HCI 2023

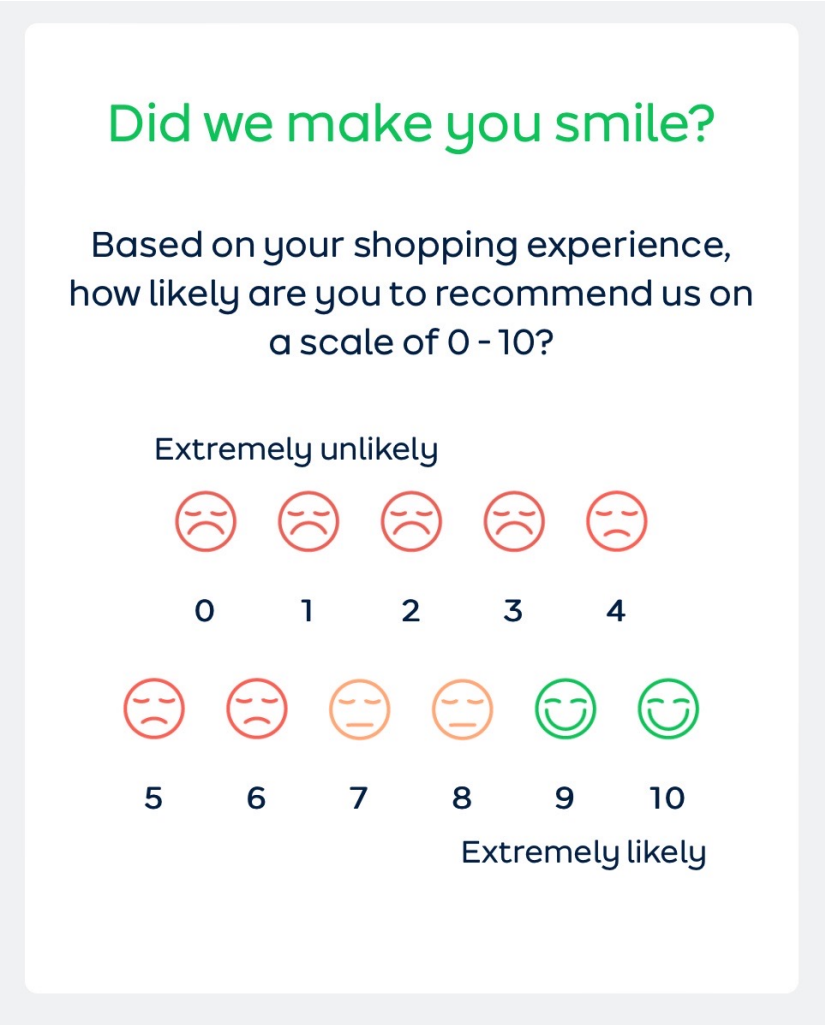
Design Theory, Principles and Guidelines

Human Computer Interaction

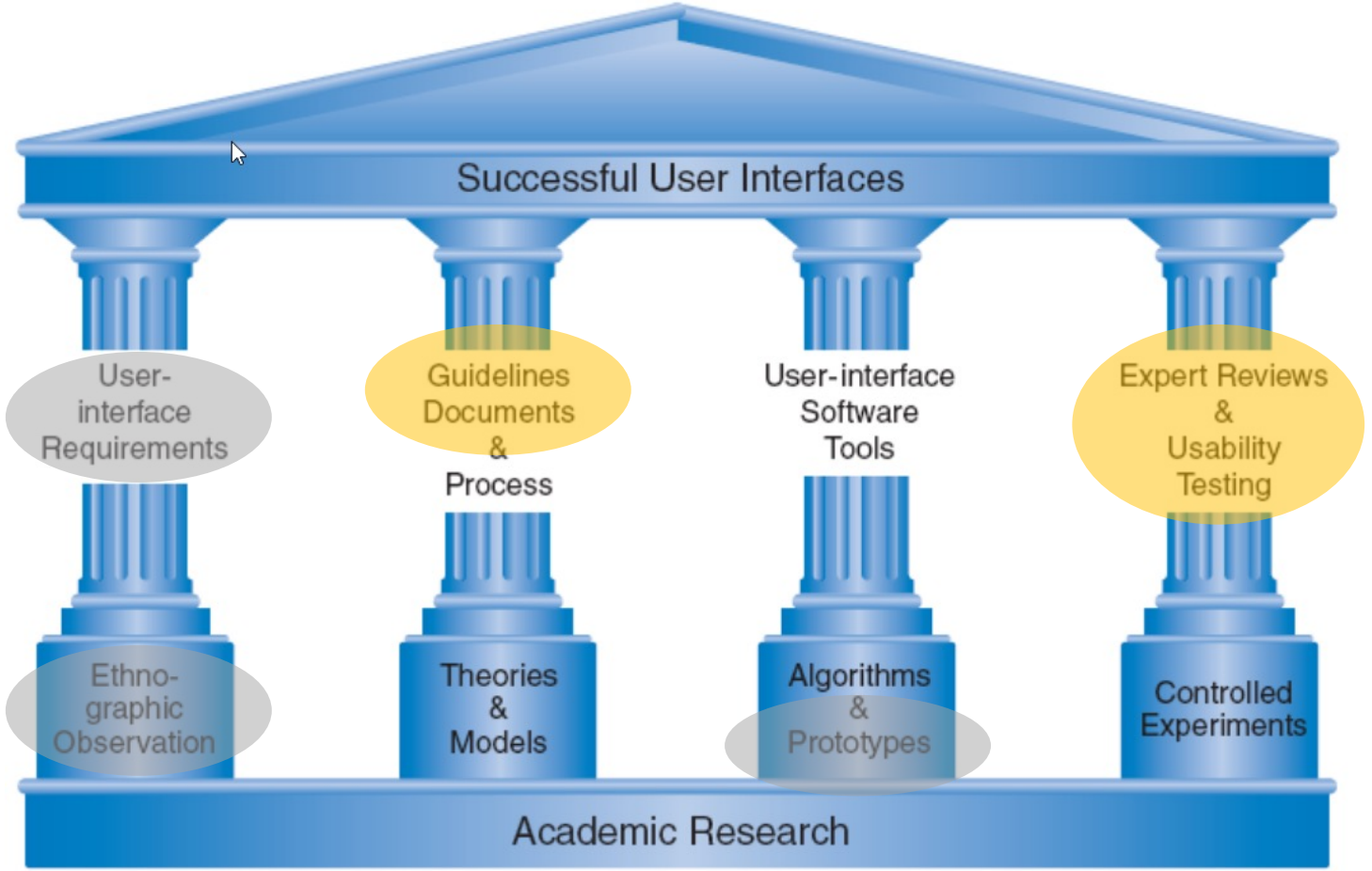
Luigi De Russis

Academic Year 2023/2024

Hall of Fame or Shame?



The Four Pillars of Design



Ben Shneiderman & Catherine Plaisant, Designing the User Interface: Strategies for Effective Human-Computer Interaction

Goals

Generating design solutions

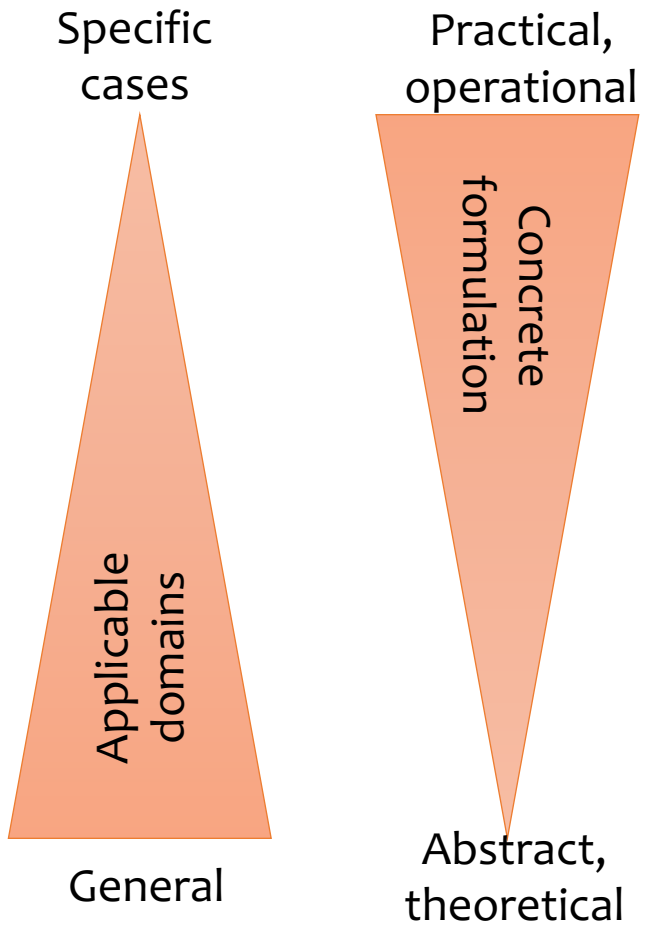
- Guidelines
- Principles
- Theories

Evaluating generated designs

- Expert reviews and heuristics
- Usability testing
- Controlled experiments

Generating Design Solutions

- **Guidelines:** Low-level focused advice about good practices and cautions against dangers
- **Principles:** Mid-level strategies or rules to analyze and compare design alternatives
- **Theories:** High-level widely applicable frameworks to draw on during design and evaluation, as well as to support communication and teaching



Design Theories

Theoretical frameworks enabling foundational research

The “Why”

Design Theories

Types of theories

- Descriptive
  - UI elements, terminology, semantics
- Explanatory
  - Sequences of events with causal relationships
- Prescriptive
  - Guidelines for designers to make decisions
- Predictive
  - Comparison of design alternatives based on performance figures

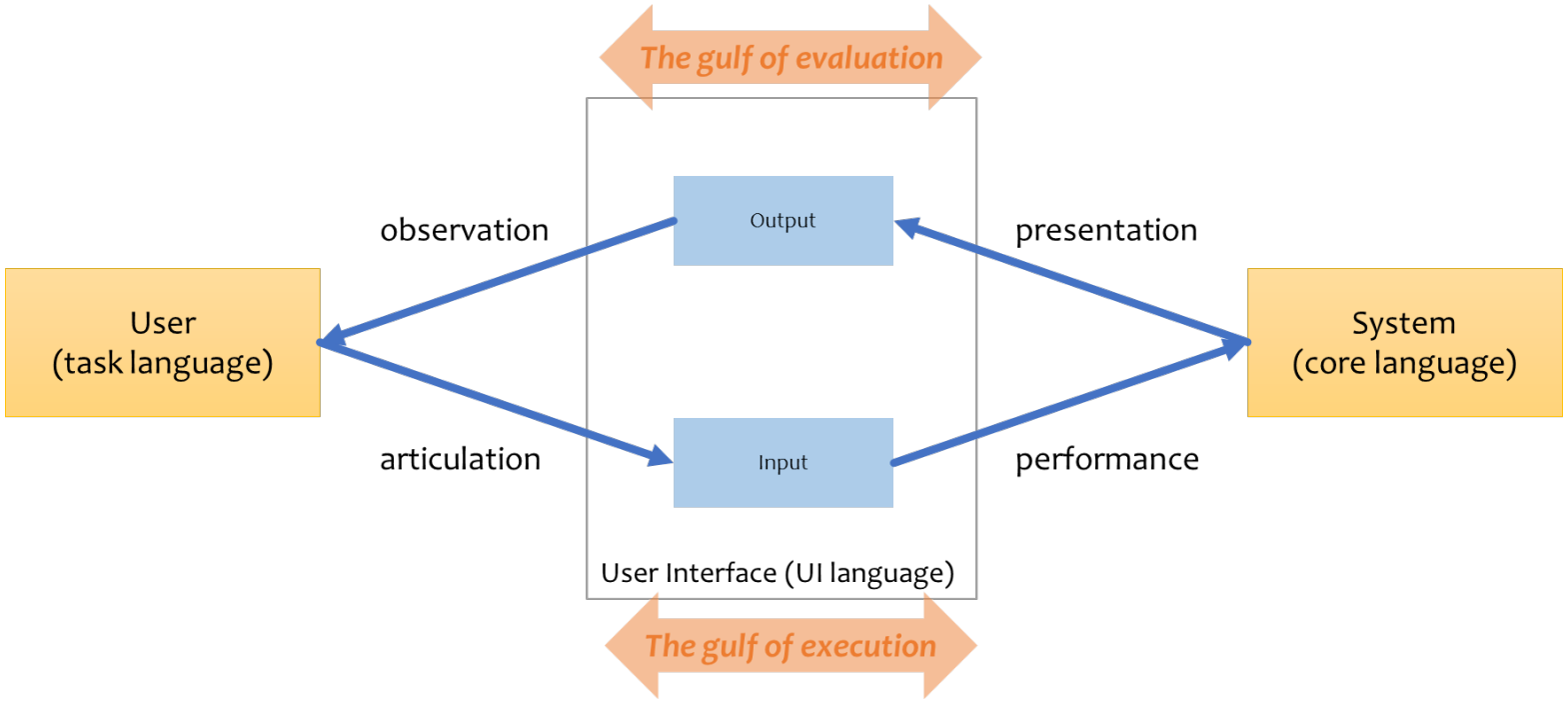
Human capacity

- Motor task
  - Skill in pointing, clicking, … movements
- Perceptual
  - Sensory inputs
- Cognitive
  - Problem-solving, short-/long-term memory

