# Designing Interactive Systems I
# Lecture 10: GOMS, Interface Efficiency, Golden Rules

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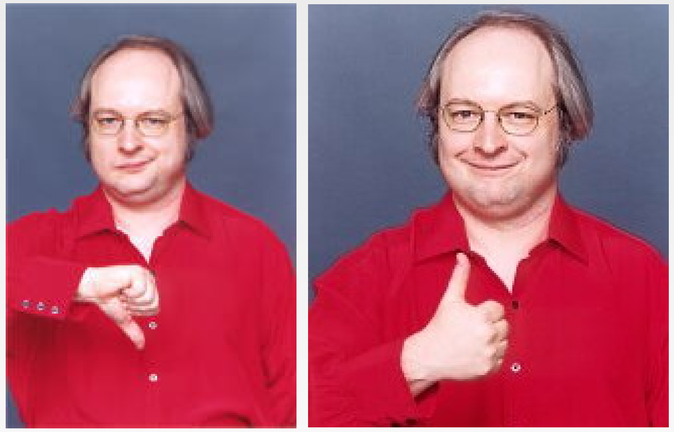
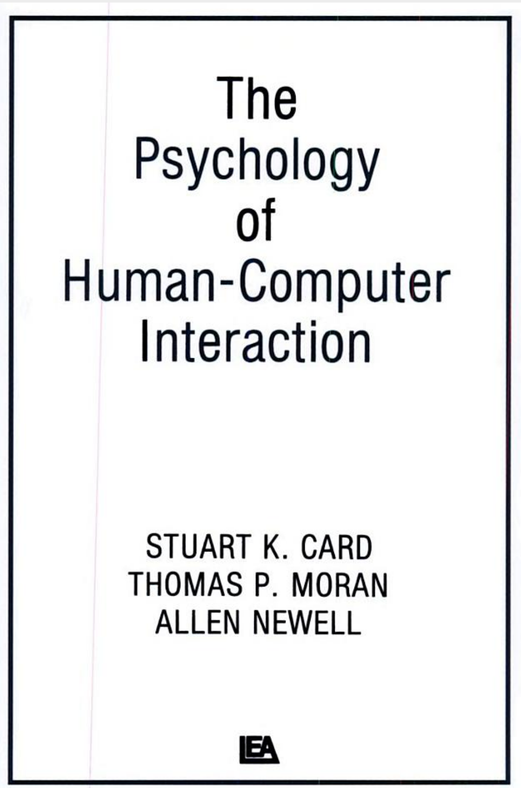
http://hci.rwth-aachen.de/dis

# A Story



- In 1995, now-famous web guru Jakob Nielsen had less than 24 hours to recommend if adding three new buttons to Sun's home page was a good idea.
    - Check out his "Alertbox" online column for good (and often fun) web design advice
- He found that each new, but unused button costs visitors .5 million $ per year.
- 2 of the 3 new buttons were taken back out.
- The method he used for his estimate: GOMS.

# GOMS




- Goals, Operators, Methods, Selection rules
- Card, Moran, Newell: The Psychology of HCI, 1983
- To estimate execution and learning times before a system is built

# GOMS: Components

- Goals describe user's end goals
  - Routine tasks, not too creative/problem-solving
    - E.g., "copyedit manuscript"
  - Leads to hierarchy of subgoals
- Operators are elementary user actions
  - Key presses, menu selection, drag & drop, reading messages, gestures, speech commands, …
  - Assign context-independent duration (in ms)
- Methods are "procedures" to reach a goal
  - Consist of subgoals and/or operators
- Selection rules
  - Which method to use for a (sub)goal
    - E.g., to delete some text (individual preferences apply!)

# Sample Method and Operators

GOAL: HIGHLIGHT-ARBITRARY-TEXT

1. MOVE-CURSOR-TO-BEGINNING 1.10s
2. CLICK-MOUSE-BUTTON 0.20s
3. MOVE-CURSOR-TO-END 1.10s
4. SHIFT-CLICK-MOUSE-BUTTON 0.48s
5. VERIFY-HIGHLIGHT 1.35s

# Variants Of Goms

- GOMS (Card, Moran, and Newell 1983)
  - Model of goals, operators, methods, selection rules
  - Predict time an experienced worker needs to perform a task in a given interface design
- Keystroke-level GOMS model (simplified version)
  - Comparative analyses of tasks that use mouse (GID) and keyboard
  - Correct ranking of performance times using different interface designs
- CPM-GOMS (critical path method)
  - Computes accurate absolute times
  - Considers overlapping time dependencies
- NGOMSL (natural GOMS language)
  - Considers non-expert behavior (e.g., learning times)

