imager**
  - Sensory modality preferences [Bartlett, 1932]
  - Verbalizer-imager [Riding & Taylor, 1976]
  - Verbalizer-visualiser [Richardson, 1977]

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CONTENT 4

Individual Differences in Cognitive Styles

- **Wholist/Analyst**
  - Field dependence-independence [Witkin, 1962]
  - Impulsivity-reflectivity [Kagan, 1965]
  - Holist-serialist [Pask, 1972]
  - Leveller-sharpener [Holzman & Klein, 1954]
  - Simultaneous-successive [Das, 1988]
  - Diverging-converging [Hudson, 1966]
  - Tolerant-intolerant [Gardner et al., 1959]

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Verbal/Imager Cognitive Style

- Describes individuals' mode of information representation and processing

- **Verbals**
  - Represent information using verbal associations
  - Prefer and perform better when hypermedia content is presented in the form of text
  - Great reading accuracy and are better at recalling textual information

[Riding and Cheema, 1991; Peterson et al., 2005; Kozhevnikov, 2007]

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Verbal/Imager Cognitive Style

- **Imagers**
  - Represent information in mental pictures
  - Prefer and perform better when the hypermedia content is provided in the form of graphical representation
  - Do not perform efficiently when an exclusively verbal representation is provided

[Riding and Cheema, 1991; Peterson et al., 2005; Kozhevnikov, 2007]

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Field Dependence-Independence

- Field Dependence-Independence is a cognitive theory interrelated with the visual behavior of users
- Reflects how individuals retrieve, recall, process and store graphical information

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Field Dependence-Independence

- **Field Independent**
  - Follow a more holistic approach to process visual information
  - They have difficulties in identifying details in complex visual scenes

- **Field Independent**
  - Follow a more analytical approach to process visual information
  - Pay attention to details
  - Easily separate simple structures from the surrounding visual context

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CONTENT 4

Wholist/Analyst Cognitive Style

- Reflects how individuals organize and structure information

- **Wholists**
  - Retain a global or overall view of information
  - View a situation and organize information as a whole
  - Proceed from the whole to the parts
  - Organize information in loosely clustered wholes

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Wholist/Analyst Cognitive Style

- **Analysts**
  - Deconstruct information into its component parts
  - View a situation as a collection of parts and stress only one or two aspects at a time
  - Proceed from the parts to the whole
  - Organize information in clear-cut groupings

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Cross-cultural Effects of Cognitive Styles

- Cognitive processing styles and abilities exist not only within a certain nation
- Across diverse nations around the globe, as they are affected by the cultural background in which they are developed [Cui et al., 2013; Varnum et al., 2010; Engelbrecht et al., 1997]
- Prior research has shown cross-cultural differences in Wholist-Analysts (Western vs. Eastern societies [Cui et al., 2013; Varnum et al., 2010], African American vs. South African [Engelbrecht et al., 1997])
- Such research works could be replicated on a multinational scale aiming the design and development of globalized systems, whose impact will affect a large number of individuals from different cultures

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Individual Differences in Cognitive Processing Abilities

- Explain the functioning of the human mind in terms of more basic processes
- **Speed of processing:** maximum speed at which a given mental act may be efficiently executed
- **Control of processing:** identify and concentrate on goal-relevant information and inhibit attention to irrelevant stimuli
- **Working memory:** maximum amount of information that the mind can efficiently activate during information processing

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Learning Styles

- Learning styles represent a particular set of strengths, techniques and preferences that individuals employ during the learning process (on how they learn)

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Kolb's Learning Styles Inventory (LSI – Kolb and Kolb 2005)

- **Convergers**, individuals that prefer to discover possibilities and relationships, concentrate better when studying alone and better understand through abstract thinking
- **Divergers**, individuals that prefer real life experience and discussion, are imaginative, like brainstorming and group work, prefer observing

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CONTENT 4

Kolb's Learning Styles Inventory (LSI – Kolb and Kolb 2005)

- **Assimilators**, individuals that solve problems with deductive reasoning and have the ability to create theoretical models
- **Accommodators**, individuals that solve problems by carrying out plans and experiments, challenges theories, are adaptable and work based on gut feeling rather than logic

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Felder/Silverman Index of Learning Styles (ILS – Felder and Silverman 1988)

- **Sensing learners** that are concrete, practical, oriented towards facts and procedures, or intuitive learners that are conceptual, innovative, oriented towards theories and meanings
- **Visual learners** that prefer visual representations of presented material (e.g., pictures, diagrams, flow charts), or verbal learners that prefer written and verbal explanations

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Felder/Silverman Index of Learning Styles (ILS – Felder and Silverman 1988)

- **Active learners** that learn by experimenting and working with others, or reflective learners that learn by thinking things through and working alone
- **Sequential learners** that work linearly, orderly and learn in small incremental steps, or global learners that have a holistic approach in learning and learn in large leaps

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CONTENT 4

How do we elicit human factors?