Foley and van Dam Four-level Approach (Descriptive)

- **Conceptual** level
  - User's mental model of the interactive system
- **Semantic** level
  - Describes the meanings conveyed by the user's command input and by the computer's output display
- **Syntactic** level
  - Defines how the units (words) that convey semantics are assembled into a complete sentence that instructs the computer to perform a certain task
- **Lexical** level
  - Deals with device dependencies and with the precise mechanisms by which a user specifies the syntax

Norman's Action Models (Explanatory)



1. **Goal** (form the goal)
2. **Plan** (the action)
3. **Specify** (an action sequence)
4. **Perform** (the action sequence)
5. **Perceive** (the state of the world)
6. **Interpret** (the perception)
7. **Compare** (the outcome with the goal)

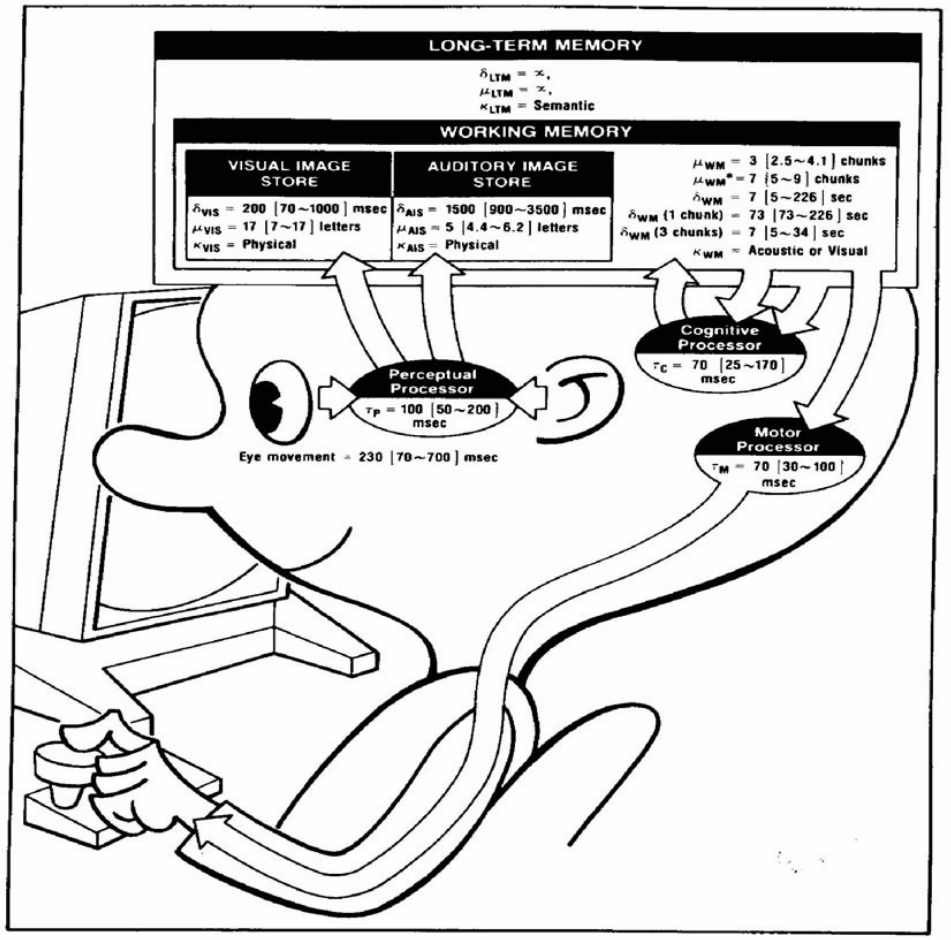
Consistent
delete/insert character
delete/insert word
delete/insert line
delete/insert paragraph

Consistency Theories (Prescriptive)

- **Consistency** of nouns (objects) and verbs (actions)
  - Reduces learning time and errors
- Consistency of
  - Color
  - Layout
  - Icons
  - Fonts and Font sizes
  - Button sizes
  - …
- Inconsistencies might be used (sparingly!) for drawing attention

Human Processor Model

- Cognitive modelling method used to **calculate** how long it takes to perform a given task
  - prediction the system's performance (time to complete a task)
  - analogy between processing and storage areas of a computer with the perceptual, motor, cognitive and memory areas (working and long-term) of a person
- The calculations can be also used to determine the probability of a user remembering an item encountered during the task
- Underlies other usability techniques (GOMS, KLM, …)



Card, Stuart K.; Moran, Thomas P; and Newell, Allen. Human-computer interaction – Psychological aspects, Erlbaum Associates, 1983, ISBN: 9780898592436

Memory

- Working memory (short-term)
  - small capacity (7 ± “chunks”)
    - +393475812632 vs. (+39) 347 581 2632
    - FGIHHJLMQ vs. FGI HHJ LMQ
  - rapid access (~70ms) and decay (~200ms)
    - pass to long-term memory after a few seconds of continued storage
- Long-term memory
  - huge (unlimited, almost)
  - slower access time (~100ms) with litte decay

Fitts's Law

- Demonstration: https://fww.few.vu.nl/hci/interactive/fitts/
- "The amount of time required for a person to move a *pointer* to a target area is a function of the distance to the target divided by the size of the target"
  - the longer the distance and the smaller the target's size, the longer it takes
  - created by psychologist Paul Fitts in 1954 examining the human motor system
- Widely used in HCI:
  - influenced the convention of making interactive buttons large (especially on finger-operated mobile devices
  - the distance between a user's task/attention area and the task-related button should be kept as short as possible

Design Principles

The important aspects that we need to consider when creating a design.

The “What”

Design Principles

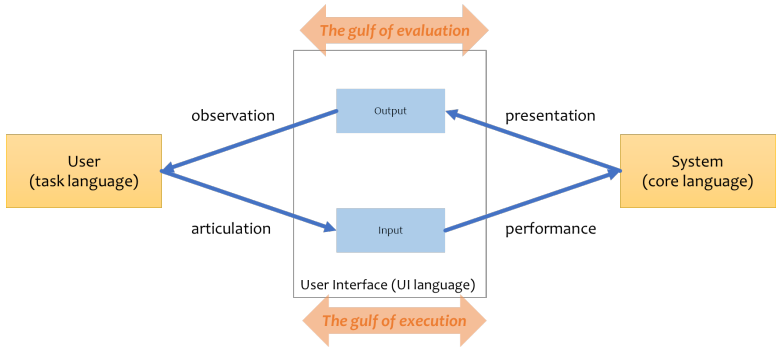
- More practical than Theories
- More fundamental, widely applicable, and enduring than Guidelines
- Fundamental principles (→ from Needfinding)
  - Determine user's skill levels
  - Identify the tasks
- 5 primary interaction styles
- 8 golden rules of interface design
- Prevent errors
- Automation and human control

Interaction Styles

- Direct manipulation
- Menu selection
- Form fill-in
- Command language
- Natural language

Advantages	Disadvantages
Direct manipulation	
Visually presents task concepts	May be hard to program
Allows easy learning	May require graphics display and pointing devices
Allows easy retention	
Allows errors to be avoided	
Encourages exploration	
Affords high subjective satisfaction	
Menu selection	
Shortens learning	Presents danger of many menus
Reduces keystrokes	May slow frequent users
Structures decision making	Consumes screen space
Permits use of dialog-management tools	Requires rapid display rate
Allows easy support of error handling	
Form fill-in	
Simplifies data entry	Consumes screen space
Requires modest training	
Gives convenient assistance	
Permits use of form-management tools	
Command language	
Flexible	Poor error handling
Appeals to "power" users	Requires substantial training and memorization
Supports user initiative	
Allows convenient creation of user-defined macros	
Natural language	
Relieves burden of learning syntax	Requires clarification dialog
	May not show context
	May require more keystrokes
	Unpredictable

Norman's Principles from Action Models



Principles of good design

- State and the action alternatives should be visible
- Should be a good conceptual model with a consistent system image
- Interface should include good mappings that reveal the relationships between stages
- User should receive continuous feedback

User failures can occur

- Users can form an inadequate goal
- Might not find the correct interface object because of an incomprehensible label or icon
- May not know how to specify or execute a desired action
- May receive inappropriate or misleading feedback

The 8 Golden Rules of Interface Design

- Strive for consistency
- Cater to universal usability
- Offer informative feedback
- Design dialogs to yield closure
- Prevent errors
- Permit easy reversal of actions
- Keep users in control
- Reduce short-term memory load

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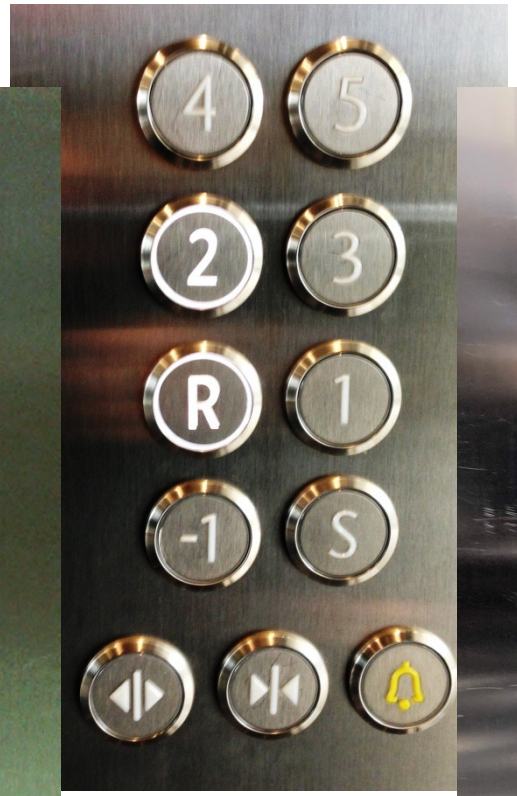
- Similar situations should lead to similar sequences of actions
- Same terminology in prompts, menus, help
- Color, layout, capitalization, fonts, …
- Exceptions should be comprehensive and limited
  - E.g., delete, password echo