# Keystroke-Level Model

- Execution time for a task = sum of times required to perform the serial elementary gestures of the task
- Typical gesture timings
  - Keying K = 0.2 sec (tap key on keyboard, includes immediate corrections)
  - Pointing P = 1.1 sec (point to a position on display)
  - Homing H = 0.4 sec (move hand from keyboard to mouse or v.v.)
  - Mentally preparing M = 1.35 sec (prepare for next step, routine thinking)
  - Responding R (time a user waits for the system to respond to input)
- Responding time R effects user actions
  - Causality breakdown after 100 ms
  - User will try again after 250 ms ⇒ R
  - Give feedback that input received & recognized

# Keystroke-Level Calculation

- List required gestures
  - E.g., HK = move hand from mouse to keyboard and type a letter
- Compute mental preparation times Ms
  - Difficult: user stops to perform unconscious mental operations
  - Placing of Ms described by rules
- Add gesture timings
  - E.g., HMPK = H + M + P + K = 0.4 + 1.35 + 1.1 + 0.2 = 3.05 sec
- Rule terminology
  - String: sequence of characters
  - Delimiter: character marking beginning (end) of meaningful unit
  - Operators: K, P, and H
  - Argument: information supplied to a command

# Rules for Placing Ms

- Rule 0, initial insertion for candidate Ms
  - Insert Ms in front of all Ks
  - Place Ms in front of Ps that select commands, but not Ps that select arguments for the commands
- Rule 1, deletion of anticipated Ms
  - Delete M between two operators if the second operator is fully anticipated in the previous one
    - E.g., PMK ⇒ PK
- Rule 2, deletion of Ms within cognitive units (contiguous sequence of typed characters that form a name)
  - In a string of MKs that form a cognitive unit, delete all Ms except the first
    - E.g., "ls↵" ⇒ MK MK MK ⇒ MK K MK

# Rules for Placing Ms

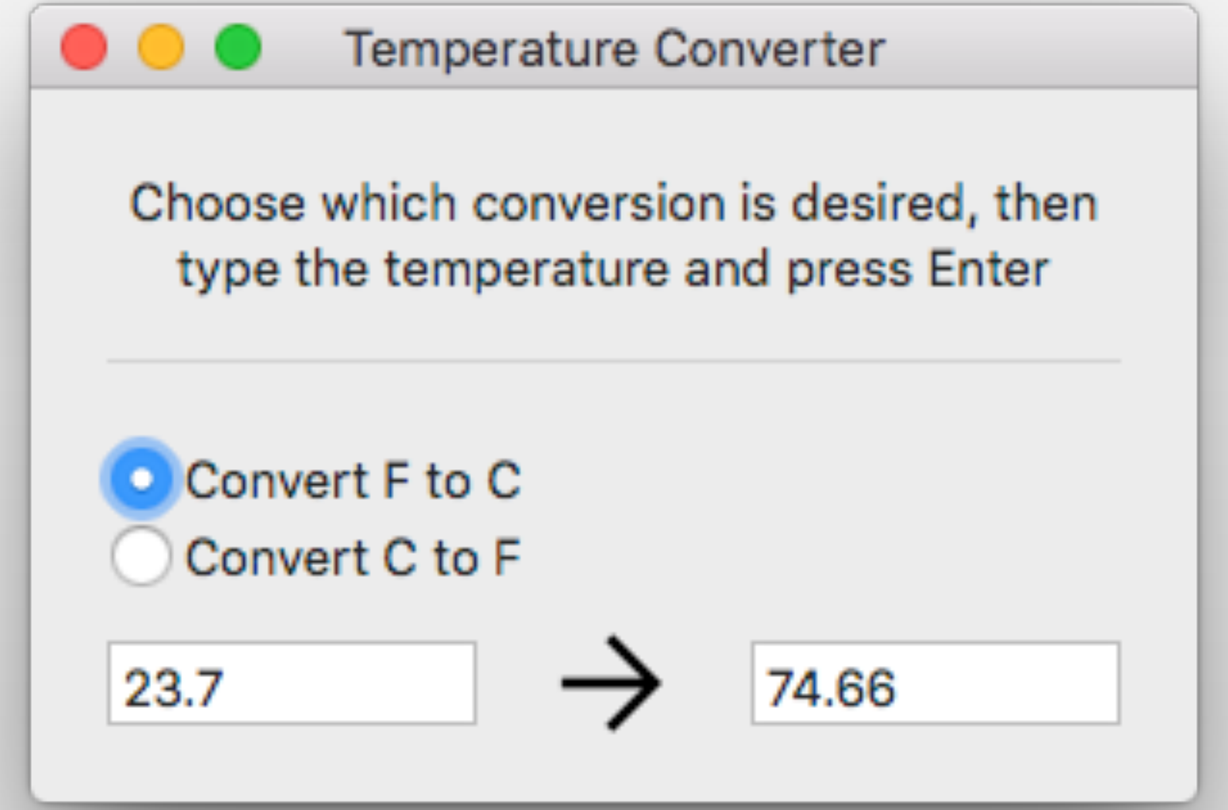
- Rule 3, deletion of Ms before consecutive terminators
  - If K is redundant delimiter at end of a cognitive unit, delete the M in front of it
    - E.g., "bla↵↵" ⇒ M 3K MK MK ⇒ M 3K MK K
- Rule 4, deletion of Ms that are terminators of commands
  - If K is a delimiter that follows a constant string then delete the M in front of it (not for arguments or varying strings)
    - E.g., "clear↵" ⇒ M K K K K K MK ⇒ M K K K K K K