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CONTENT 4

Elicitation Methods

- Questionnaires
- Cognitive aptitude tests

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CONTENT 4

Elicitation of Cognitive Styles: Verbal/Imager

- The Verbal/Imager CSA test indicates an individual's tendency to process information verbally or in mental pictures.
- Task and Stimuli: Present a series of 48 questions about conceptual category and appearance (i.e., color) to be judged by the users to be true or false
  - 24 statements require comparing two objects conceptually (e.g., "Are ski and cricket the same type?")
  - 24 statements require comparing the color of two objects (e.g., "Are cream and paper the same color?")

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CONTENT 4

Elicitation of Cognitive Styles: Verbal/Imager

- Assumption for Classification
  - Verbals respond faster than Imagers in the conceptual types of stimuli
    - semantic conceptual category membership is verbally abstract in nature and cannot be represented in visual form
  - Imagers respond faster than Verbals in the appearance statements
    - objects can be represented as mental pictures

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VICS Test - Verbal–Imagery Cognitive Style

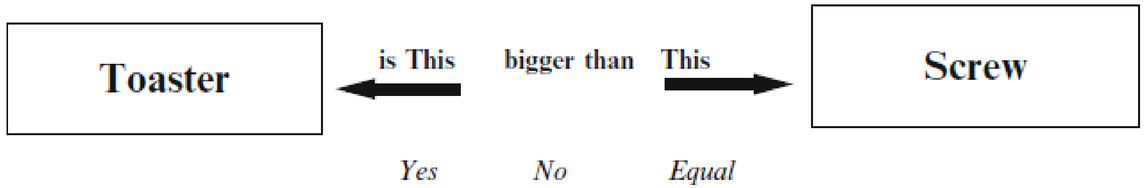

Fig. 2.4 Example of an imagery item in the word form (Peterson et al. 2005)

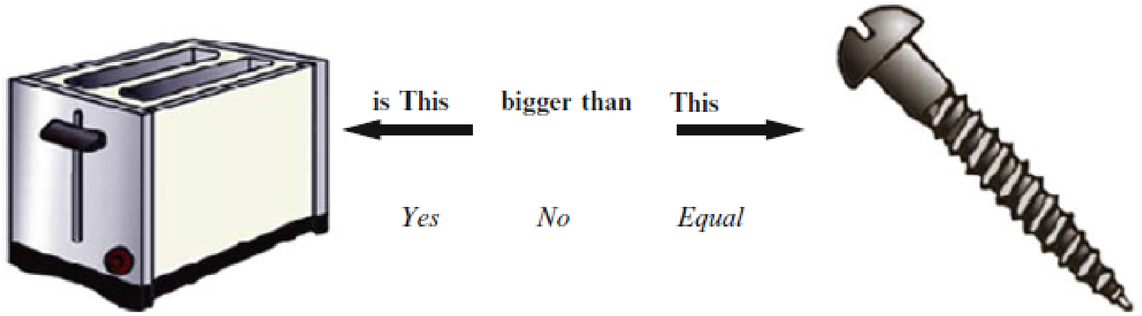

Fig. 2.5 Example of an imagery item in the picture form (Peterson et al. 2005)

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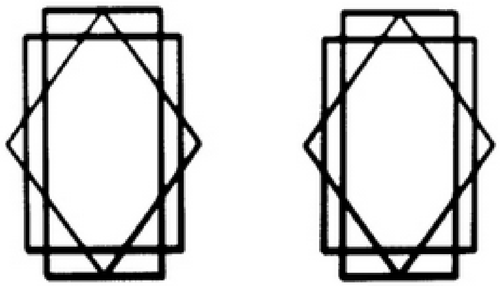
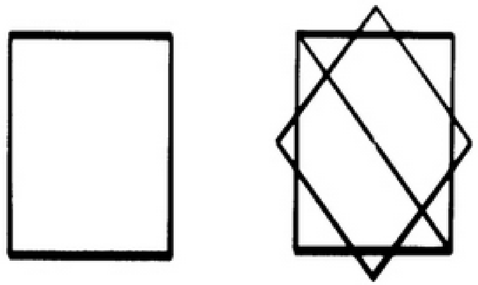
Elicitation of Cognitive Styles: Wholist/Anayst