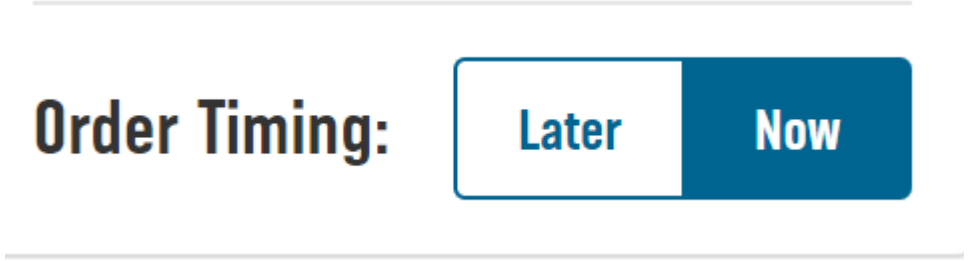
Internal Consistency

Consistency with mental models



https://twitter.com/grmcall/status/1182586857814659073?s=20

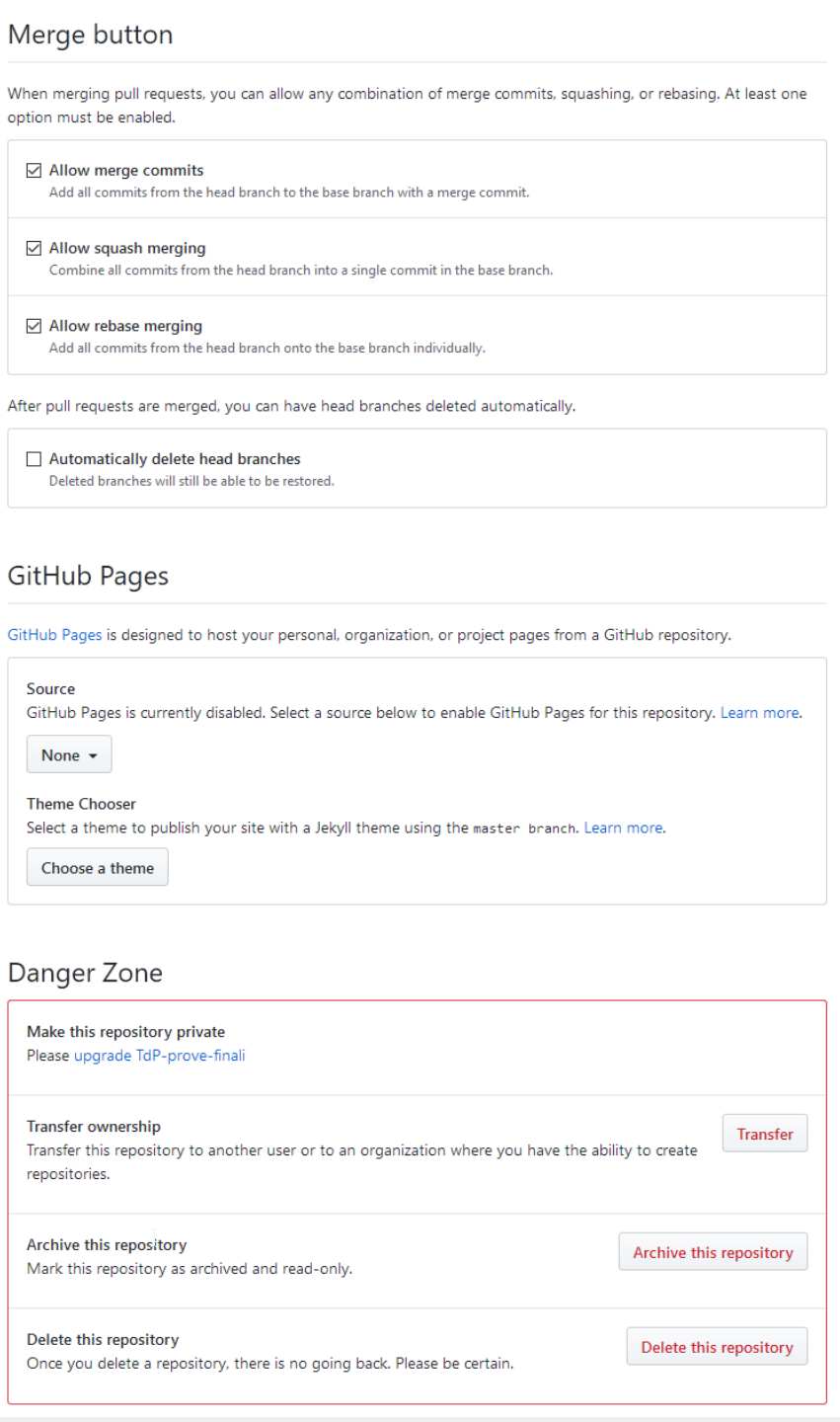
Consistency of Interpretation



- Which one is the selected one?
  - Color codes are ambiguous
  - No further internal clues
  - No external clues
- Does it represent the current status?
- Does it represent the status that we want to achieve?

Inconsistency for Drawing Attention

The border color and button text color in the “danger zone” are deliberately different than the rest of the page



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- Users with different needs: let the interface *adapt*, let content be *transformed*
- Novices vs. experts. Young vs elderly. Web vs. mobile. Users with disabilities (→Accessibility)
- **Responsive** design
- International (and cultural) variations

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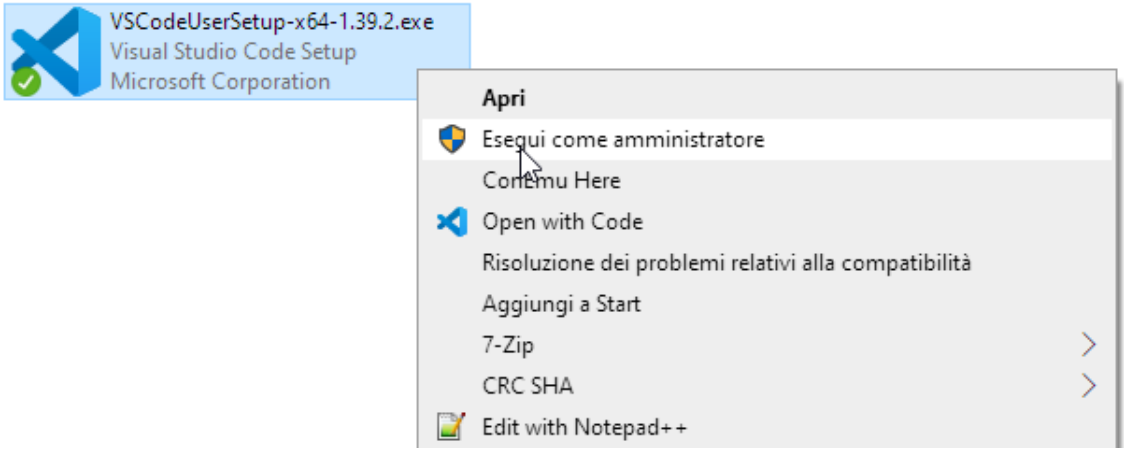
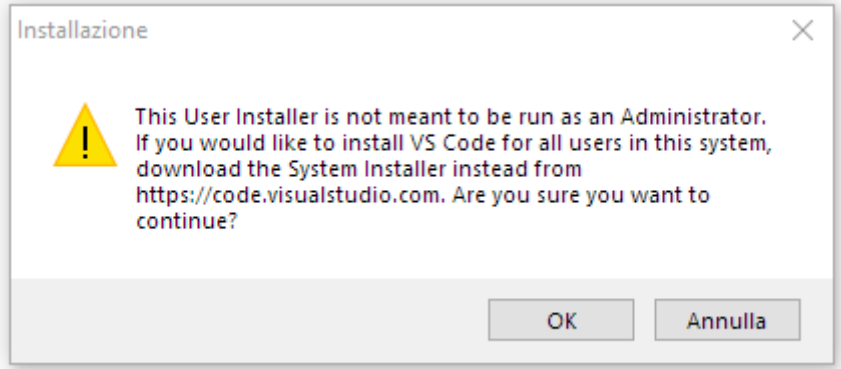
- For ***every*** human action, there should be an interface feedback
- Frequent and minor actions: light feedback
- Infrequent and major actions: stronger feedback
- Visual presentation of objects helps showing the changes (e.g., dim, highlight, grey out, …)

Example

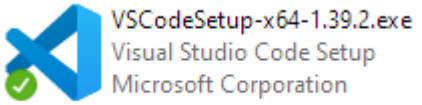

POLITECNICO
DI TORINO
Servizi per la didattica
myPoli
PORTALE DELLA DIDATTICA
Problemi nell'invio del messaggio (-1)
Close

Example





Try to install VS Code for all users on a computer (install to Program Files rather than user's folders)



We Went a Long Way From…

The 8 Golden Rules of Interface Design

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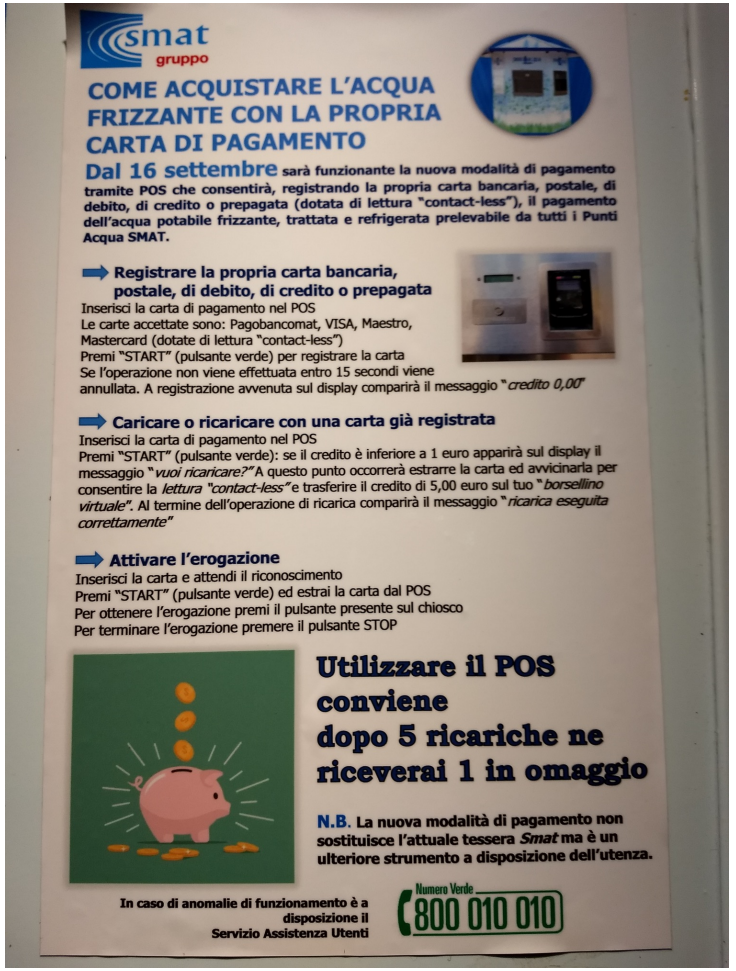
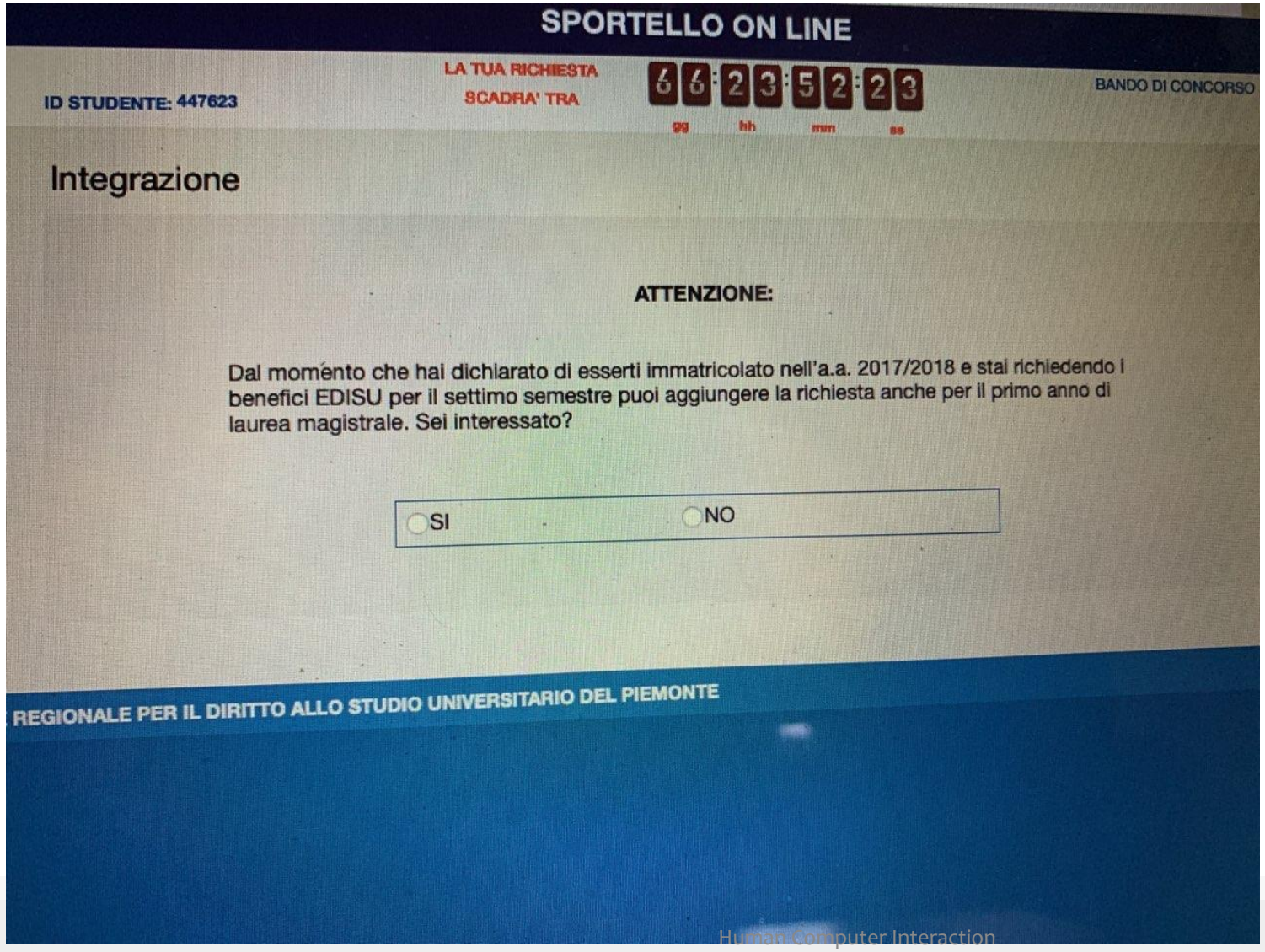
- Every sequence of actions should have
  - Beginning
  - Development
  - End
- Provide clear feedback at end
  - Satisfy users
  - ‘Delete’ current task from their working memory, prepare for the next

