17-423/723: Software System Design

Design for Usability

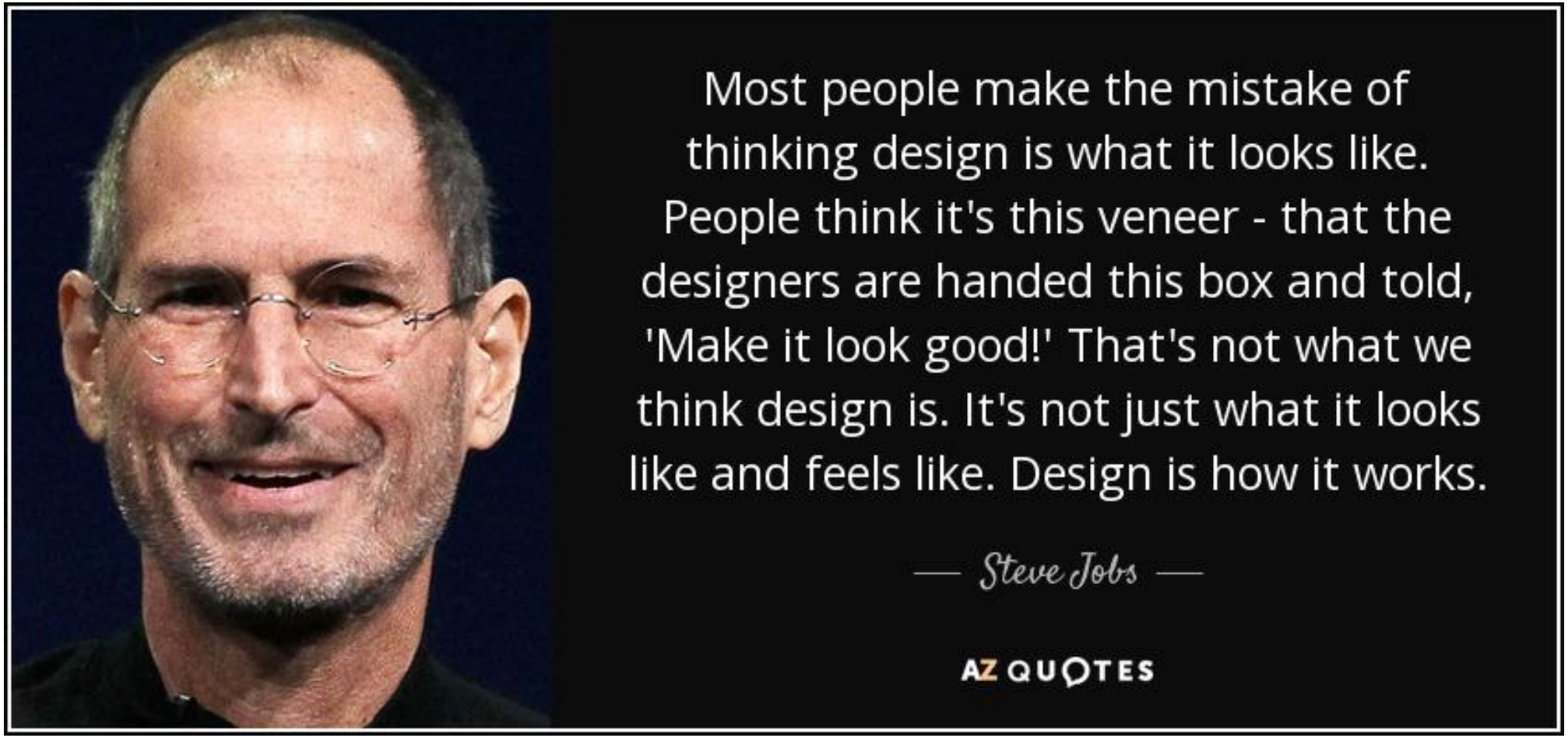
April 6, 2026

Logistics

- **Reminder**: M4 due on this Wednesday
  - All the services must be fully integrated and working end-to-end
  - The course staff will begin calling your external APIs and interact with the food rescue apps soon after
- HW2 out
  - Exploring a redesign of the food rescue system for scalability
  - Due Friday, April 17

Learning Goals

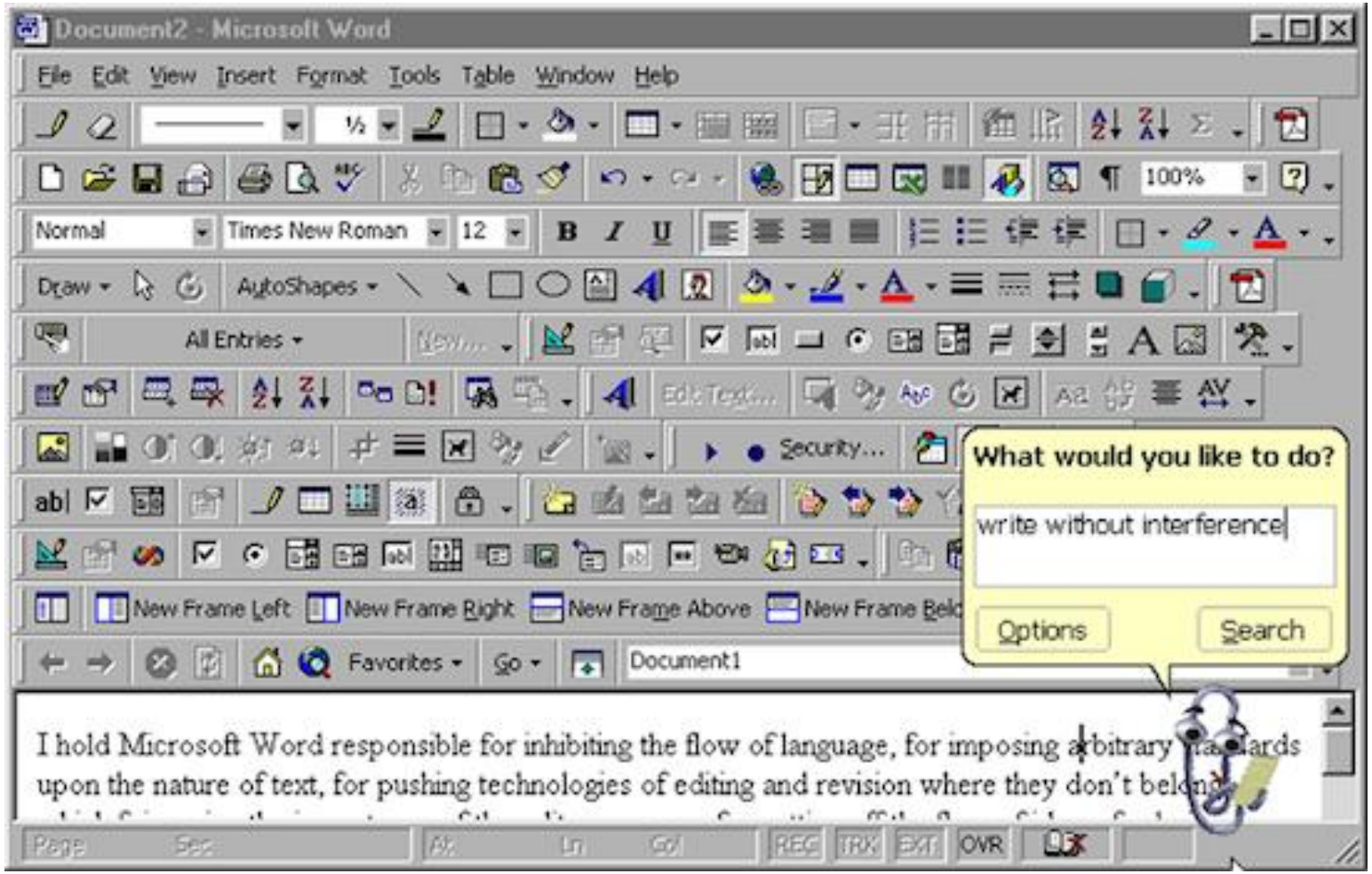
- Describe the basic concepts in usability and the goal of usable design
- Identify a user's mental model for the system being designed
- Identify potential mismatches between the mental model and the system
- Apply strategies to help adjust the user's mental model to the system


Most people make the mistake of thinking design is what it looks like. People think it's this veneer - that the designers are handed this box and told, 'Make it look good!' That's not what we think design is. It's not just what it looks like and feels like. Design is how it works.
— Steve Jobs —
AZ QUOTES