- The Wholist/Analyst CSA test indicates an individual's tendency to process information as a whole or analytically
- Task and Stimuli: Present a series of 40 questions on comparing figures

wholist-type: similarity comparison



analyst-type: dis-embedding of figures



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CONTENT 4

Elicitation of Cognitive Styles: Wholist/Anayst

- Assumption for Classification
  - Wholists will respond faster than Analysts in the wholist-types of stimuli
  - Analysts will respond faster in the analyst-types of stimuli

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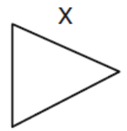
CONTENT 4

Group Embedded Figures Test

- Consists of 18 pattern-recognition tasks
- Identify a given pattern within a complex context
- The higher the score, the more field independent you are

Here is a simple form which we have labeled "X":



This simple form, named "X", is hidden within the more complex figure below:

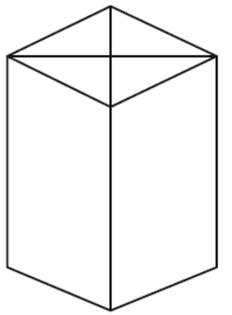


Fig. 2.6 Sample item from the GEFT booklet (Witkin et al. 1971)

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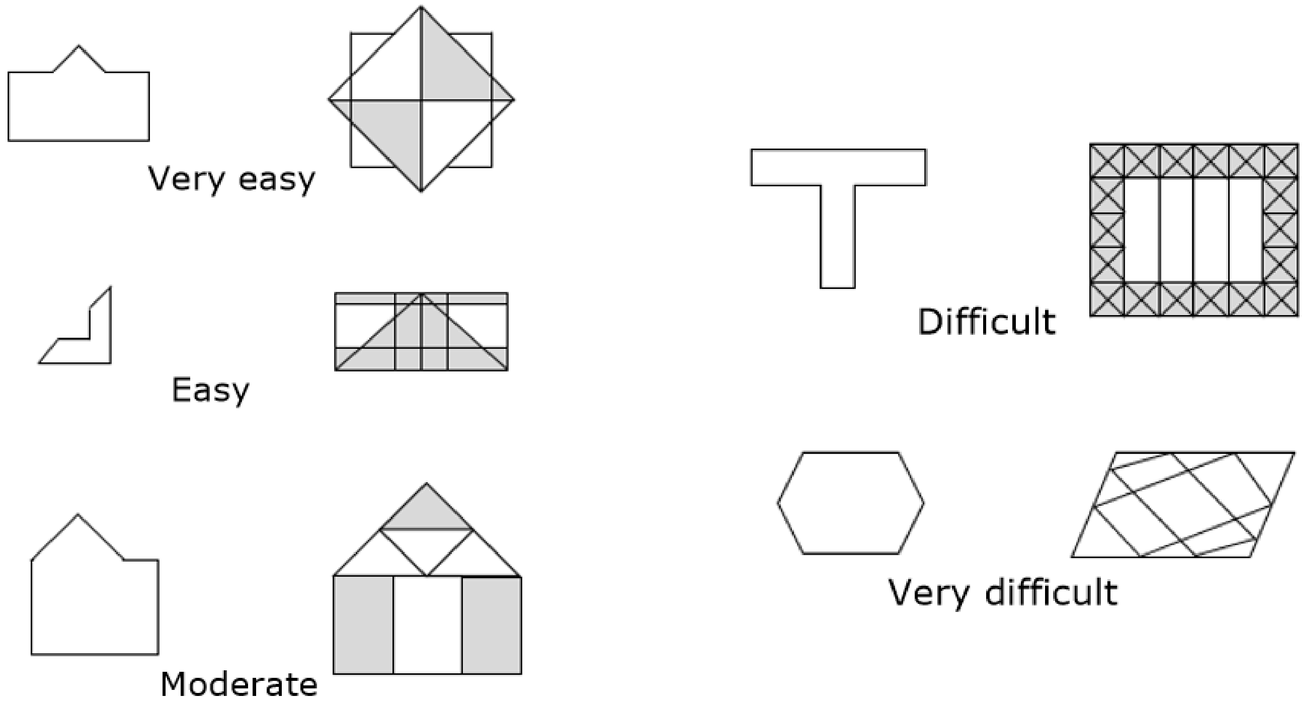
CONTENT 4