Clear Dialog Sequence



Clear Dialog Sequence



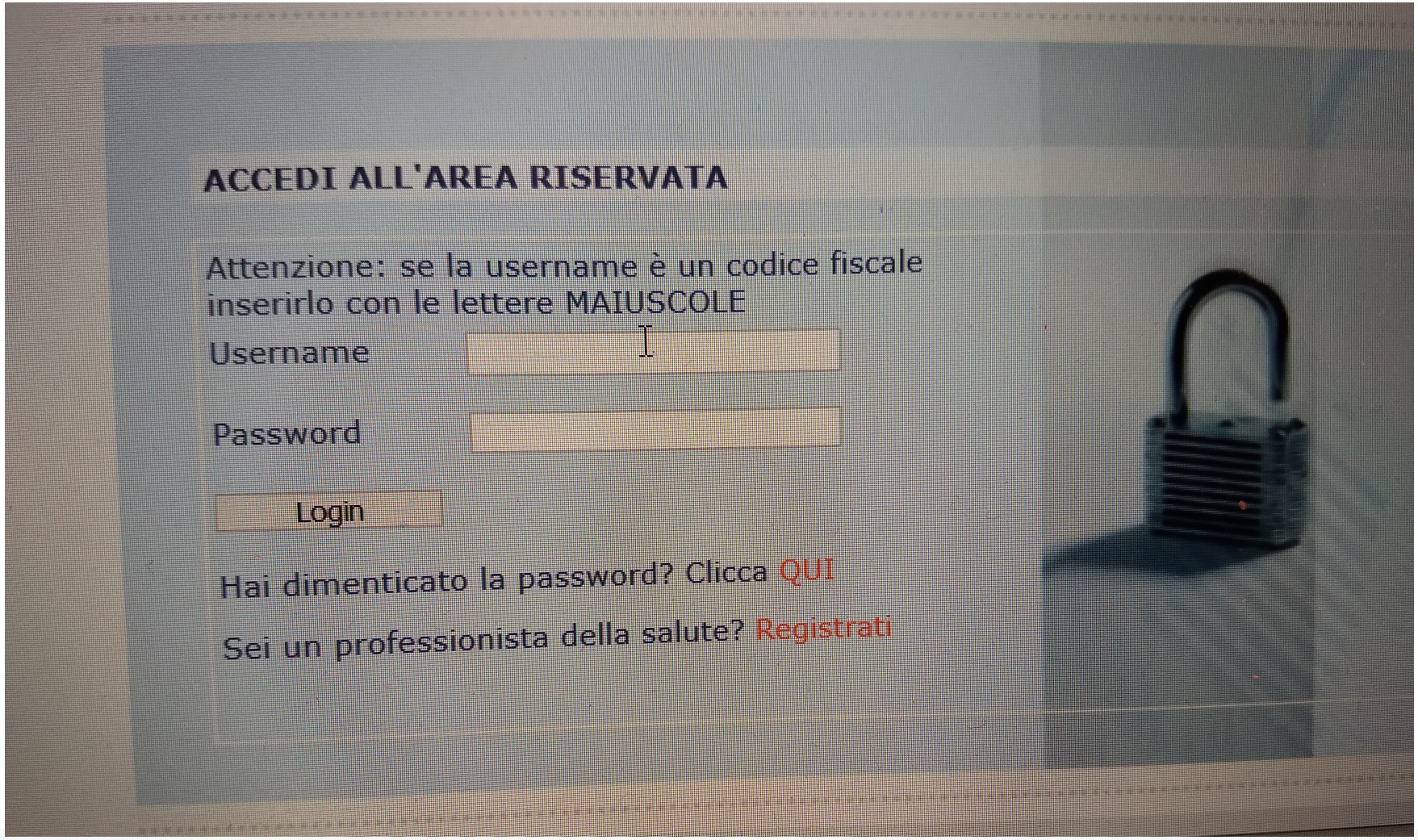
- OK
- Submit
- Confirm
- Next
- …?

The 8 Golden Rules of Interface Design

- Strive for consistency
- Cater to universal usability
- Offer informative feedback
- Design dialogs to yield closure
- **Prevent errors**
- Permit easy reversal of actions
- Keep users in control
- Reduce short-term memory load

- Avoid the possibility of making errors
- Disable menu items, buttons, links, … that are not applicable
- Prevent entering illegal characters
- Offer simple, constructive and specific instructions for recovery
  - Repair only the faulty part
- Errors should not alter application state (or make it easy to restore)

Error Prevention



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- Prevent errors
- **Permit easy reversal of actions**
- Keep users in control
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- Actions should be reversible (at the cost of extra development effort)
  - Relieves anxiety
  - Encourages exploration
- Different levels of reversibility
  - A single action
  - A data-entry task
  - A complete group of actions

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- **Keep users in control**
- Reduce short-term memory load

- The interface should *always* respond to user actions
- Minimize the tedious and lengthy tasks
- Avoid surprises or changes in familiar behavior
- Provide undo/redo, cancel/confirm

Example

*Come docente, quali problemi hai avuto nello svolgimento degli esami?

Scegliere una o più delle seguenti opzioni

- [x] Non ho avuto problemi
- [x] Organizzazione dell'esame (poca chiarezza nella spiegazione delle modalità, sovrapposizione di date, procedure troppo confuse, deposito e consultazione documentazione complesso, ecc.)
- [ ] Dispongo di hardware/software inadeguato
- [ ] La connessione che uso è lenta/non continua
- [ ] Problemi ambientali (troppo rumore, confusione, scarsa possibilità di concentrazione)

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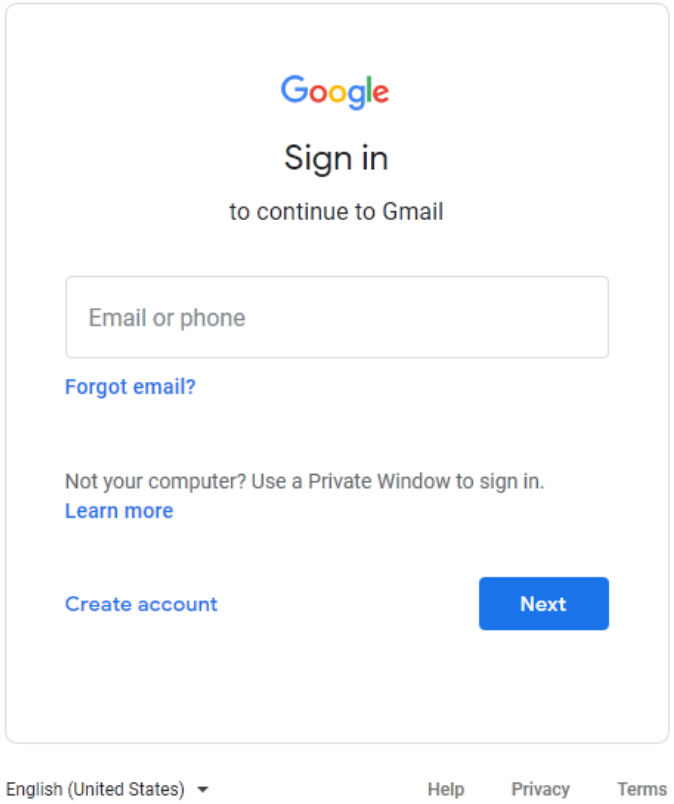
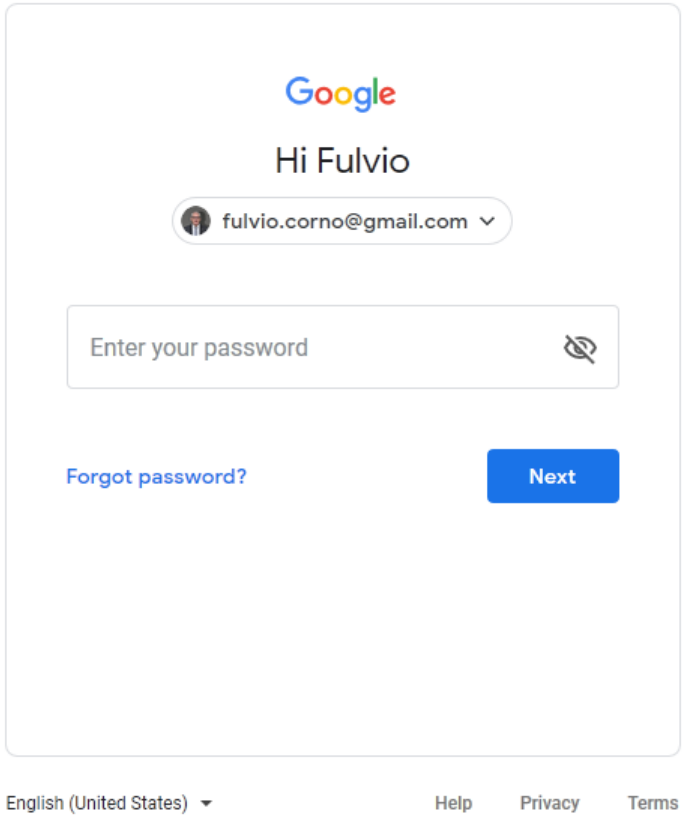
- **Reduce short-term memory load**

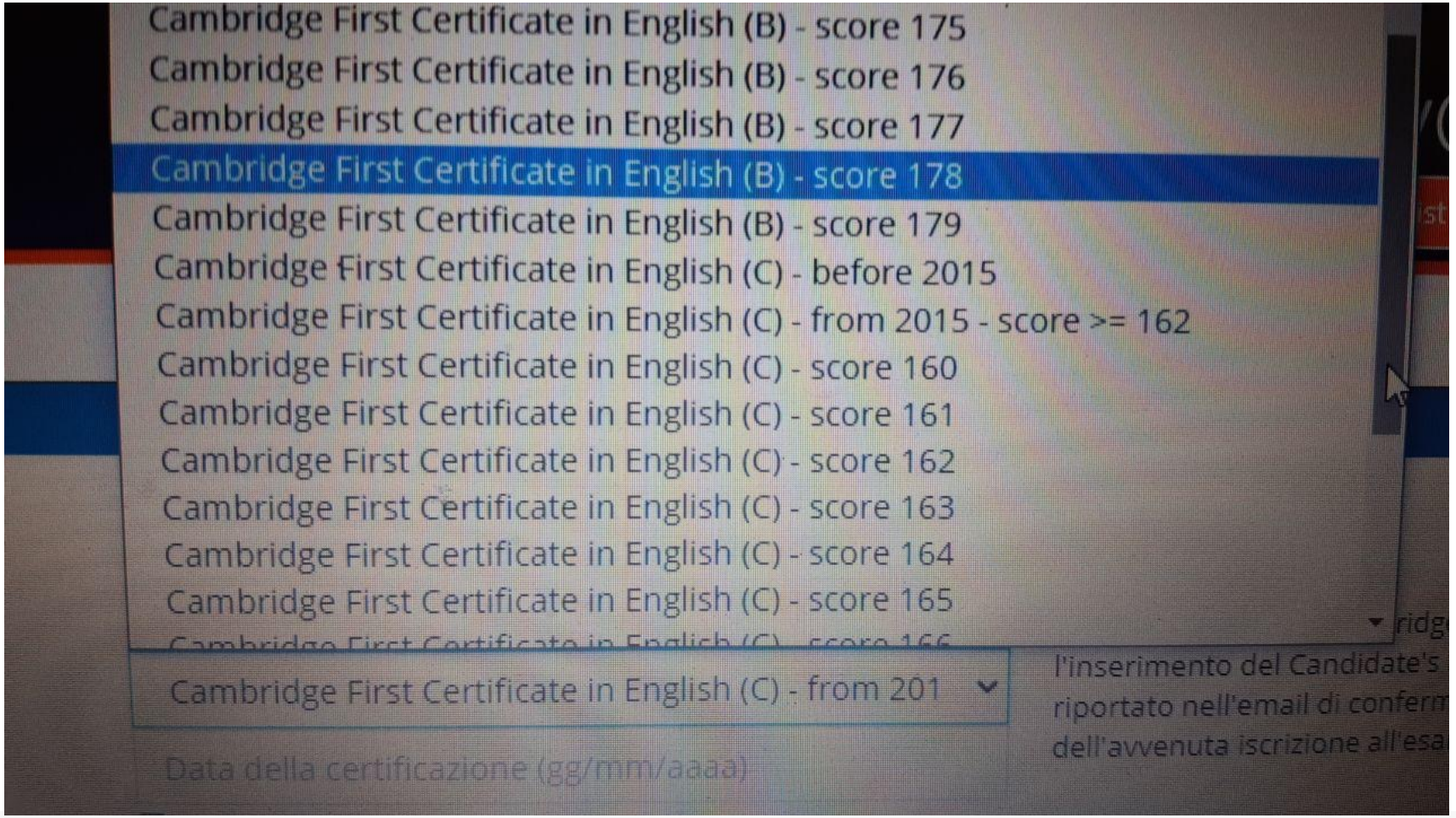
- Rule of thumb:
  - People can remember 7±2 chunks of information
- Information on a screen should not be needed (remembered) in the next screen
- No entry of phone numbers (collect from addressbook), show website location, fit long forms in a single page, …

Discussion – An Exception?