Usability Concepts

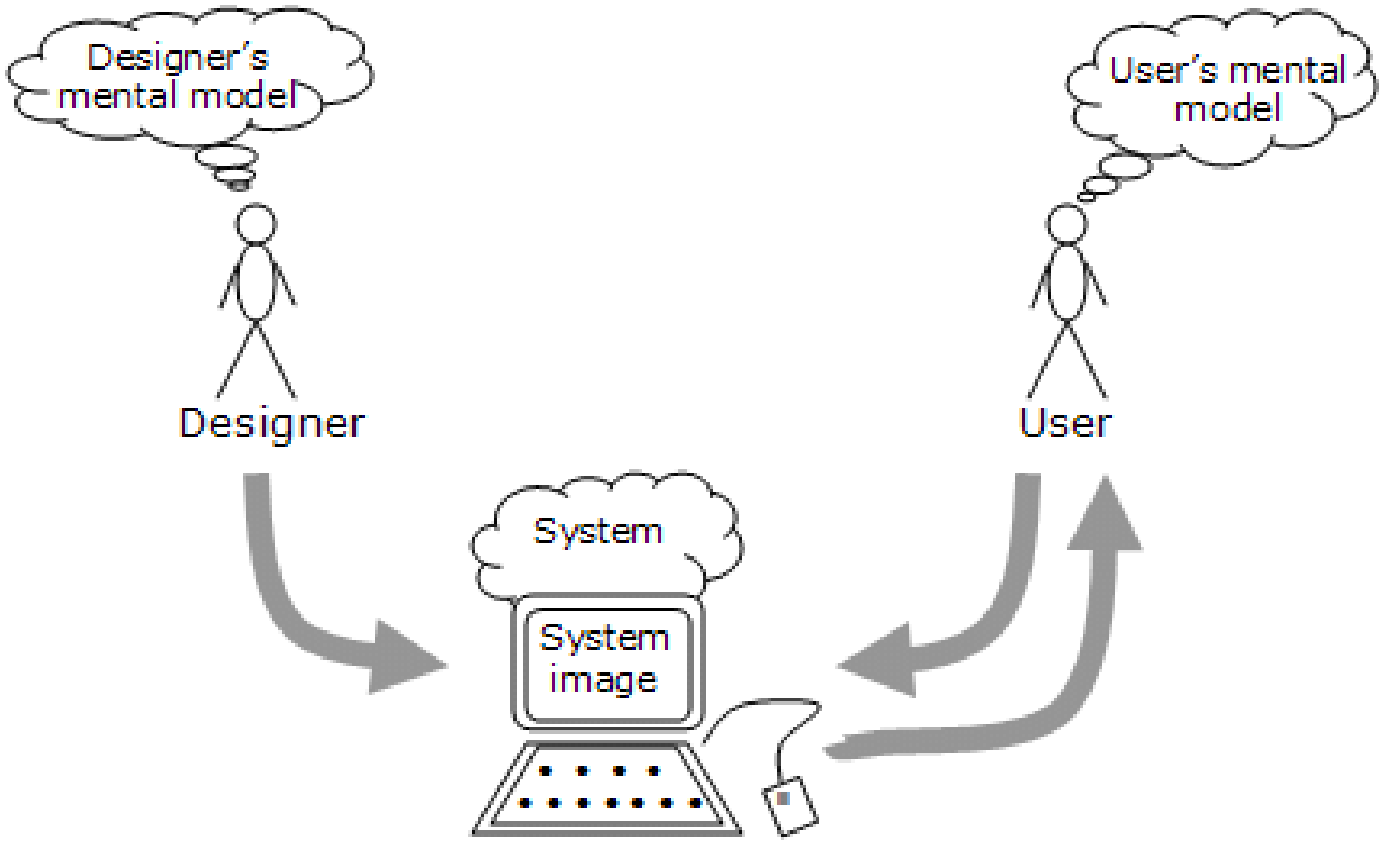
- **Learnability**: How easy is it for users to perform a task the first time?
- **Efficiency**: After learning, how efficiently can users perform the task?
- **Memorability**: Can users remember to perform the task after a period of not using the system?
- **Errors**: How often do users make errors, how severe are these errors, and how easily can they recover from the errors?
- **Satisfaction**: How pleasant is it to use the design?

Interaction Cost

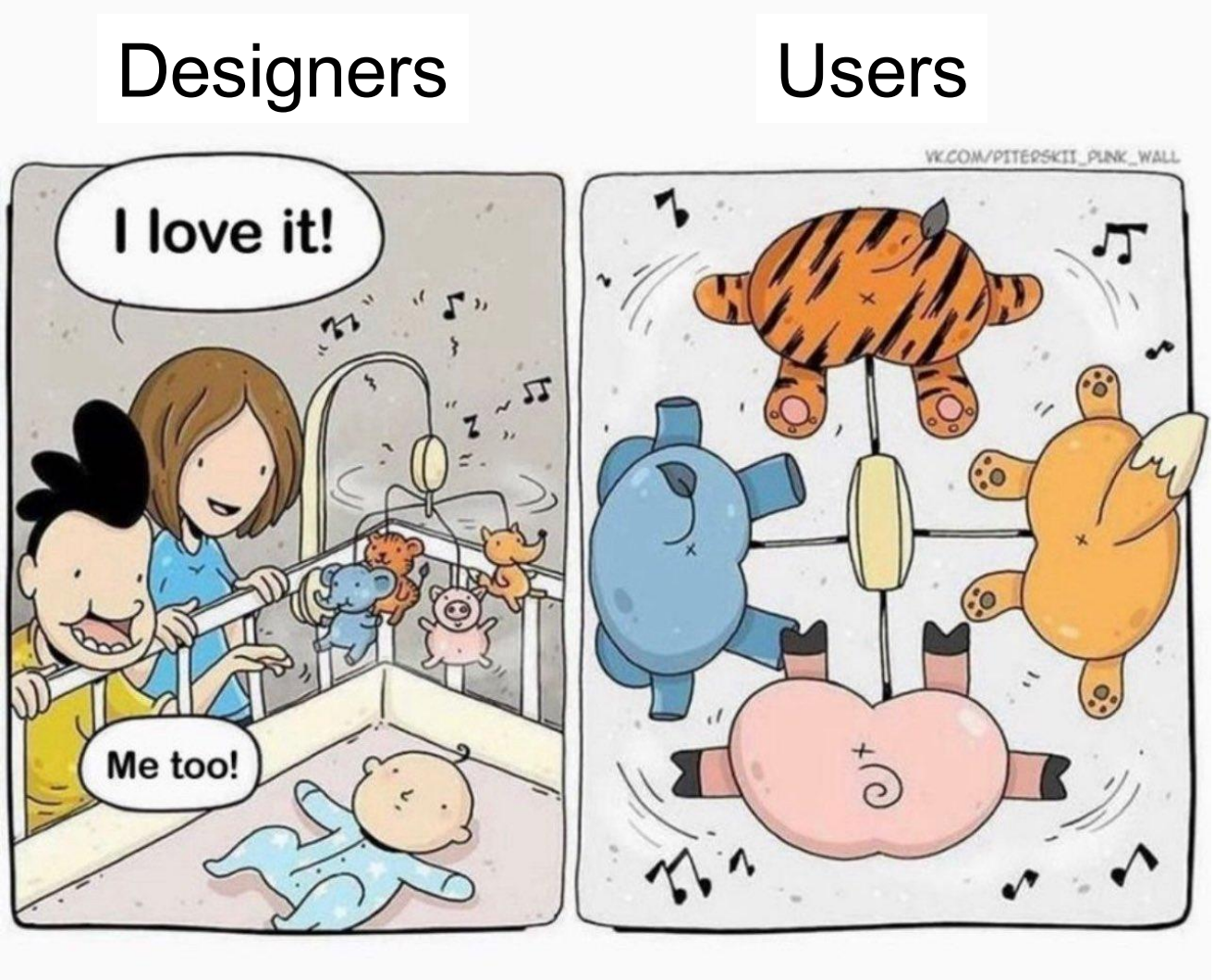


- Amount of mental & physical effort to perform a desired task
  - Reading, scrolling, clicking, typing, switching contexts, memorizing
- **Goal of usable design**: Minimize interaction cost while allowing users to achieve their goals

Mental Model



- A person's expectation and belief of how a system works
  - What is the sequence of actions that I need to perform to complete my task?
  - What is the current state of the system?
  - What actions can I perform from the current state?
  - What will happen next if I perform Action X?



What the designer sees ≠ what the user sees!