Group Embedded Figures Test



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CONTENT 4

Elicitation of Speed of Processing (SP)

- Read a number of words designating a color written in the same or different ink color
- Eighteen words were illustrated to the participants illustrating the words “red”, “green” or “blue” either written in red, green or blue ink color, and the participants had to respond as quick as possible utilizing the keyboard.
- The reaction times between eighteen stimuli and responses were recorded and their mean and median were automatically calculated

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CONTENT 4

Elicitation of Controlled Attention (CA)

- A similar test to the previous one was utilized
- Instead of denoting the word itself, participants were required to recognize the ink color of words denoting a color different than the ink
- Eighteen words were illustrated to the participants illustrating the words “red”, “green” or “blue” either written in red, green or blue ink color, and the participants had to respond as quick as possible utilizing the keyboard
- The reaction times between eighteen stimuli and responses were recorded and their mean and median were automatically calculated

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CONTENT 4

Elicitation of Visual Working Memory Capacity (WMC)

- Assess visual working memory capacity with a Web-based psychometric instrument that measures the amount of information a person can efficiently activate simultaneously

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CONTENT 4

Elicitation of Verbal Working Memory Capacity (WMC)

- Respond to statements to be either true or false
- Remember last word of each sentence and write the last word of the sentence
- The test included six levels of difficulty
- The level each participant reached indicated his/her verbal working memory capacity

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CONTENT 4

Issues in Explicit Elicitation Methods

- An important limitation of cognitive style research is the explicit and non-real-time elicitation of the users' cognitive styles
  - Traditional in-lab techniques, e.g., "paper-and-pencil" and questionnaires
  - Time-consuming, e.g., 15-20 mins
  - Human intervention
- Compromising real-time integration of human cognitive factors, and negatively affecting user acceptance

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CONTENT 4

A Multifactorial Model for Implicit Elicitation of Human Cognitive Factors

- When humans explore a visual scene
  - Humans perform varying visual activities which incorporate information processing to some extent, depending on the nature of the activity, and thus they involve human cognition
  - Research has shown that there are inter-dependencies among human cognition, visual behavior, and activity factors

- *Raptis, G., Katsini, C., Belk, M., Fidas, C., Samaras, G., Avouris, N. (2017). Using eye gaze data and visual activities to infer human cognitive styles: method and feasibility studies, ACM User Modeling, Adaptation and Personalization (UMAP 2017), ACM Press, 164-173*

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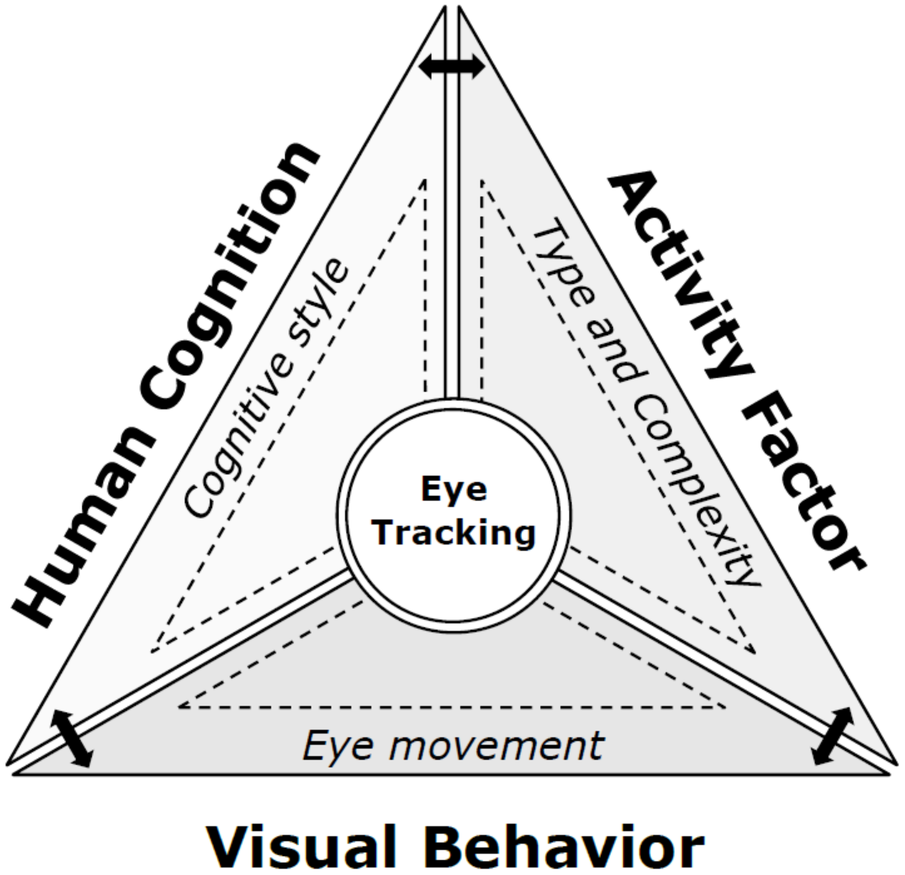
A Multifactorial Model for Implicit Elicitation of Human Cognitive Factors