Exceptions…
sometimes entering is better than selecting



Design Principles by Benyon (I)
(adapted from Norman, Nielsen and others)

- **Learnability** – helping people access, learn and remember the system
  - *Visibility* – ensure that things are visible, so users can see what functions are available and what the system is currently doing
  - *Consistency* (→above)
  - *Familiarity* – use language and symbols that the intended audience will be familiar with
  - *Affordance* – design things so it is clear what they are for (e.g., buttons should be pushed). Maps the (perceived) properties of the objects with how they can be used

Affordance

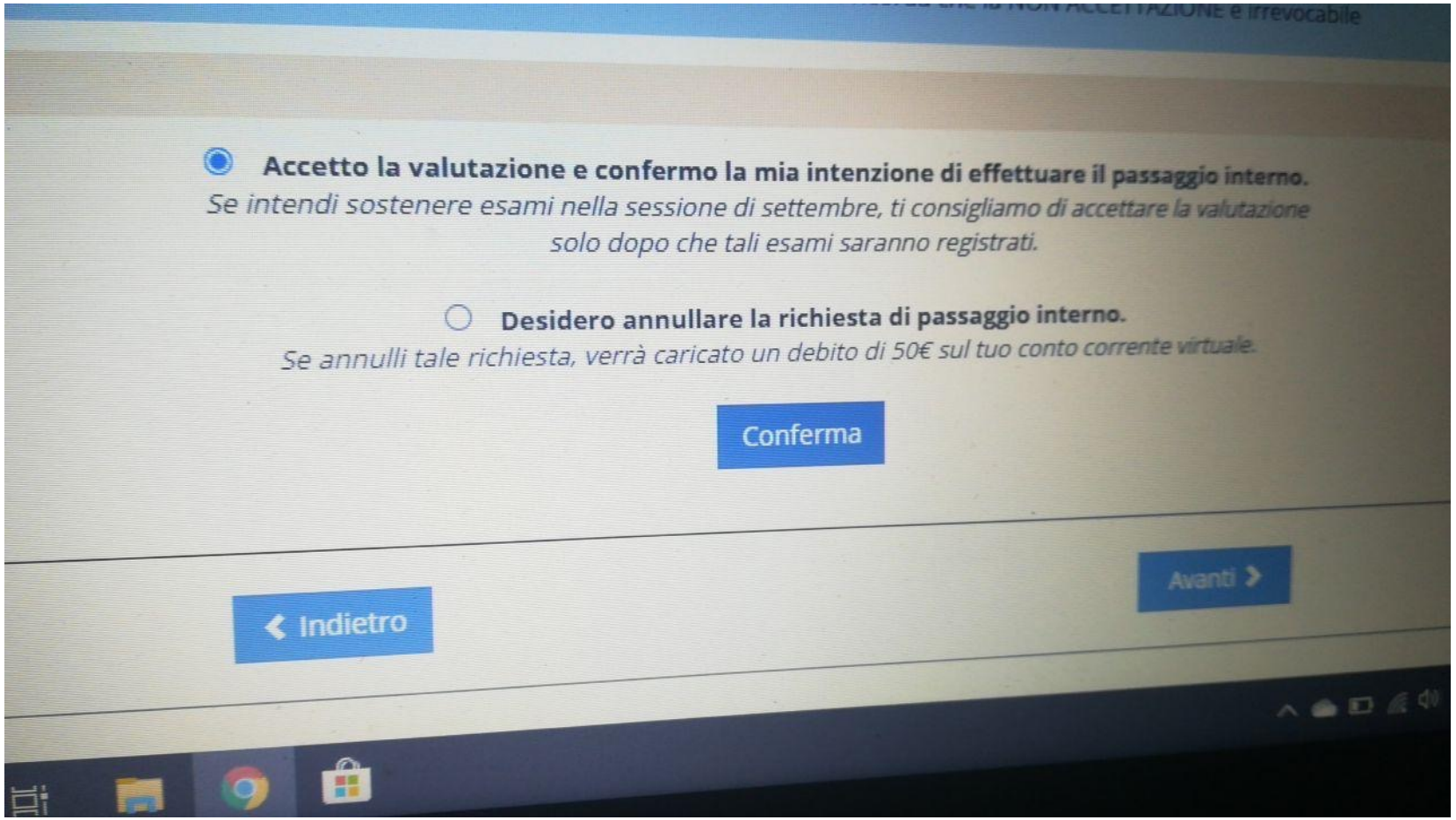

CDs/DVDs
PILES
BOMBETES
BOMBETES BAIX CONSUM
CARTUTXOS TINTA
MÒBILS I CARREGADORS
ESPRAIS
Separar bé
no costa tant
Ajuntament de SantCugat


CDs/DVDs
PILES
BOMBETES
BOMBETES BAIX CONSUM
CARTUTXOS TINTA
MÒBILS I CARREGADORS
ESPRAIS
Separar

Design Principles by Benyon (II)
(adapted from Norman, Nielsen and others)

- **Effectiveness** – giving users the sense of being in control, knowing what to do and how to do it
  - *Navigation* – support people in moving around the different sections: maps, directional signs, information signs
  - *Control* – who is in control for the next interaction? Clear and logical mapping between controls and their effect. Relationships with the "side effects" in the real world
  - *Feedback* (→feedback above)

Example: Navigation and Control?



Design Principles by Benyon (III)
(adapted from Norman, Nielsen and others)

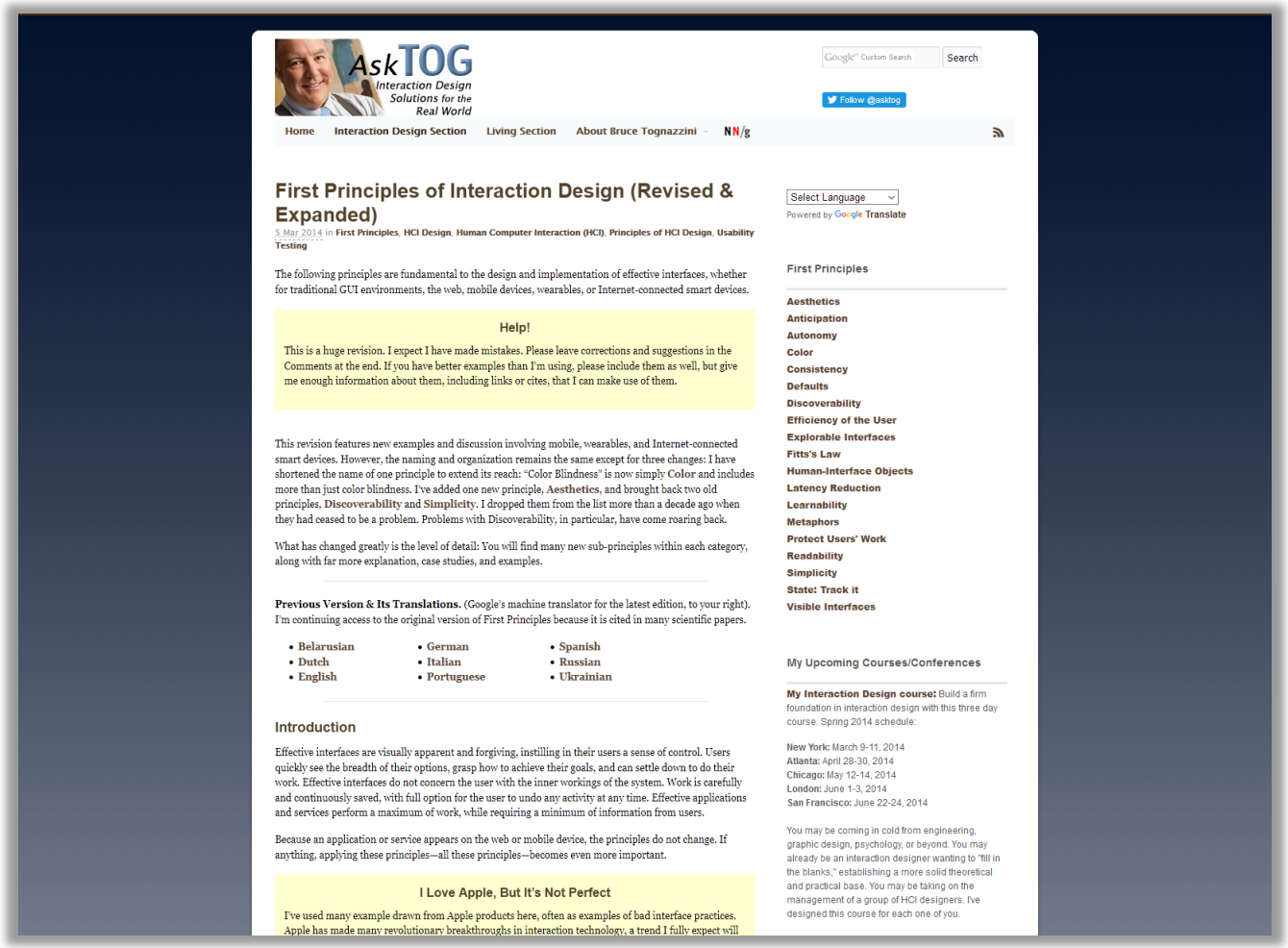
- **Safety and Security**
  - *Recovery* (→error recovery)
  - *Constraints* (→prevent errors)
- **Accommodation** – offer an interaction way that suits the users
  - *Flexibility* (→universal usability)
  - *Style* – stylish, attractive, nice-looking
  - *Conviviality* – polite, friendly, pleasant. No abrupt interruptions

Norman's Seven Principles for Transforming Difficult Tasks into Simple Ones

- Use both knowledge in the world and knowledge in the head
- Simplify the structure of tasks
- Make things visible
- Get the mappings right
- Exploit the power of constraints, both natural and artificial
- Design for error
- When all else fails, standardize

D. Norman, The Design of Everyday Things

First Principles of Interaction Design
(Bruce Tognazzini, 2014)



https://asktog.com/atc/principles-of-interaction-design/

[Aesthetics](#)
[Anticipation](#)
[Autonomy](#)
[Color](#)
[Consistency](#)
[Defaults](#)
[Discoverability](#)
[Efficiency of the User](#)
[Explorable Interfaces](#)
[Fitts's Law](#)
[Human-Interface Objects](#)
[Latency Reduction](#)
[Learnability](#)
[Metaphors](#)
[Protect Users' Work](#)
[Readability](#)
[Simplicity](#)
[State: Track it](#)
[Visible Interfaces](#)

Design Guidelines

Shared language to promote **consistency** among multiple designers in terminology usage, appearance, and action sequences

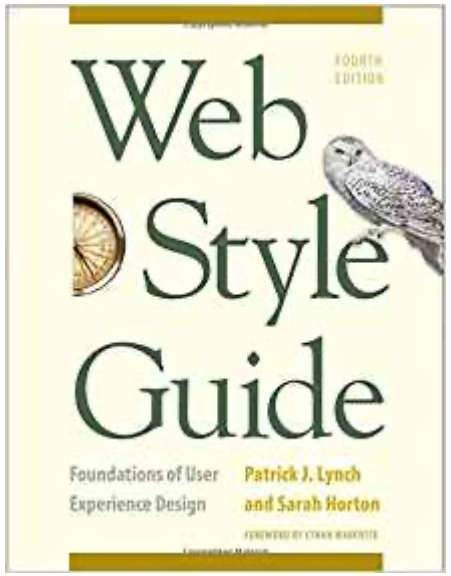
The “How”