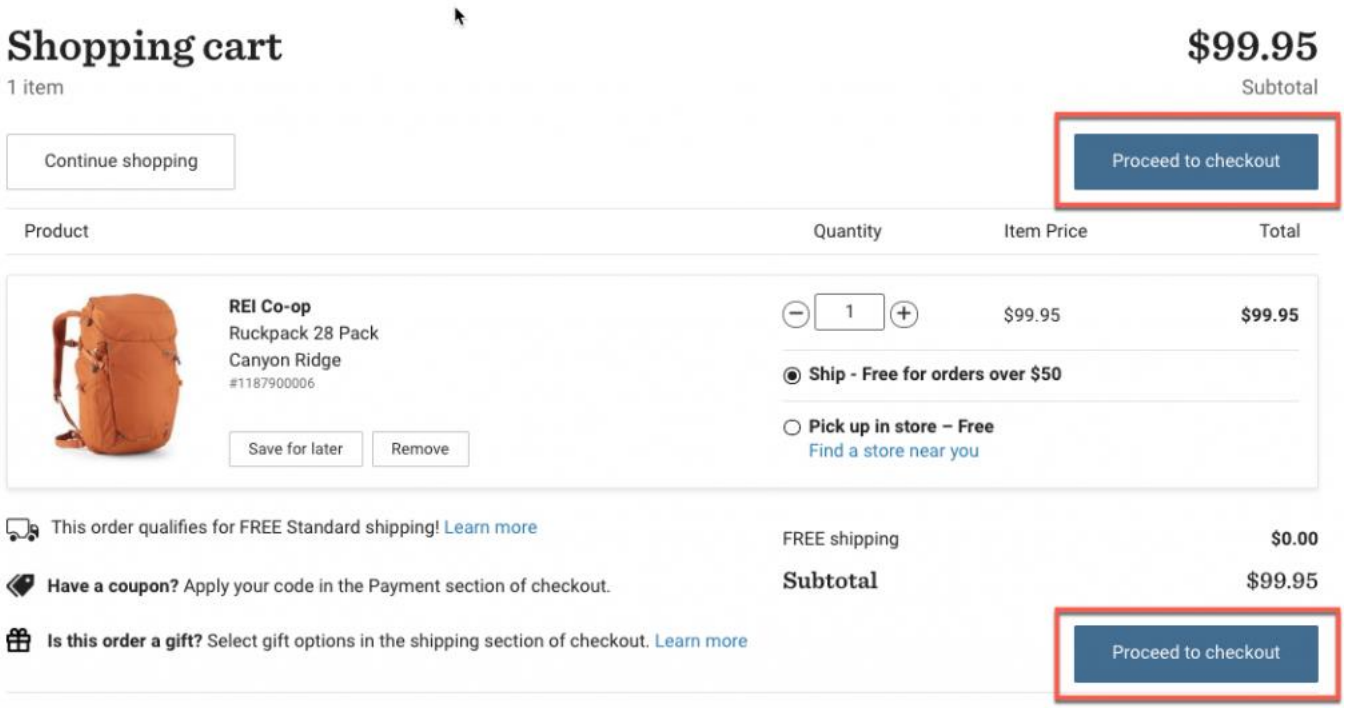
Mental Model Mismatch

- Divergence between a user's mental model & actual system behavior
- A mental model mismatch can manifest as the user
  - Showing confusion about the current state of the system
  - Being unsure about what actions are available and/or trying out random actions
  - Performing an incorrect/erroneous action
  - Restarting or simply quitting the system

Mental Model Mismatch

- Divergence between a user's mental model & actual system behavior
- A mental model mismatch can:
  - Cause confusion and frustration in users
  - Increase interaction costs
  - Increase chance of user errors
- Usually these lead to negative consequences for the system
  - Loss of users and revenues, complaints, low product ratings, accidents…

Example: Shopping Cart Checkout



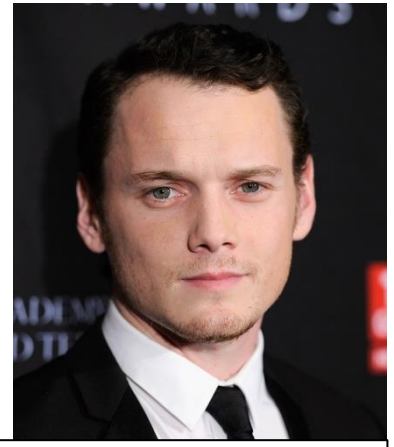
- Common mental model for online shopping:
  - Browse for items -> Add items to cart -> Choose checkout -> Enter shipping & billing data -> Press submit -> Get confirmation

Example: Shopping Cart Checkout

- Common **anti-pattern**: Non-linear interaction process
  - Interrupts the flow: Create an account, open a new dialog to enter a preferred address, suggest other items to buy…
  - Deviates from the user's mental model
  - **~60% of customers abandon** their shopping cart; failure to convert into sales!

Source: Why Your Checkout Process Should Be Completely Linear

Example: Gear Shifter

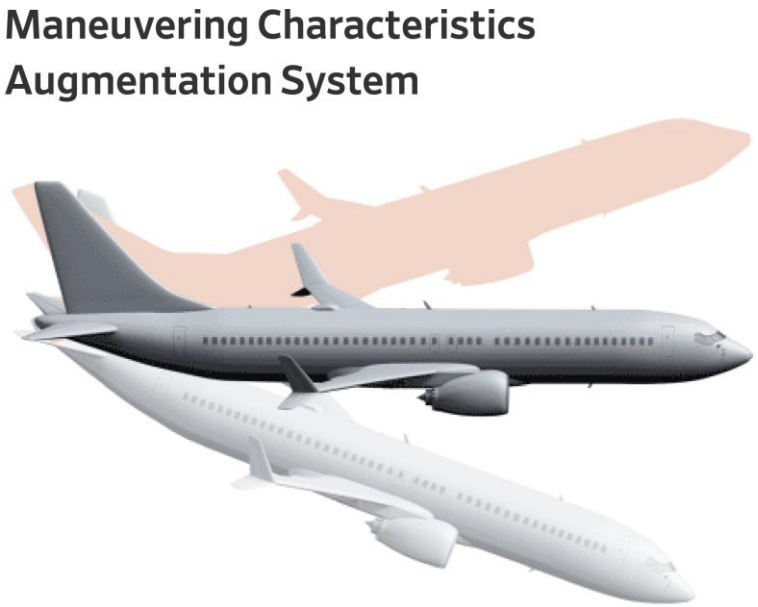


Recalled Shifter May Have Played a Part in Actor Anton Yelchin's Death

His Jeep Grand Cherokee has the type of shifter many find confusing

- Fiat Chrysler vehicles (mid 2010s)
- A new gear shifter design; radical departure from standard design
- Drivers frequently became confused between modes (e.g., Park vs. Reverse)
- 266 crashes, 68 injuries, 1.1 million vehicles recalled

Example: Boeing 737 MAX



Source: Preliminary accident reports accidents

- MCAS: Keep the plane nose down if the detected angle is too high
- A faulty sensor indicates high nose angle; MCAS is activated
- Pilot sees nose being pushed down and attempts to correct, but is unaware that MCAS is overriding the control

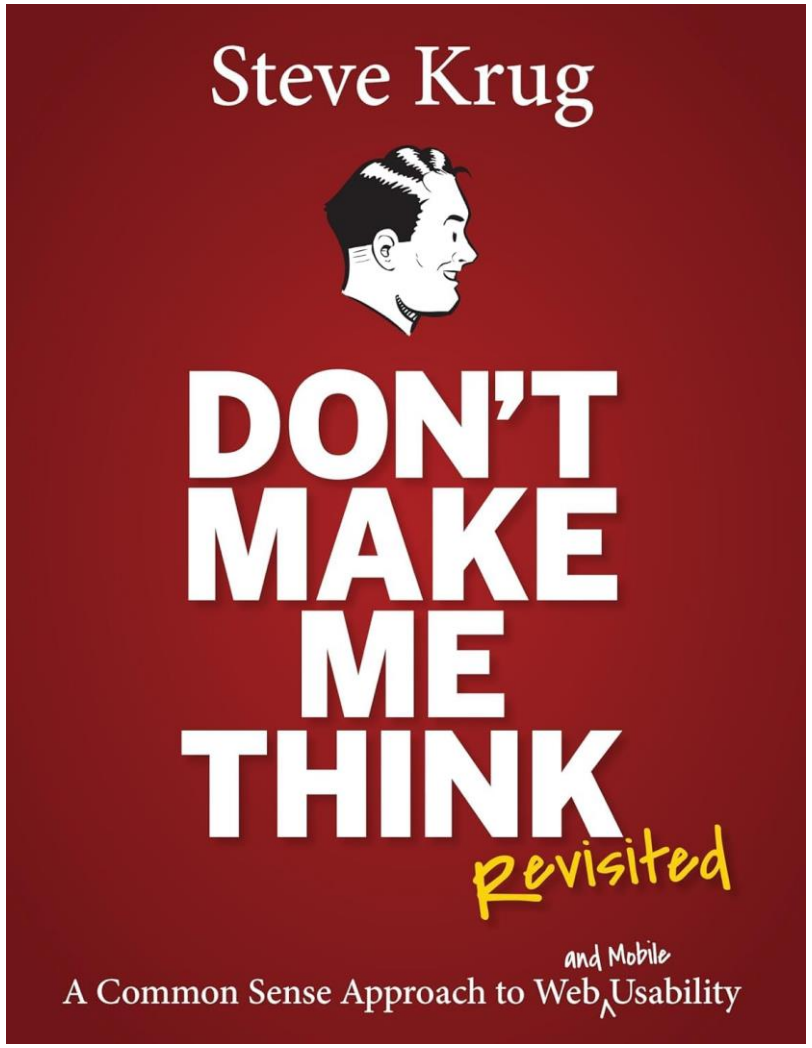
Boeing 737 MAX

- Boeing skipped out on proper pilot training (to save costs)
- Pilots often confused & not equipped to respond to MCAS failures
- Two major accidents involving a MCAS failure:
  - Lion Air Flight 610: 189 deaths (2018)
  - Ethiopian Airlines Flight 302: 157 deaths (2019)

Mental Model Alignment

- **Principle**: The user's mental model must be **aligned** with the observable behavior of the system
- **Strategies** for achieving alignment:
  - Identify the user's existing mental model
  - Adjust the system to conform to the user's mental model
  - Adjust the user's mental model to conform to the system

Identifying User's Mental Model



- Find similar systems & identify a common mental model
  - **Mental-model inertia**: Users tend to stick to an existing model and are reluctant to change
    - Users rarely read documentation or manuals
    - Users are unwilling to learn a new interface unless there are clear benefits
  - Be conservative; don't innovate in user interfaces unless necessary