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Gaze and Scatter Plots of FD vs. FI Individuals

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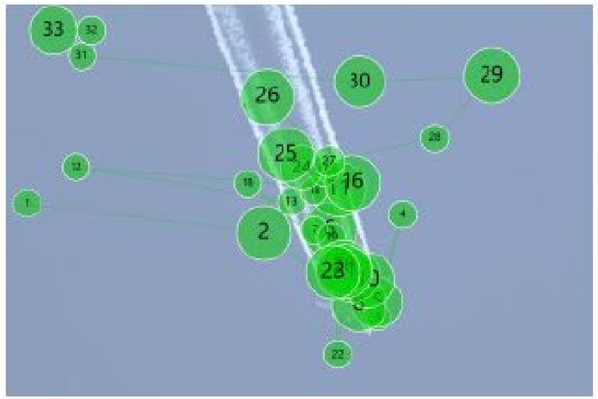
Gaze and Scatter Plots of FD vs. FI Individuals



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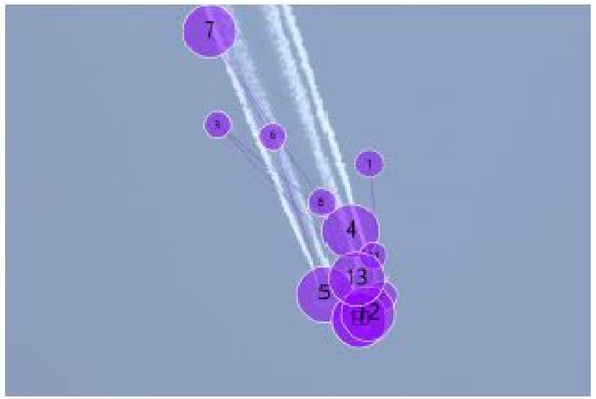
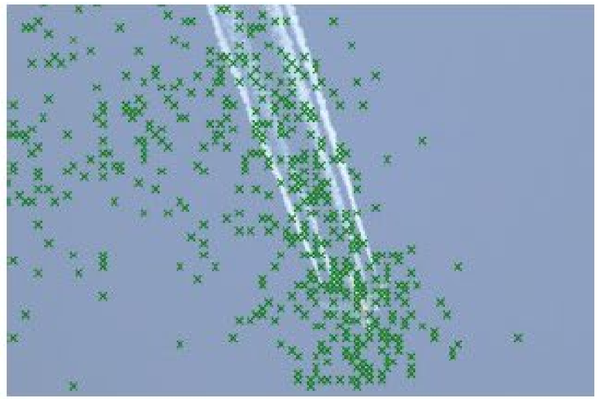


Field Independent



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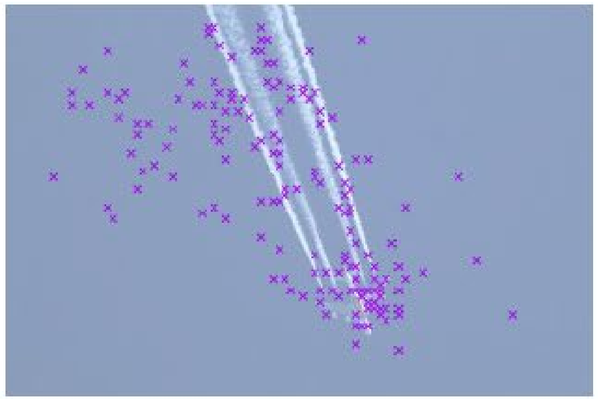