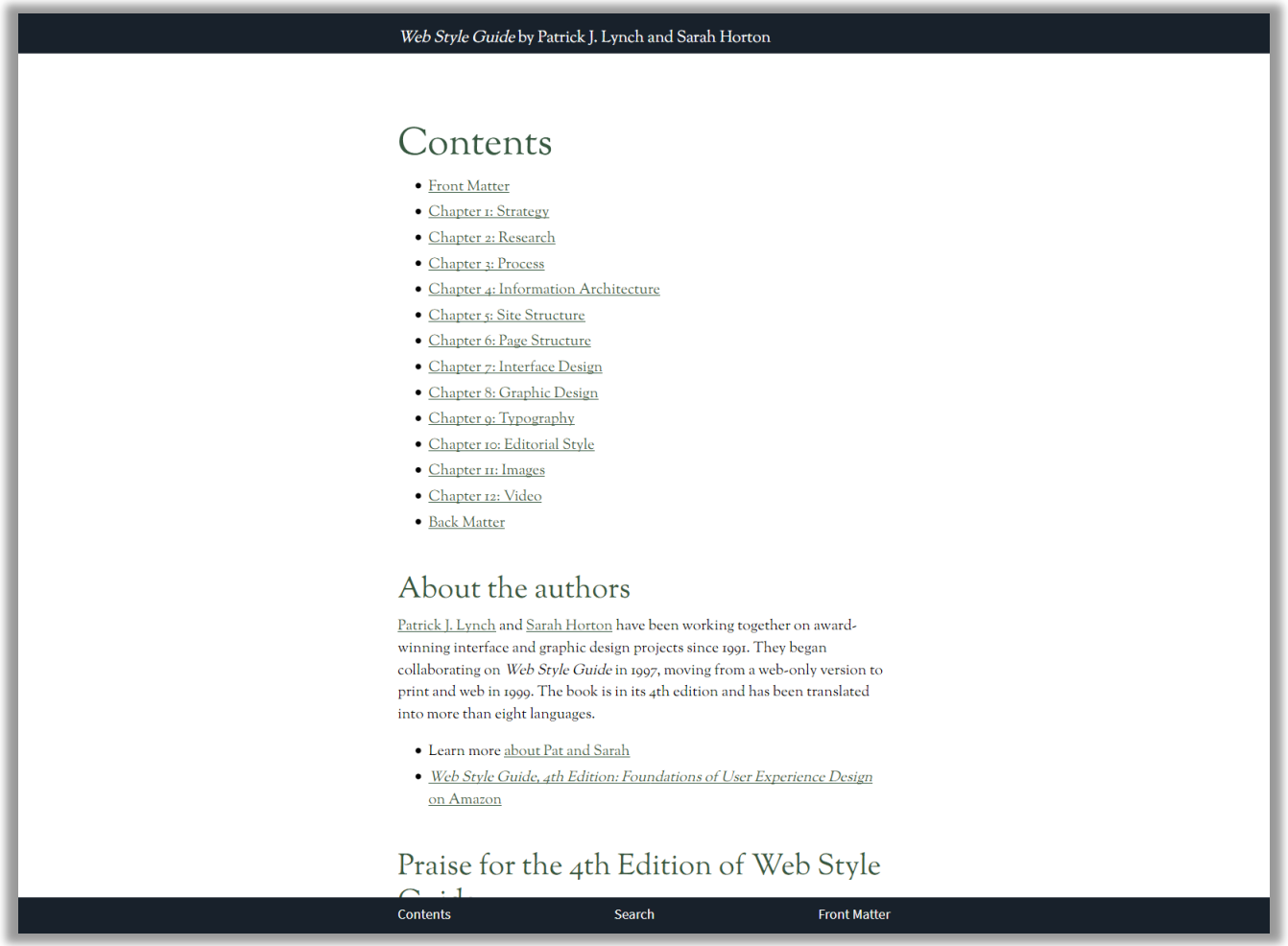
Design Guidelines

- Concrete suggestions about “How” the Principles may be satisfied
- Often rule-based
- Based on best practices
- Encapsulate experience of expert designers
- Sometimes blessed as «standards»
- But:
  - May be too specific and hard to apply to your situation
  - Difficult to develop a general-purpose guideline

Web Style Guide

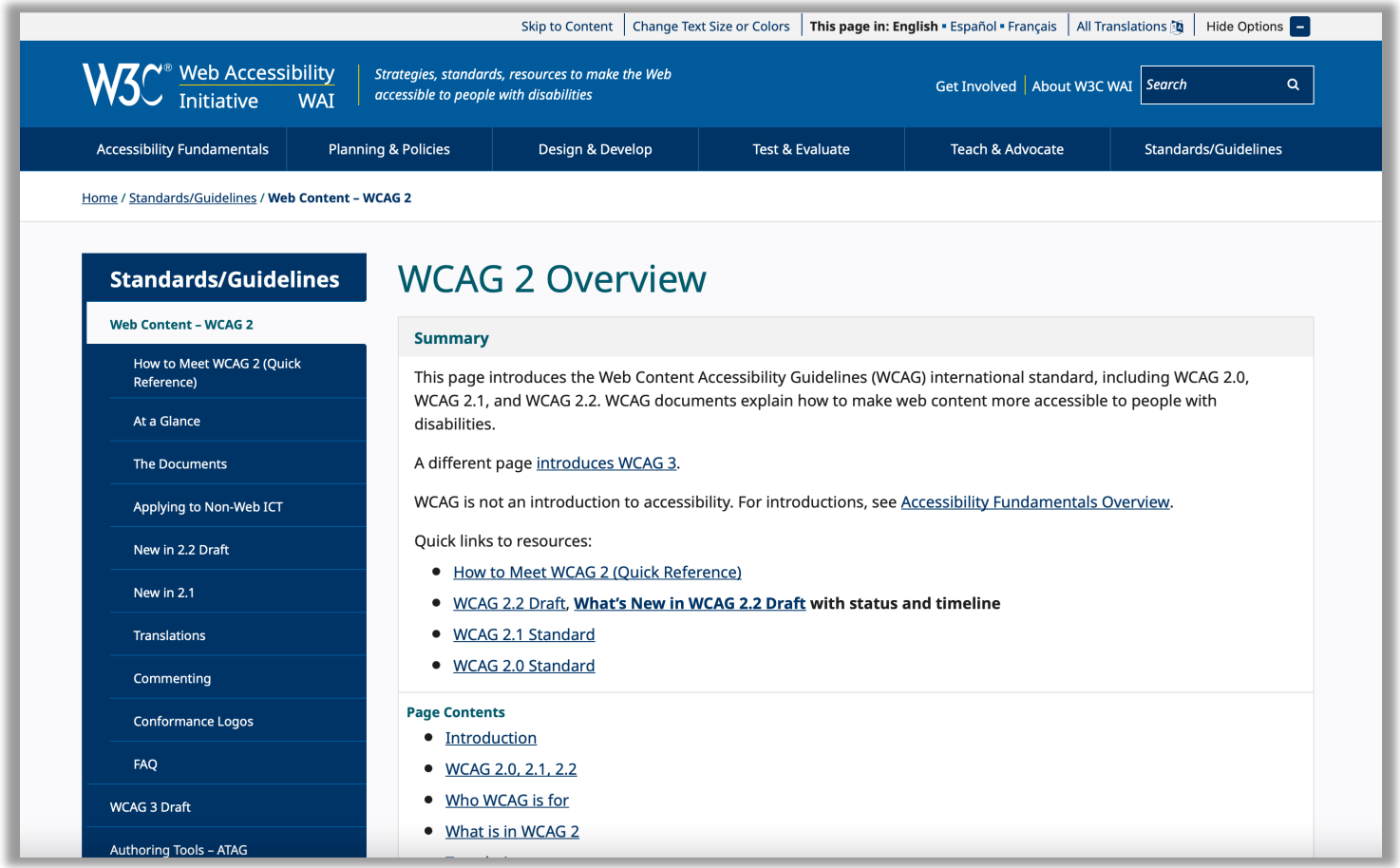
Web Style Guide, 4th Edition: Foundations of User Experience Design (2016)
https://webstyleguide.com/





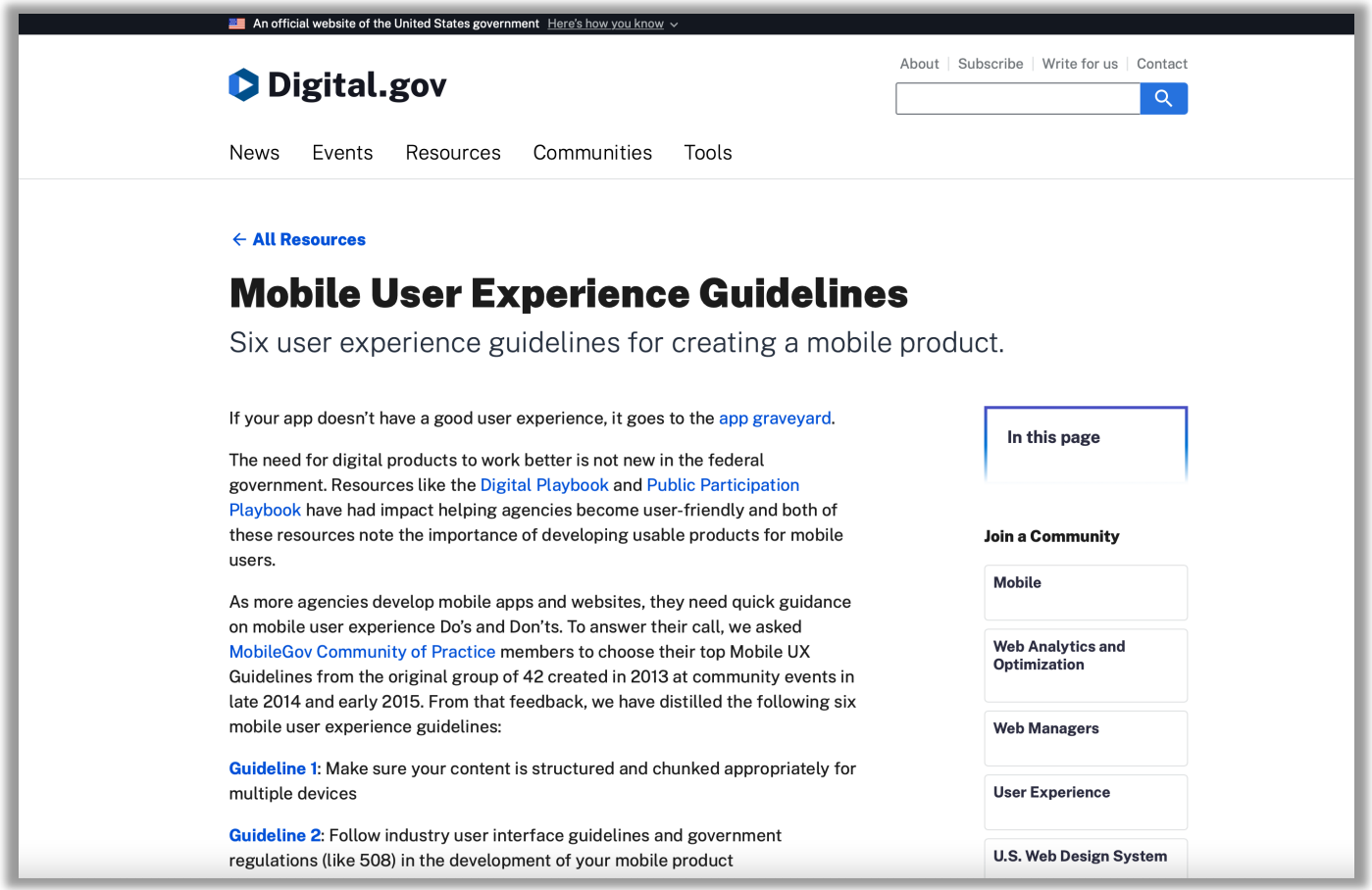
Web Content Accessibility Guidelines (WCAG)