Shopping Cart and Checkout Process

Browsing Products

Add items to Cart

Billing Info

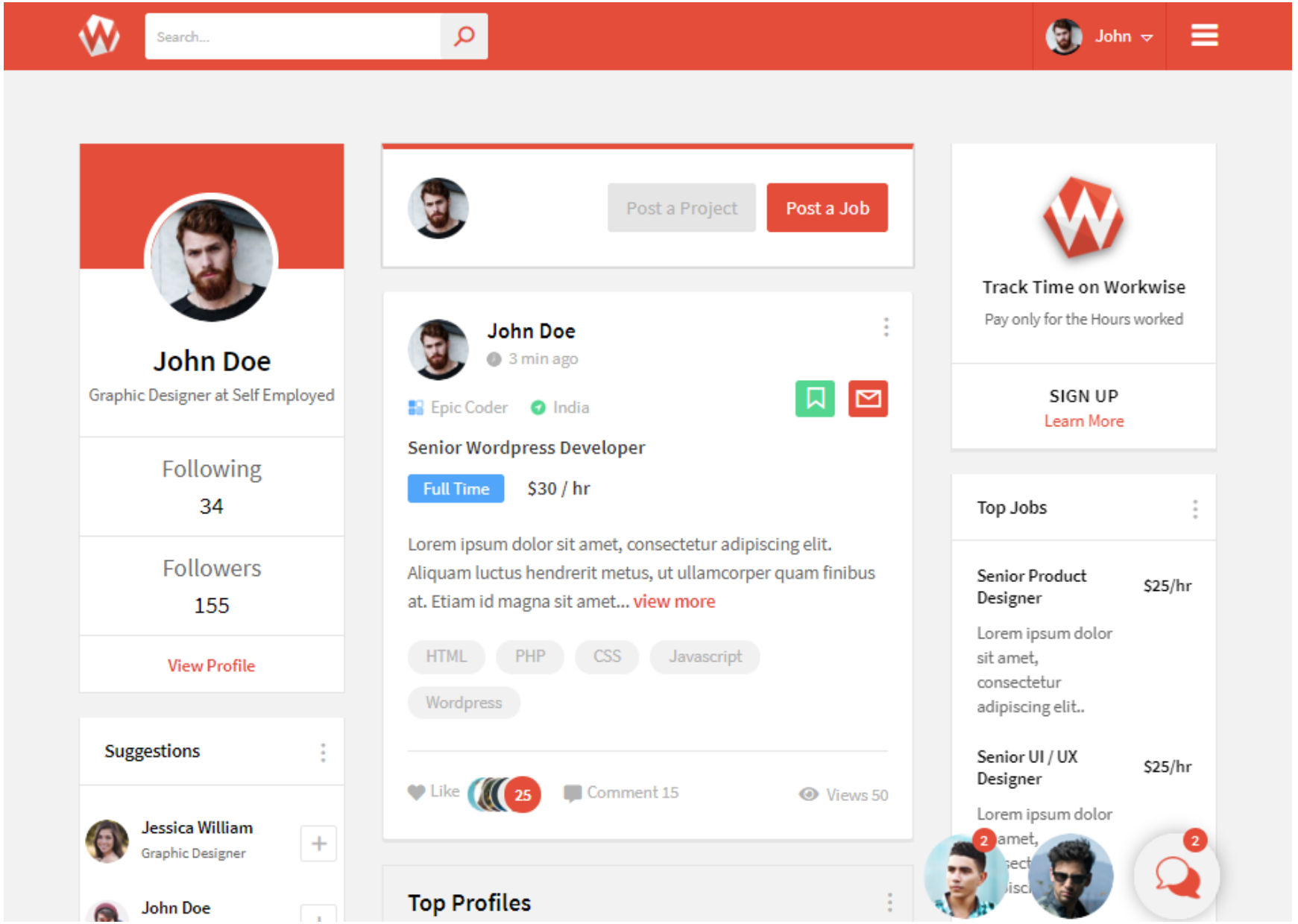
Shipping Info

Preview Order

Payment

Confirmation

nimbbl.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Senior UI / UX Designer
$25/hr
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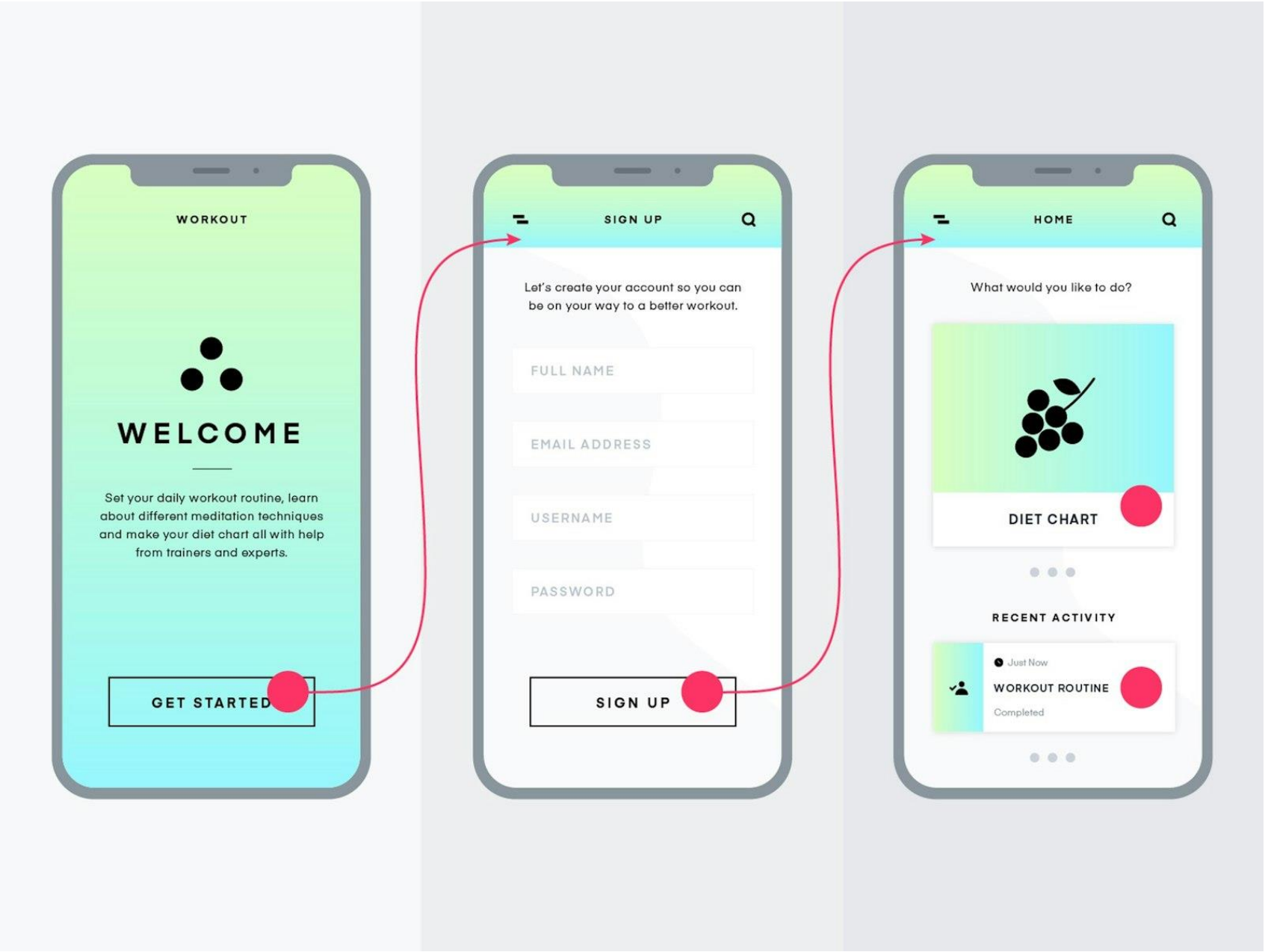
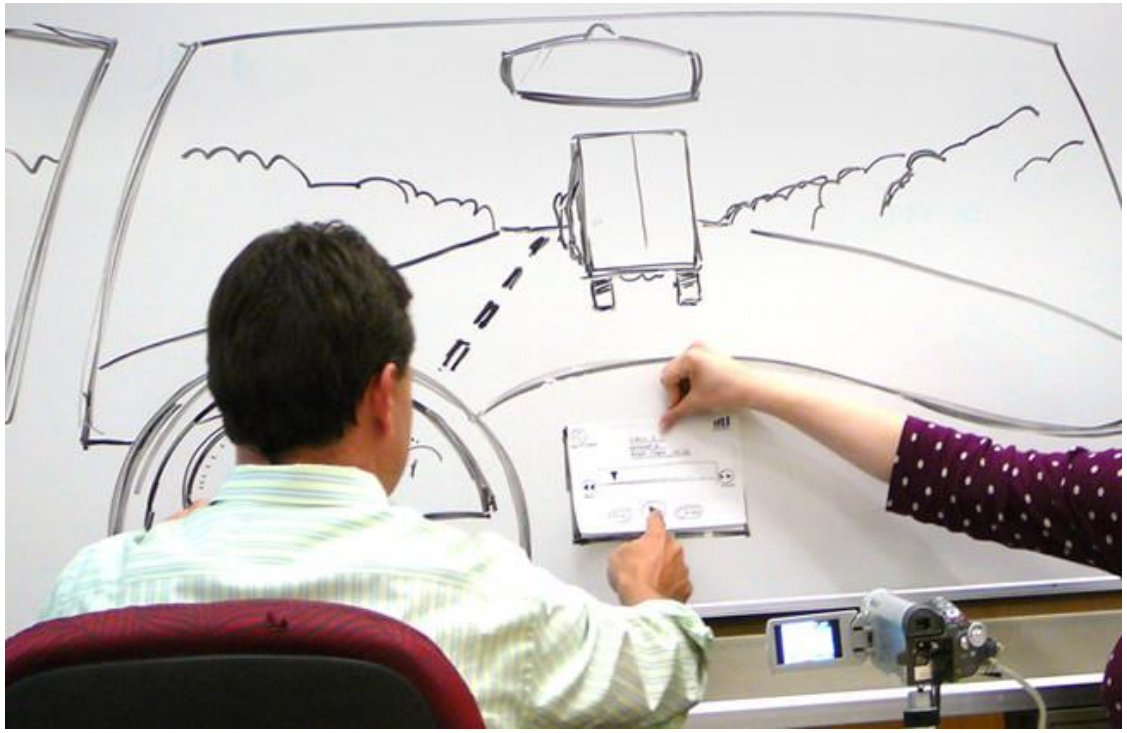