Field Independent

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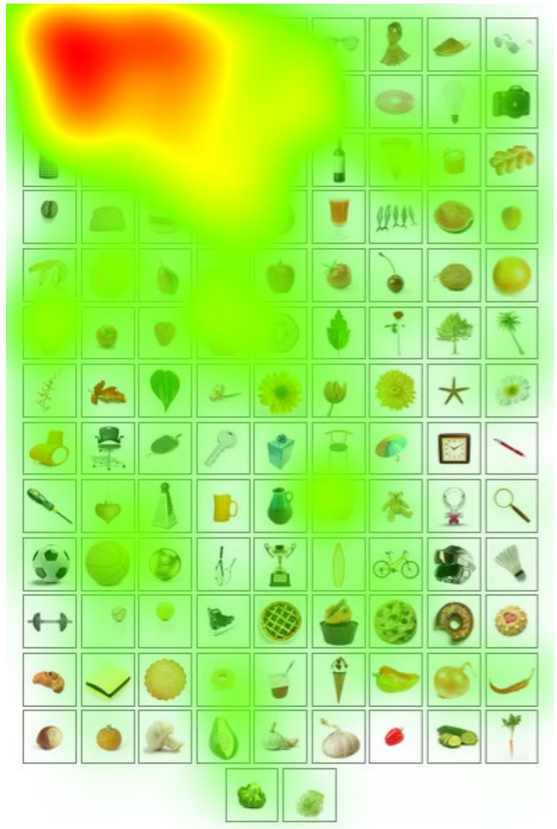
CONTENT 4

Heat Maps based on Fixations

- Heat map data further indicate that FI individuals scanned a larger part of the image grid, and fixated on a larger number of images than FDs



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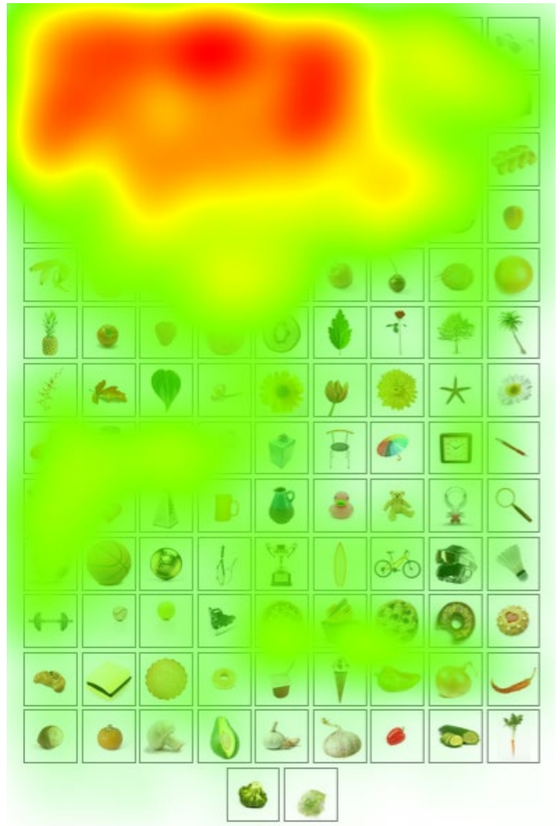

Field Independent

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CONTENT 4

Method: Implicit Elicitation through Eye-tracking

- Eye-tracking
  - Use eye gaze data to leverage the interplay among the model factors

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CONTENT 4

Implicit Elicitation Method

- Step 1: Data collection
  - Raw eye gaze data, which is captured through eye-tracking
- Step 2: Two-phase data processing
  - Decide which eye-tracking measure is the most suitable to perform user classification
  - Transform the data to the corresponding measure. The selection of the most suitable measures depends on the activity and the cognitive style
- Step 3: Classification
  - When the transformed eye-tracking measures are provided in our model, it classifies the corresponding individuals on their cognitive style

Raptis, G., Katsini, C., Belk, M., Fidas, C., Samaras, G., Avouris, N. (2017). Using eye gaze data and visual activities to infer human cognitive styles: method and feasibility studies, ACM User Modeling, Adaptation and Personalization (UMAP 2017), ACM Press, 164-173

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CONTENT 4

Sources and further readings

- Germanakos, P., Belk, M. (2016). Human-Centred Web Adaptation and Personalization - From Theory to Practice. Human-Computer Interaction Series, Springer, doi: 10.1007/978-3-319-28050-9

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