https://www.w3.org/WAI/standards-guidelines/wcag/

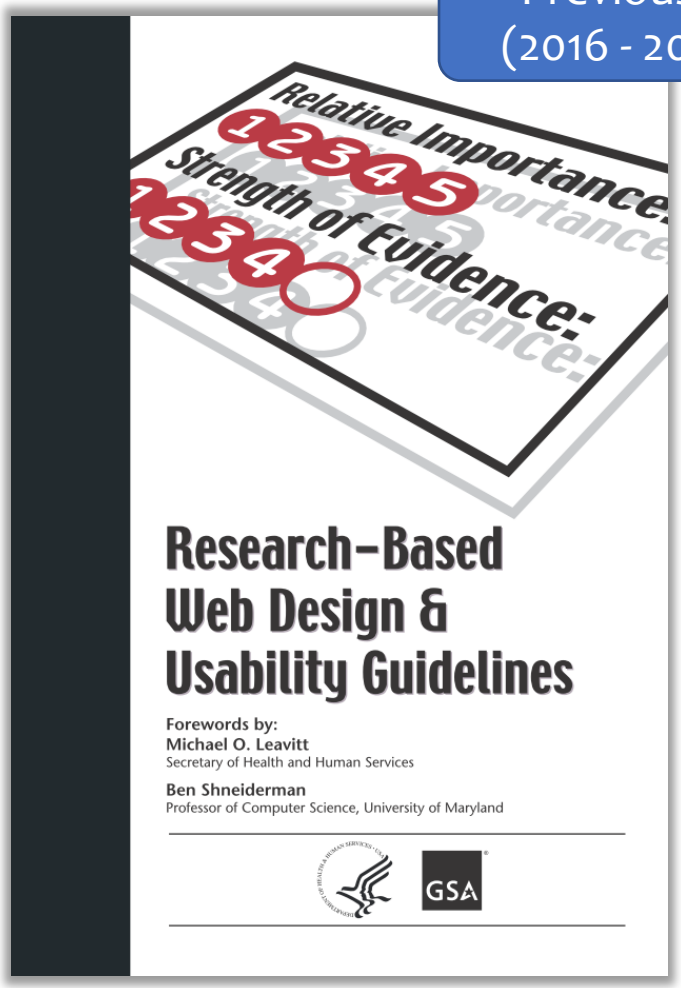


U.S. Government Mobile User Experience Guidelines

U.S. General Service Administration
https://digital.gov/resources/mobile-user-experience-guidelines/

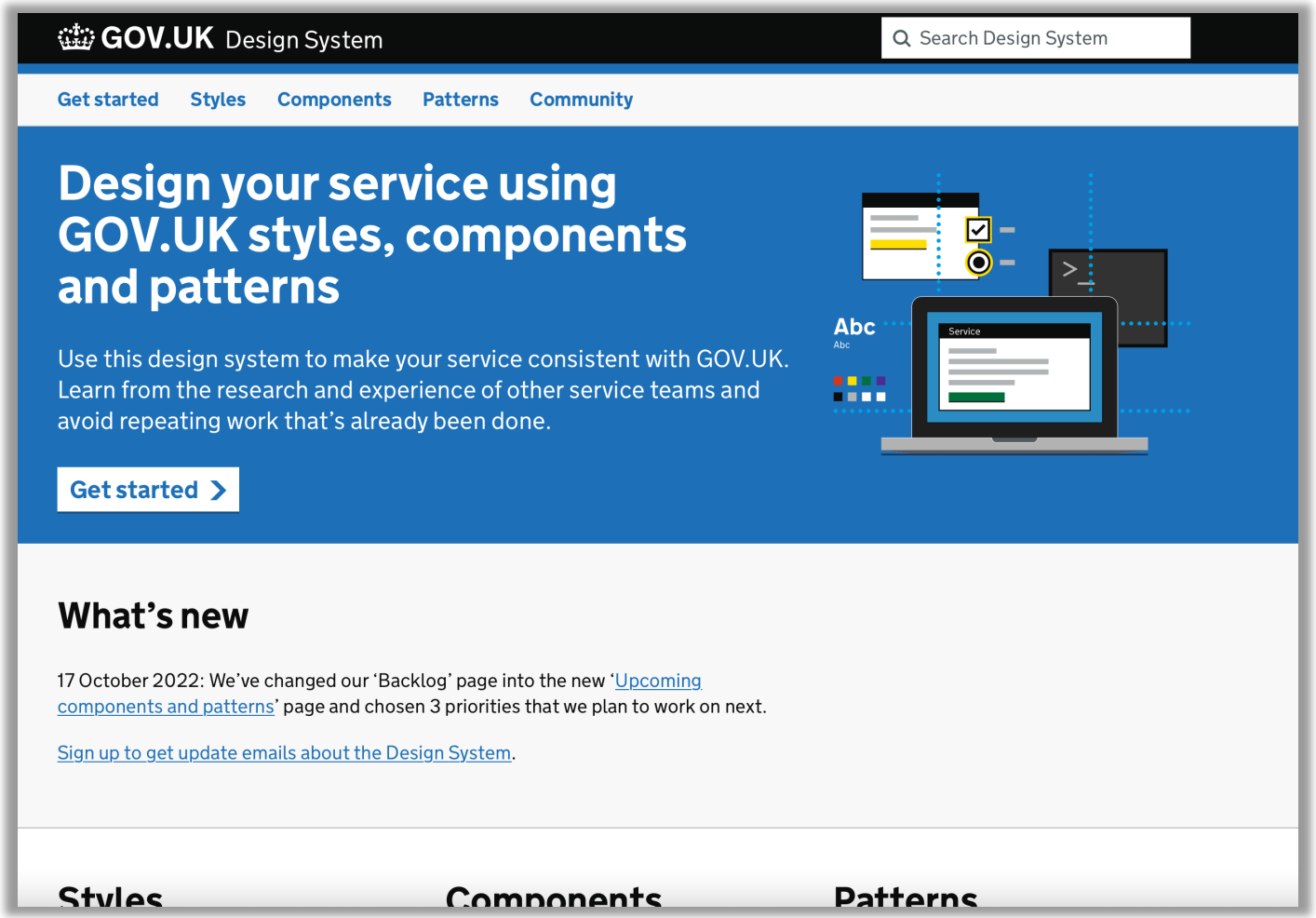


Previously (2016 - 2021)



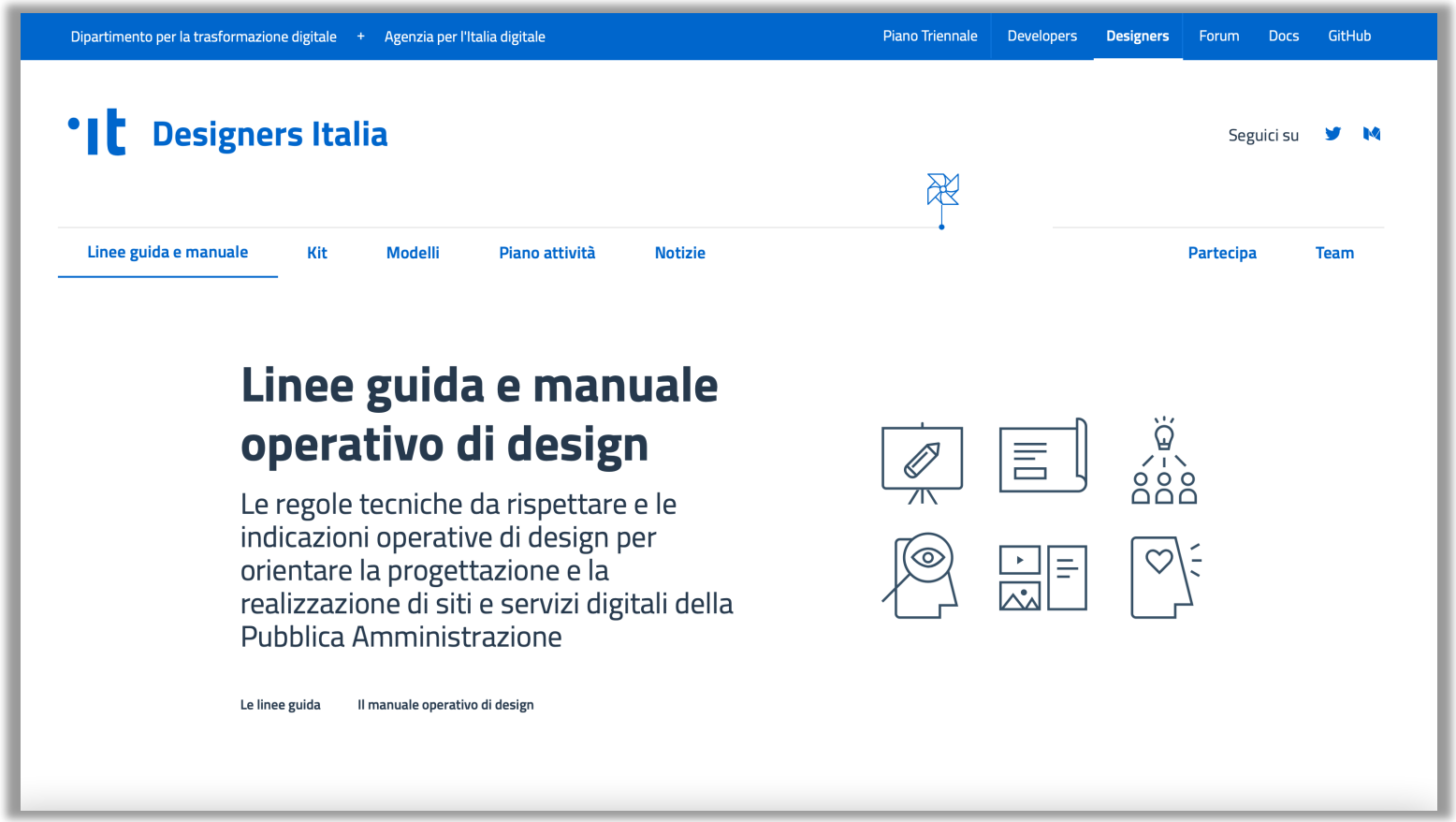
U.K. Government Design System

https://design-system.service.gov.uk



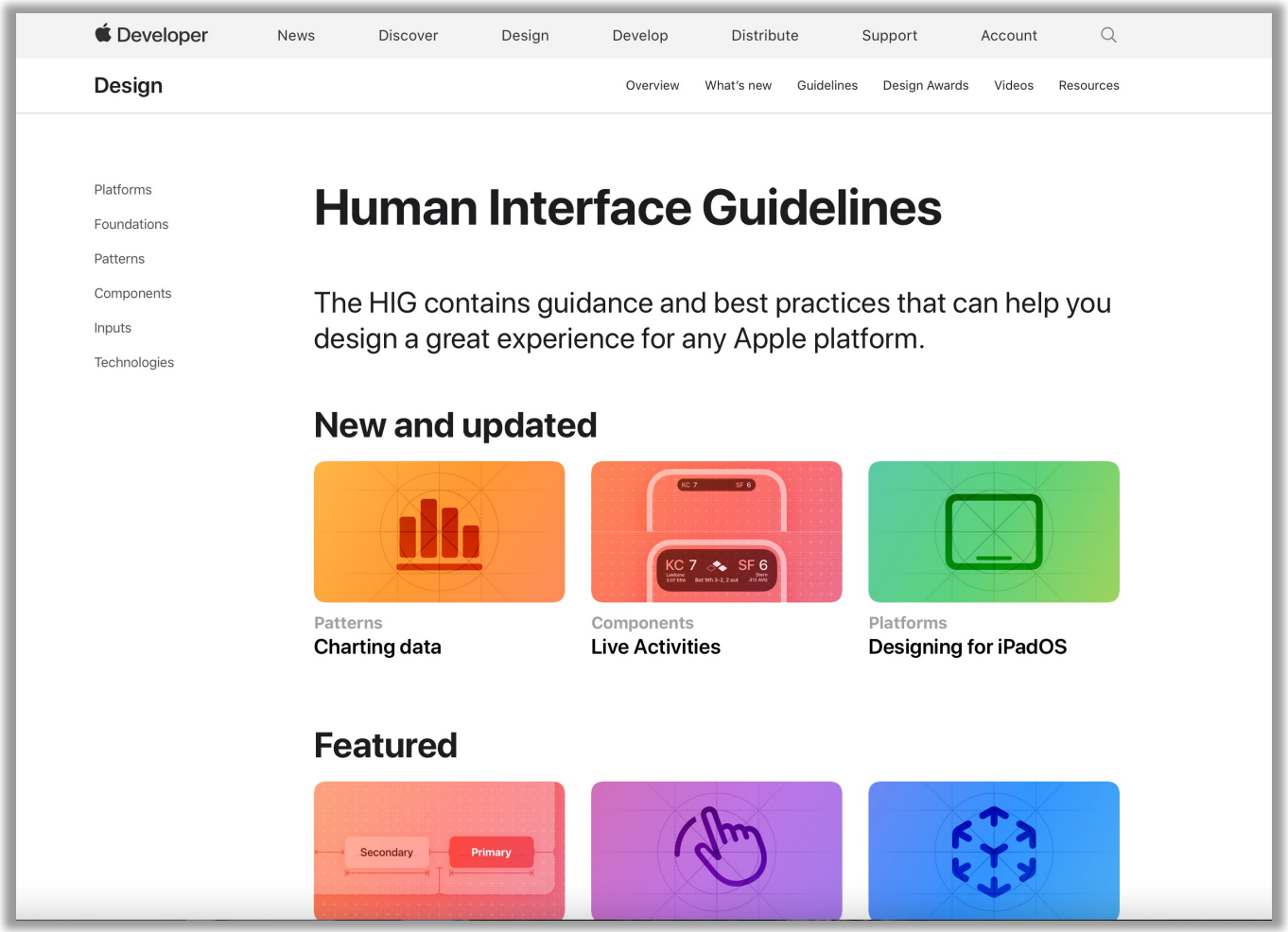
Italian Government Guidelines and Design System