WORKOUT
WELCOME
Set your daily workout routine, learn about different meditation techniques and make your diet chart all with help from trainers and experts.
GET STARTED
SIGN UP
Let's create your account so you can be on your way to a better workout.
FULL NAME
EMAIL ADDRESS
USERNAME
PASSWORD
SIGN UP
HOME
What would you like to do?
DIET CHART
RECENT ACTIVITY
Just Now
WORKOUT ROUTINE
Completed

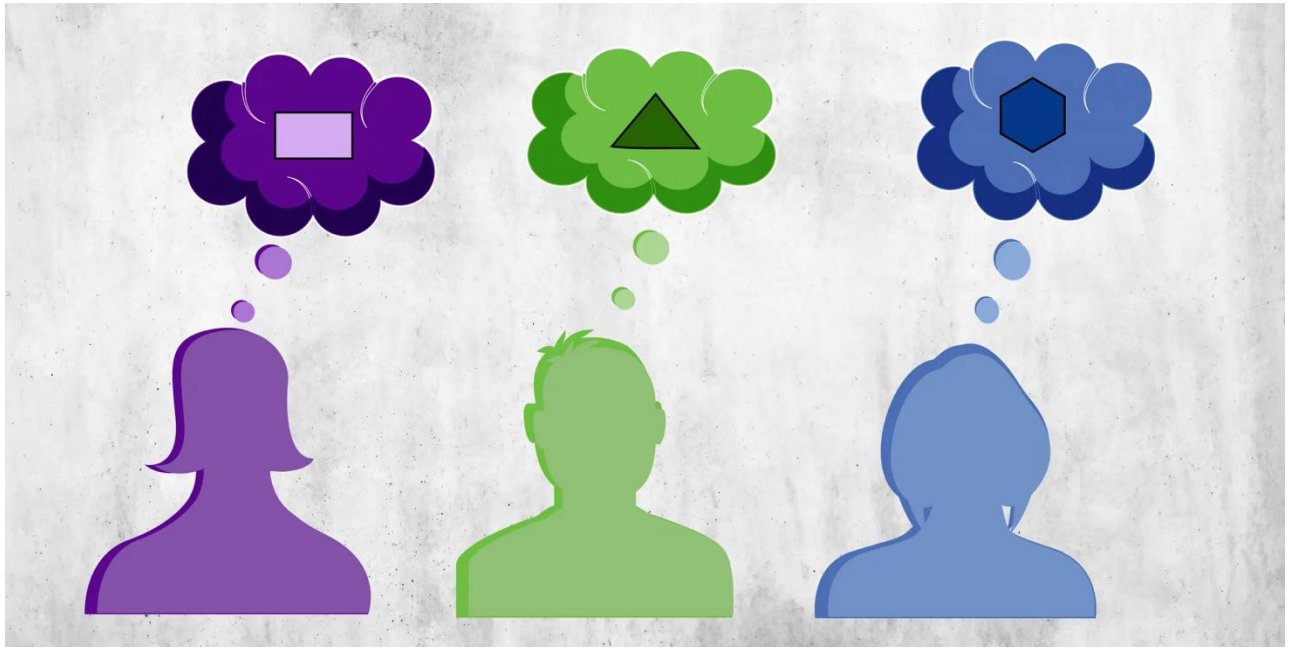
Identifying User's Mental Model

- Perform usability testing to identify a pre-existing mental model
  - Build a mock-up or prototype
  - Ask potential users to perform common tasks & observe their interactions
  - Record user errors or unexpected behaviors
  - Perform an interview to identify user confusion



Identifying User's Mental Model

- **Caveat**: There is no "perfect" mental model
- Even for the same product, different users likely have different ideas about how it works
- Users often have a hard time expressing what they think



- In general, system should be designed assuming a flawed mental model
- A huge topic on its own:
  - See article "Usability Testing 101"
  - For in-depth: *Usability Engineering* by Jakob Nielsen

Adjust the System to the Mental Model

- **During design**:
  - Document and compare the user's mental model against the actual system to identify potential mismatches
  - Modify the design to reduce the mismatches
- **After deployment:** Collect & analyze user complaints and errors to identify unforeseen mismatch
- **Design patterns** for mental model alignment
  1. Make the system state visible
  2. Leverage familiarity with existing real-world concepts
  3. Give control over interaction flow to the user

1. Make the System State Visible

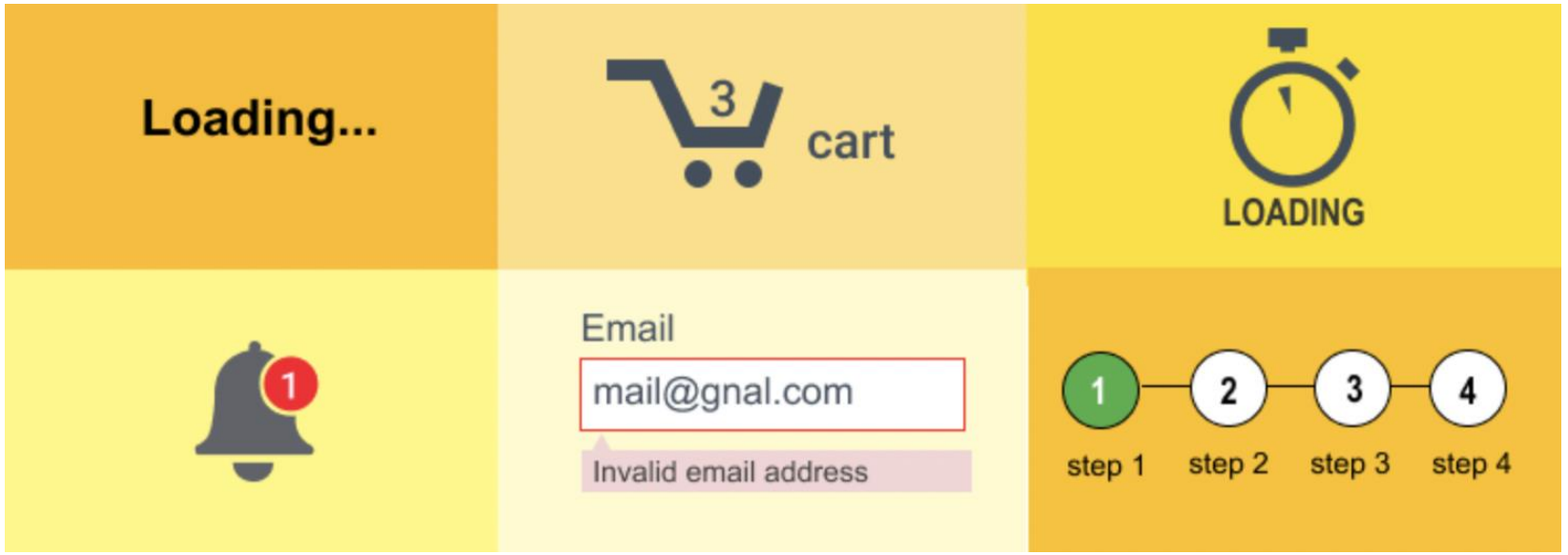


Image source

- **Goal**: Keep the user informed of the current system state
- Include **clearly visible** indicators of the system state
- Provide **timely** and **noticeable** feedback to the user when state changes
- Indicate which actions are available for the user to perform

Example: Failure from State Confusion

- Precision Lightweight GPS Receiver (PLGR)
- **Accident**: US Army Special Forces team, Afghanistan, 2001
  - Soldier uses PLGR to mark adversary's location
  - Battery runs out on device & replaced halfway
  - Previous coordinate erased; set to a default value (the device's own location)
  - Coordinate transmitted to a nearby B-52; 8 killed & 20 others wounded

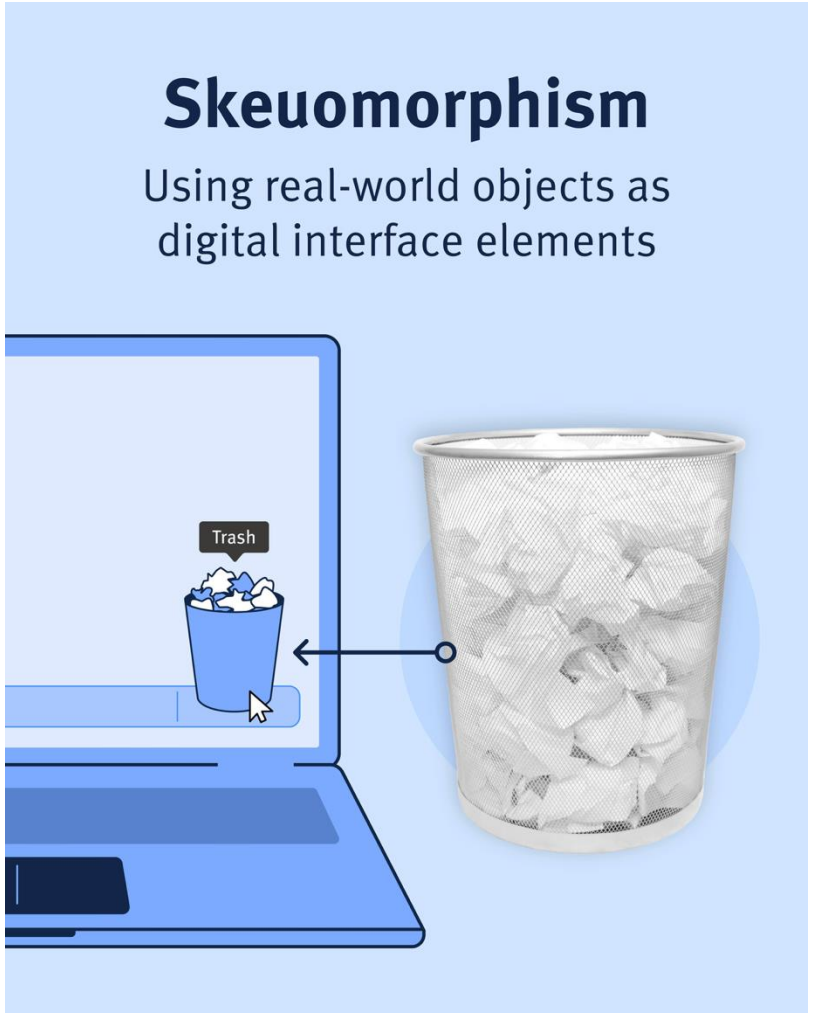
After the batteries are swapped out, the soldier must make no fewer than 18 different button presses just to get the unit back to the state where it can be once more programmed to determine its previously computed solution. (source)

Trade-offs: Visibility vs. Cognitive Load

Bloomberg Terminal

- Exposing too much information about the state can increase interaction costs
  - Can increase (not reduce) confusion or slow down the user when it's time-sensitive!
- Present only the **relevant part** of the system at an appropriate **level of abstraction**
- **Miller's Law**: Average person can keep 7 (+/- 2) items in their working memory

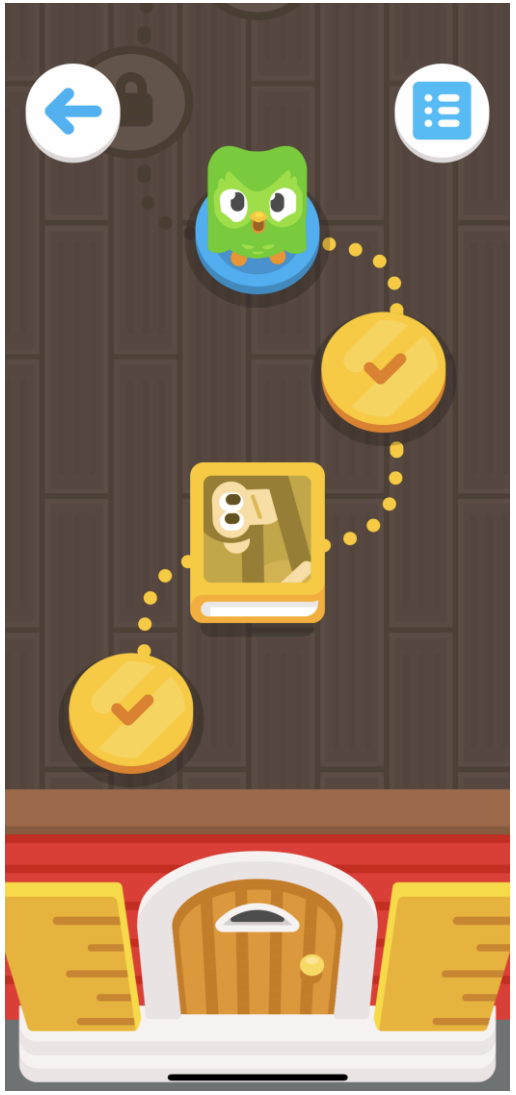
2. Familiarity with Real World: Skeuomorphism



Source: Nielsen Norman Group

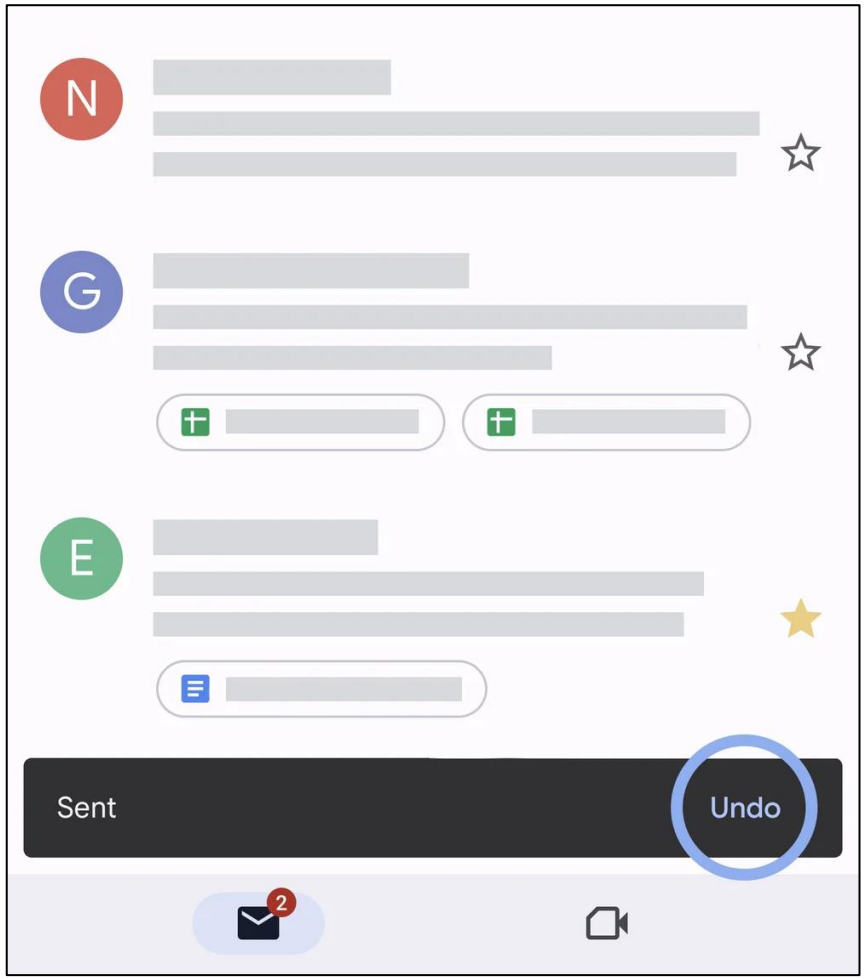
- Incorporate real-world elements that are familiar to the user
- **Goal**: Leverage familiarity to reduce learning time and interaction costs
- **Example**: Trash cans in OS desktops
  - **Q. Other examples?**
- **Caveats**
  - Can be misleading: Be aware of subtle differences vs. the real world
    - e.g., “Deleting” things by moving into trash doesn’t free up disk space
  - Not every aspect of a real-world concept is useful or intuitive in digital form
    - e.g., Analog clock vs. digital clock

Skeuomorphism: Physical Metaphors



- Physical-space metaphors (e.g., maps, doors) to mimic experiences that users encounter in the real world
  - e.g., navigation layout in educational apps (Duolingo)

3. Give User Control over Interaction Flow



- **Goal**: When the user makes an error/changes their mind, give them a way to adjust their plan
  - **Back button**: Give the user an ability to return to the previous step in a workflow
  - **Undo/redo action**: Allow the user to undo (redo) a change to the system state
  - **Exit link:** Give the user with a way to cancel or restart the current workflow
- Make these options **easily discoverable** by the user