https://designers.italia.it/linee-guida/



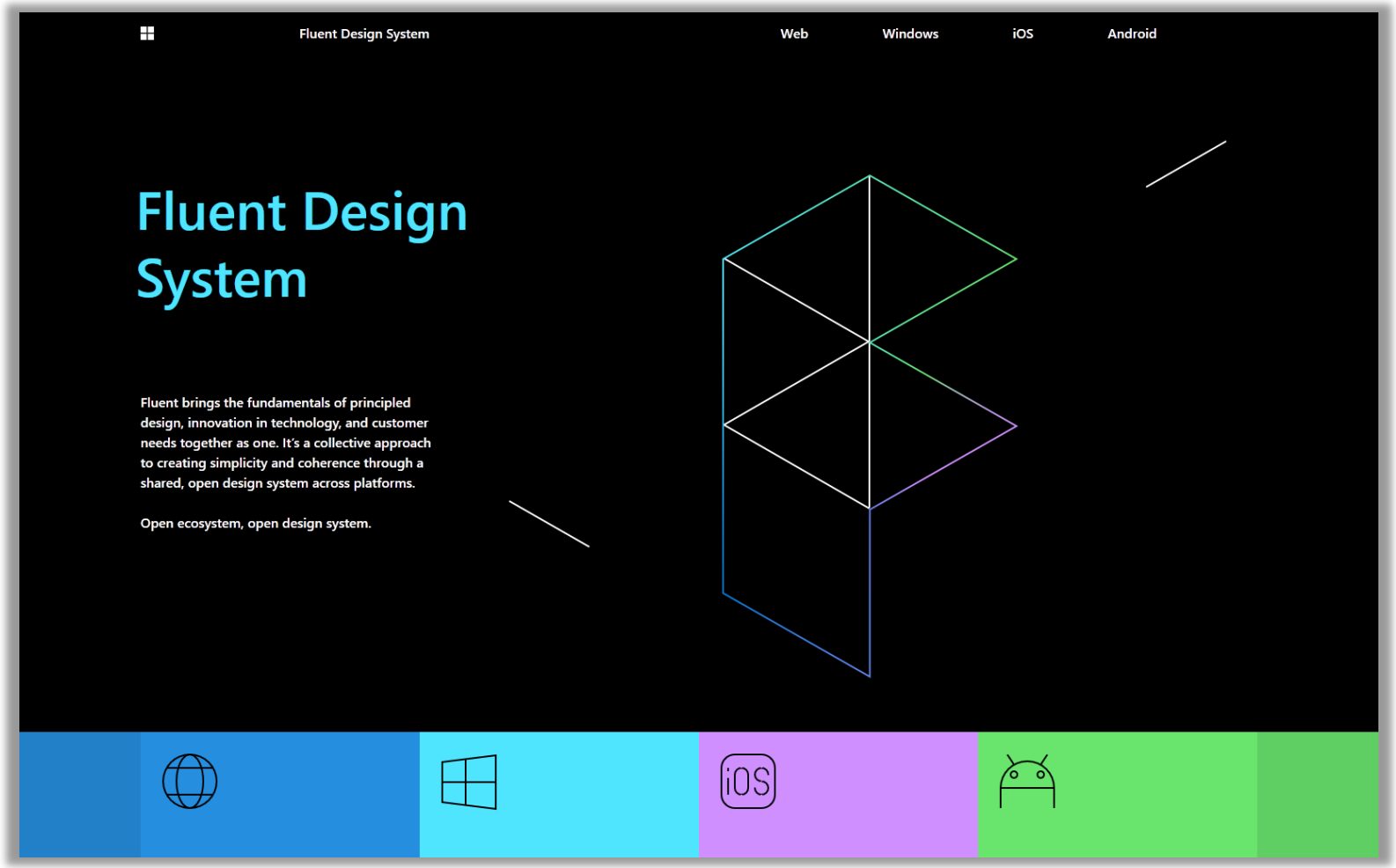
Apple HIG

https://developer.apple.com/design/human-interface-guidelines/



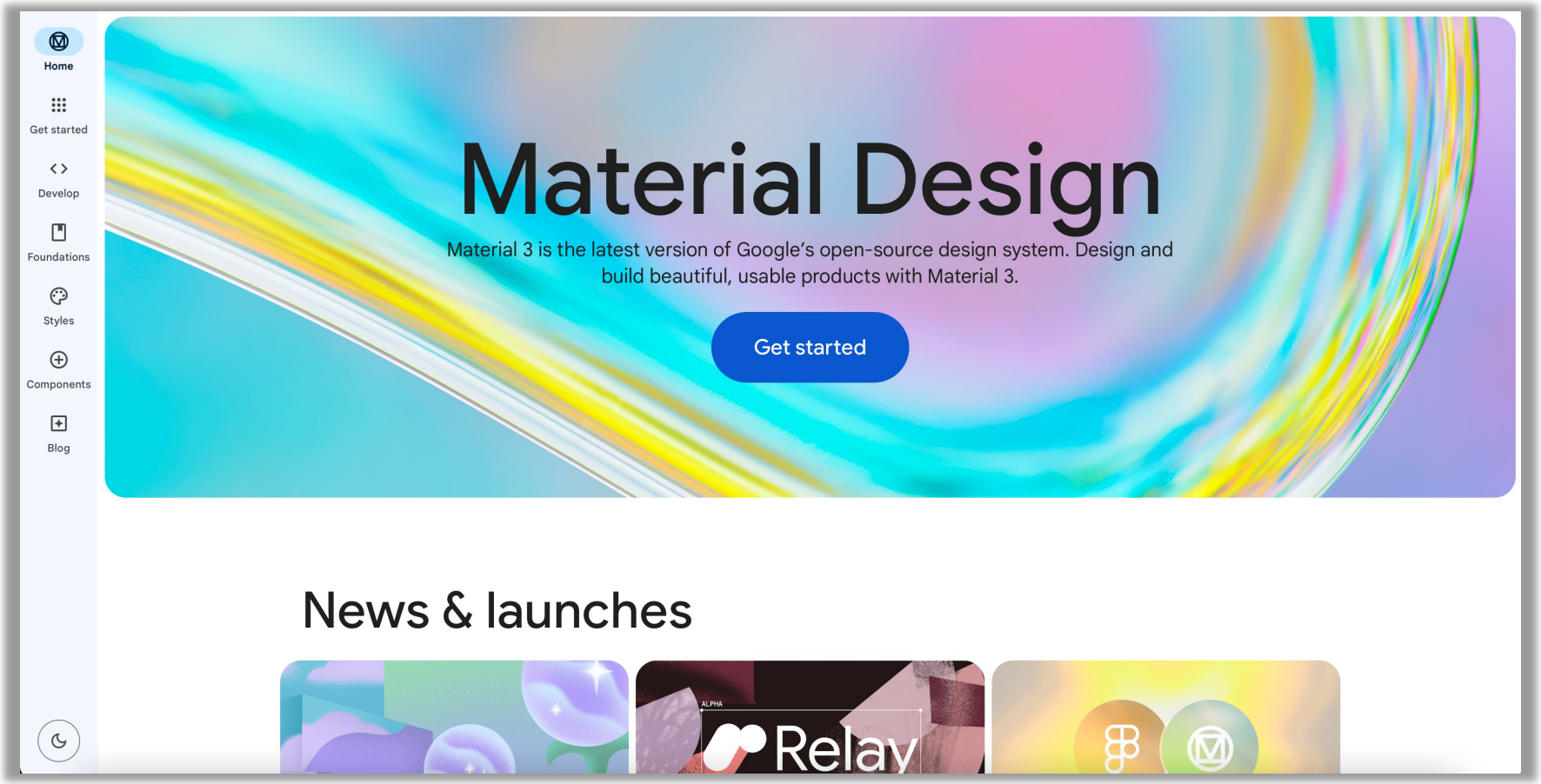
Microsoft «Fluent» Design

https://www.microsoft.com/design/fluent/



Google Material Design

https://material.io/



Guidelines for Human-AI Interaction

- By Microsoft Research:
  - https://www.microsoft.com/en-us/research/project/guidelines-for-human-ai-interaction/
  - https://www.microsoft.com/en-us/haxtoolkit/ai-guidelines/

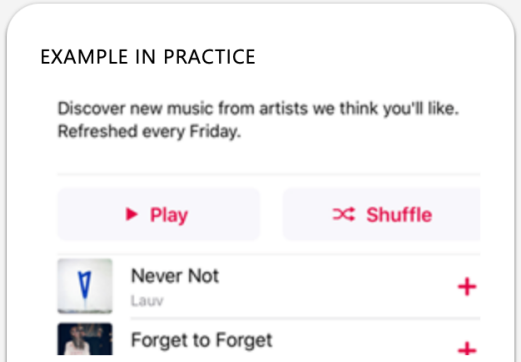
Guidelines for Human-AI Interaction: Examples

2
INITIALLY

Make clear how well the system can do what it can do.

Help the user understand how often the AI system may make mistakes.

EXAMPLE IN PRACTICE



The recommender in **Apple Music** uses language such as "we think you'll like" to communicate uncertainty.

Make clear how well the system can do what it can do. 2

9
WHEN WRONG

Support efficient correction.

Make it easy to edit, refine, or recover when the AI system is wrong.

EXAMPLE IN PRACTICE

When **Bing** automatically corrects spelling errors in search queries, it provides the option to revert to the query as originally typed with one click.

Support efficient correction. 9

Guidelines for Augmented Reality

- By Apple Design: https://developer.apple.com/design/human-interface-guidelines/technologies/augmented-reality/

Creating an engaging, comfortable experience

Let people use the entire display. Devote as much of the screen as possible to displaying the physical world and your app's virtual objects. Avoid cluttering the screen with controls and information that diminish the immersive experience.

Strive for convincing illusions when placing realistic objects. Design detailed 3D assets with lifelike textures to create objects that appear to inhabit the physical environment in which you place them. Using information from ARKit, you can scale objects properly and position them on detected real-world surfaces, reflect environmental lighting conditions and simulate camera grain, cast top-down diffuse object shadows on real-world surfaces, and update visuals as the camera's position changes. To help avoid breaking the illusion you create, make sure your app updates scenes 60 times per second so objects don't appear to jump or flicker.

Consider how virtual objects with reflective surfaces show the environment. Reflections in ARKit are approximations based on the environment captured by the camera. To help maintain the illusion that an AR experience is real, prefer small or coarse reflective surfaces that downplay the effect of these approximations.

Use audio and haptics to enhance the immersive experience. A sound effect or bump sensation is a great way to confirm that a virtual object has made contact with a physical surface or other virtual object. Background music can also help envelop people in the virtual world. For guidance, see Playing audio and Playing haptics.

Minimize text in the environment. Display only the information that people need for your app experience.

References and Acknowledgments

- Ben Shneiderman, Catherine Plaisant, Maxine S. Cohen, Steven M. Jacobs, and Niklas Elmqvist, Designing the User Interface: Strategies for Effective Human-Computer Interaction
  - Chapter 3: Guidelines, Principles, and Theories
- David Benyon: Designing Interactive Systems, Pearson, 2014
  - Section 4.5: Design Principles
- COGS120/CSE170: Human-Computer Interaction Design, videos by Scott Klemmer, https://www.youtube.com/playlist?list=PLLssT5z_DsK_nusHL_Mjt87THSTlgrsyJ
- Fitts' Law: https://www.interaction-design.org/literature/topics/fitts-law

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