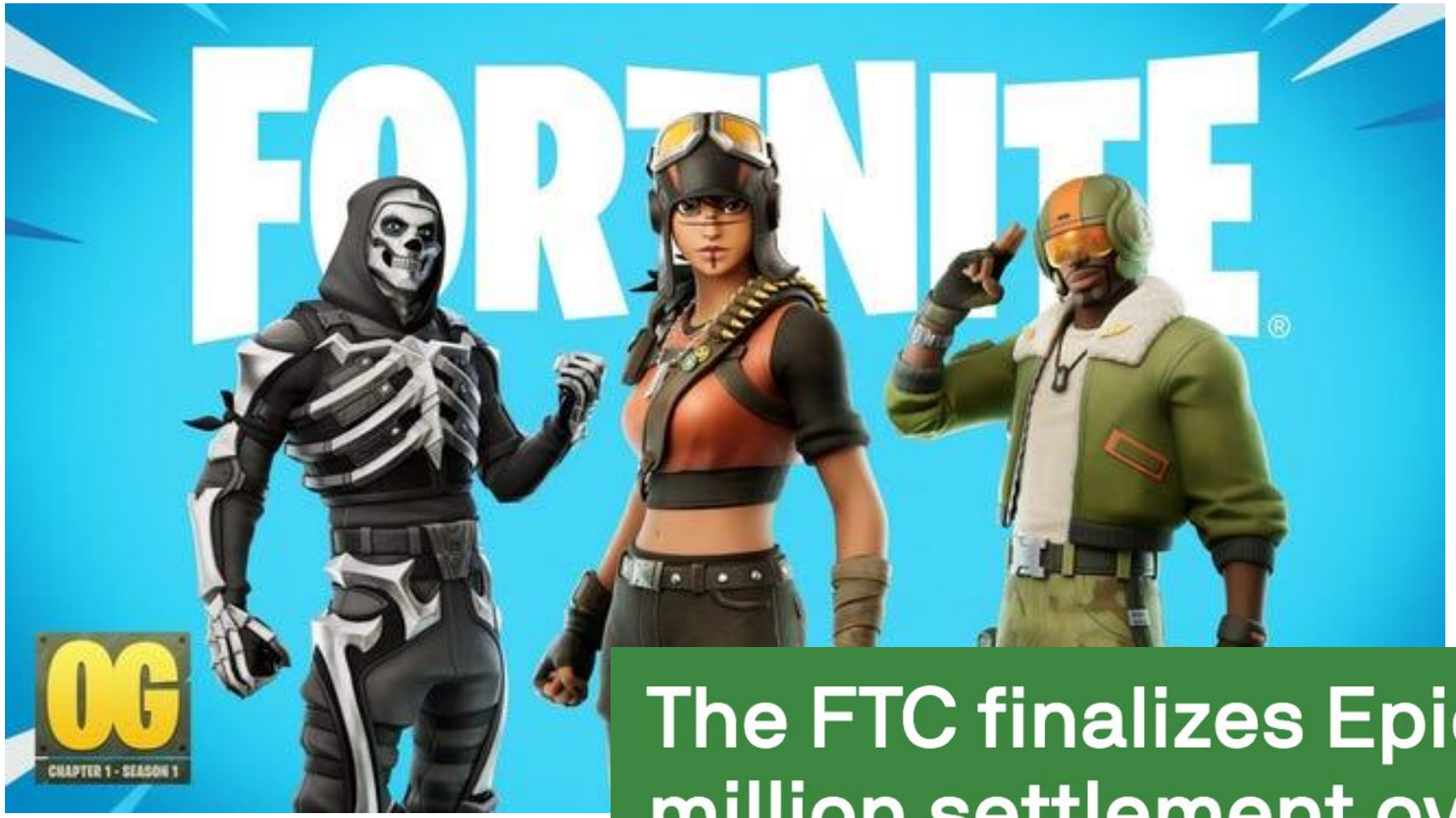
Activity: Usability of Food Rescue App

- Open the Food Rescue App developed by one of the group members
- Walk through the main user workflows (e.g., browsing available donations, claiming a donation, canceling a donation)
- Discuss the following:
  - Is the relevant system state visible? Are available actions clearly indicated?
  - Is the app using a mental mode that is familiar to most users?
  - Does the app give the user an ability to go back, undo/redo, or exit/restart a workflow?

Aside: Dark Patterns

- Patterns that are deliberately used by a developer to deceive the user into performing an unintended action
- Antithesis of design patterns discussed earlier
  - Make certain system states **obscure/invisible**
  - Leverage familiarity with the real world or psychology to **trick** the user into an action
  - **Restrict or take control away** from the user
- Many examples: Deceptive patterns
  - Some recent regulations, but many patterns still go unpunished

- Fake urgency
- Offer of dubious value
- Fake social proof
- Obscure opt-out with confirm-shaming
- Hard-to-click preselected checkbox with trick wording



The FTC finalizes Epic's $245 million settlement over sketchy Fortnite purchases

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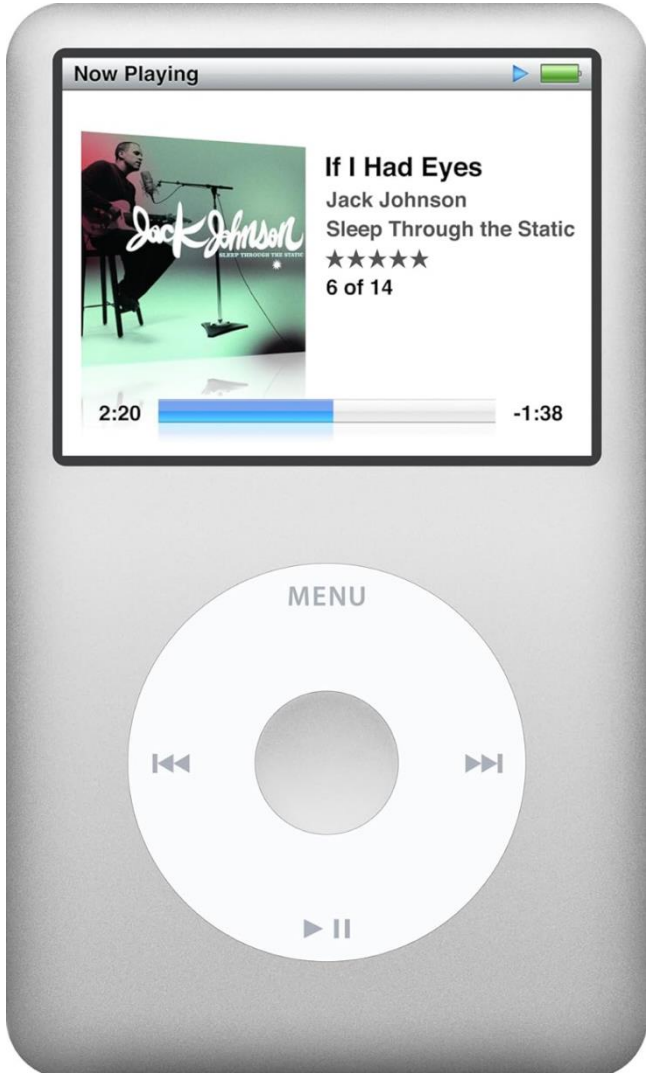
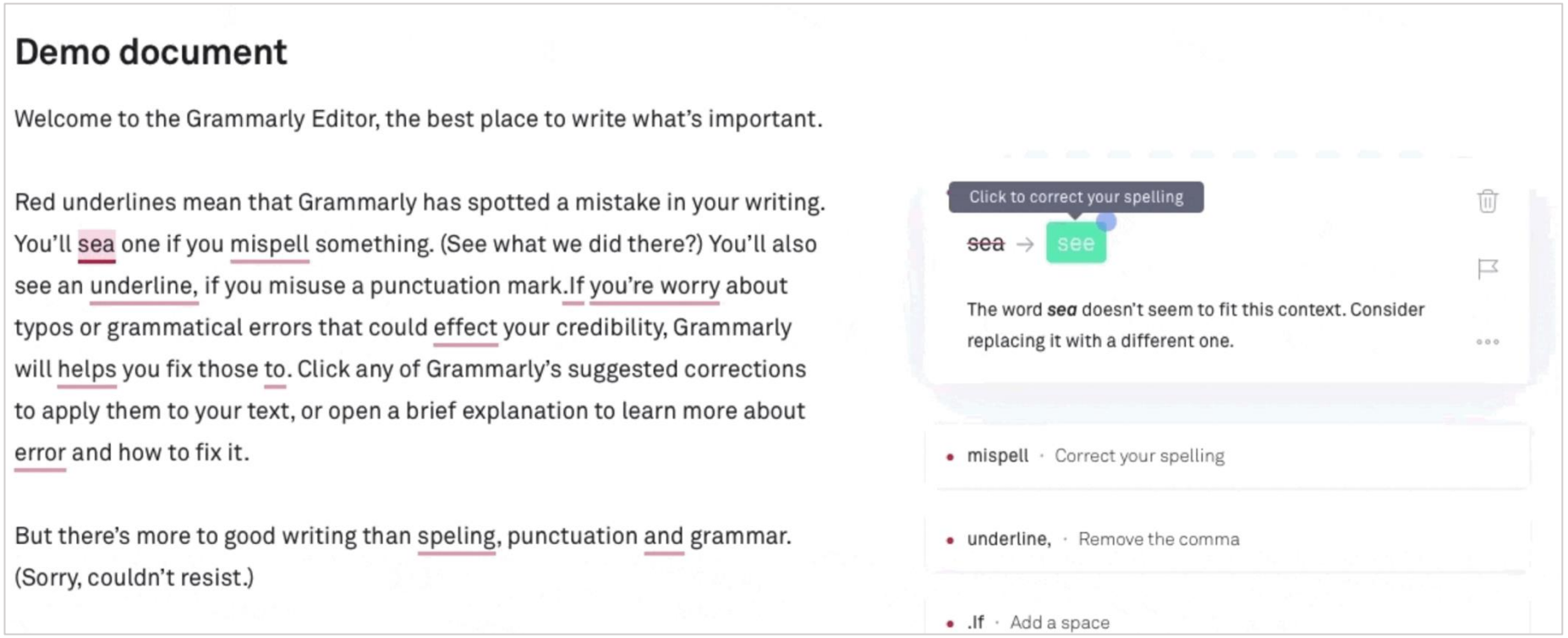
- Many examples: Deceptive patterns
  - Some recent regulations, but many patterns still go unpunished
- **Be a responsible designer!** Do not use your design against the user's best interests

Adjusting the Mental Model to the System

- Certain innovative products have user interactions that do not fit into an existing mental model
- Provide an aid to help the user adjust or develop a proper mental model that aligns with the system
- **Strategies**
  - Set the user's expectations through onboarding
  - Increase transparency about how the system works by explaining its behavior to the user

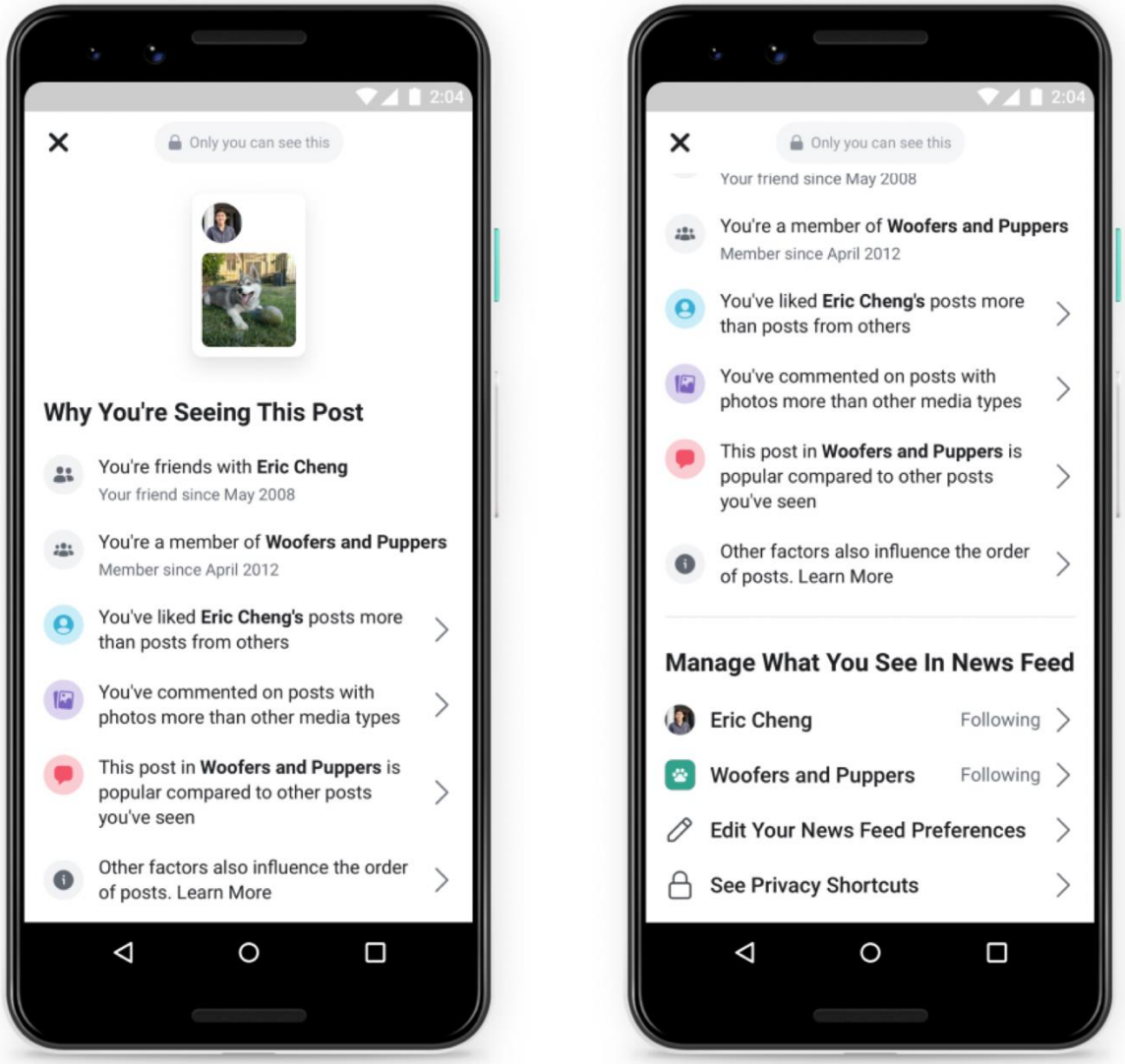


Onboarding



- Introduce the user to the expected interactions with the system
- Provide examples of how the system works
- Be explicit about what the system can and cannot do

Explaining System Behavior

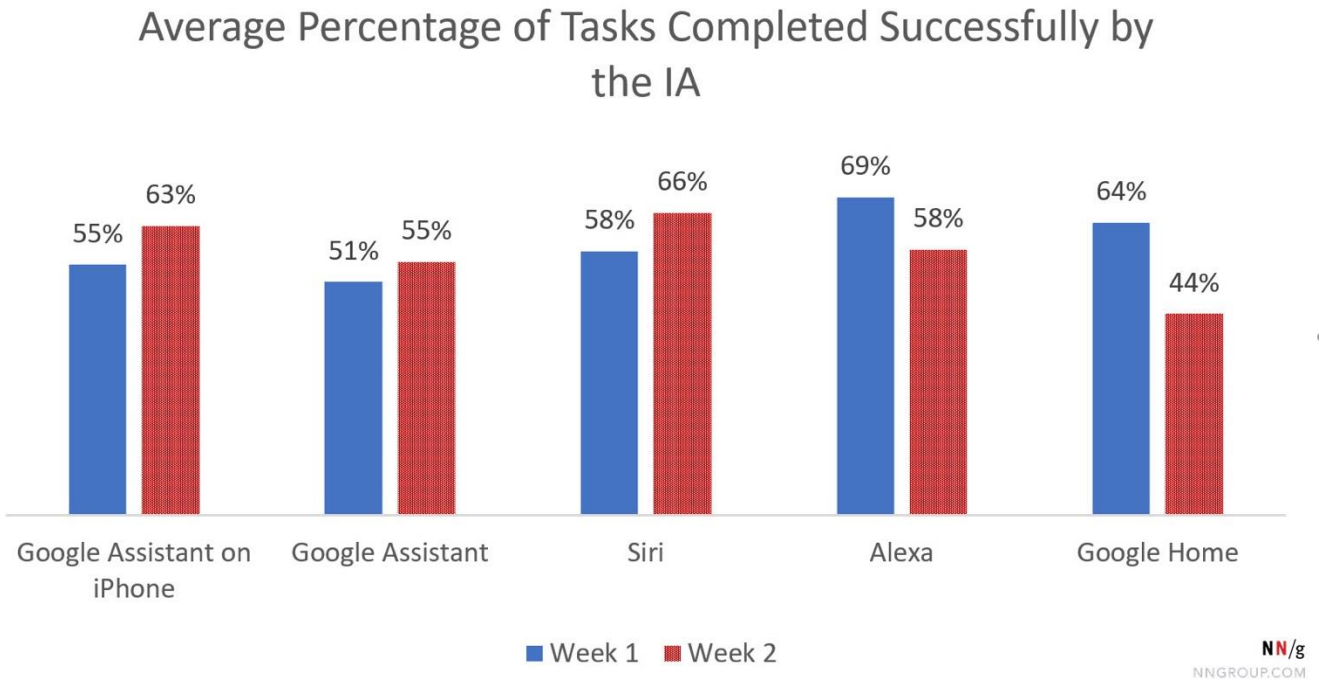


- Be transparent about how the system behaves
- Inform the user about available actions
- Aid the user in gradually building or adjusting their mental model

Example: Intelligent Assistants

- Holy grail of UI design: Reduce interaction cost to near zero
- **Q. What is your mental model of what an intelligent assistant does?**

Mental Model for Intelligent Assistants



(source)

- Study: Most users have a poor mental model of these systems
  - What can it do? What are its limitations?
  - Is an interface to online tools? Handy helper? Knowledge repository?
  - How do I get it to do/say X? Why did it do/say Y instead of X?

amazon | digital and device forum

Search the forum

Home > Echo Devices > Echo Show > Why is Alexa so dumb??

LeeIsMyName! asked a question.
September 8, 2024 at 3:50 AM

Why is Alexa so dumb??

Hi,

Why is it like pulling teeth to get the incredibly dumb Alexa to understand anything? How do I get Alexa to understand simple requests?

It is a joke at how unbelievably difficult it is to get "her" to recognize anything I ask. It takes an insane amount of tries to try and maybe get just the perfect combination of words together in a sentence to get "her" to FINALLY acknowledge what I'm trying to ask "her" to do. In most cases after hearing her play dumb so many times over, I get so frustrated and give up.

Buying these echo devices was a colossal waste of time and money unless there's anyone here that can unlock the mystery of why "she" is so dumb and cannot understand what anyone is saying like Google can do effortlessly then tell me how I can figure out how to get "her" to do simple tasks that I ask. What on earth is the secret?

Effects of Poor Mental Model

BUSINESS INSIDER

TECH

Amazon thought Alexa would be the next iPhone. Turns out it's a 'glorified clock radio.'

Analysis by Jake Swearingen + Nov 30, 2022, 5:35 AM ET

- Amazon's Alexa was Jeff Bezos' pet project; now it's a target for the company's cost-cutting.
- Insider reported the Amazon division that built Alexa is on track to lose $10 billion this year.
- Voice assistants were supposed to be revolutionary, but no one's figured out how to make them profitable.

- User settles on a suboptimal mental model and fails to benefit from the full capabilities of the system (e.g., check weather & play music)

Mental Model Alignment

- **Principle**: The user's mental model must be **aligned** with the observable behavior of the system
- **Strategies** for achieving alignment:
  - Identify the user's existing mental model
  - Adjust the system to conform to the user's mental model
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Designing for Usability: Tips

- Developers focus on design & code, and often do not see the software from the user's perspective
- Ultimately, it's the users who decide how the software will be used
  - They are always right, even if they seem erratic or incompetent
  - Software that is not usable will likely be misused or not used at all
- Understanding the user's mental model is the key to usable software
- Engage with users & identify their common mental model
- Be conservative! Use an interaction design that matches an existing mental model
- If the product is innovative, explicitly guide the user in building an accurate mental model through onboarding and transparency

Summary

- Exit ticket!