      Note that the 'clear' command does not take any arguments, and is therefore a constant string. 'ls,' on the other hand, can take arguments and Rule 4 cannot be applied there.
- Rule 5, deletion of overlapped Ms
  - Do not count any M that overlaps an R
    - E.g., user waiting for computer response

# Exercise: Temperature Converter

- Convert from degrees Fahrenheit (F) to Celsius (C) or vice versa, requests equally distributed
- Use keyboard or mouse to enter temperature
- Assume active window awaiting input, an average of four typed characters (including point and sign), and no typing errors
- Task: create and analyze your own interface!

# The Dialog Box Solution with Radio Buttons…



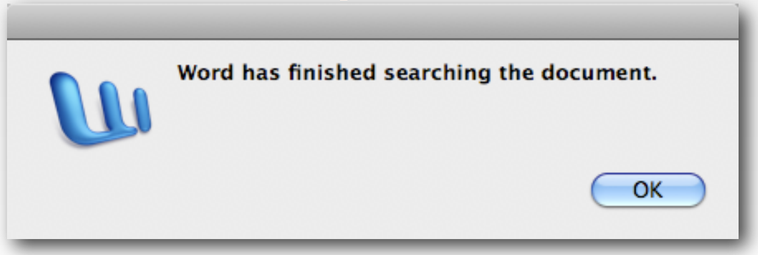
# …And Its Keystroke-Level Model

- Case 1: select conversion direction
  - Move hand to mouse, point to desired button, click on radio button (HPK)
  - Move hands back to keyboard, type four characters, tap enter (HPK HKKKK K)
  - Rule 0 (insert M's): (HMPMK HMKMKMKMK MK)
  - Rule 1 (deletion of anticipated M's): (HMP_K HMKMKMKMK MK)
  - Rule 2 (deletion of M's within cog. units): (HMP_K HMK_K_K_K MK)
  - Result: HMPK HMKKKK MK
  - Estimated time = 7.15 sec
- Case 2: correct conversion direction already selected
  - MKKKKMK = 3.7 sec
- Average time = (7.15 + 3.7) / 2 = 5.4 sec

# GOMS Results

- Execution (& learning) times of trained, routine users for repetitive tasks (goals), leading to cost of training, daily use, errors
  - Can be linked to other costs (purchase, change, update system), resulting in $$$ answers
  - Use to model alternative system offers
    - E.g., "new NYNEX computers cost $2M/year more" [Gray93]
- Estimate effects of redesign
  - Training cost vs. long-term work time savings
- Starting point for task-oriented documentation
  - Online help, tutorials, …
- Don't use for casual users or new UI techniques
  - Operator times not well defined

# Measuring Interface Efficiency




- How fast can you expect an interface to be?
- Information as quantification of amount of data conveyed by a communication (Information theory)
  - E.g., speech, messages sent upon click…
- Lower bound on amount of information required for task is independent of interface design
- Information-theoretic efficiency $E = \frac{\text{Minimal info required for the task}}{\text{Info supplied by user}}$
  - $E \in [0, 1]$ (e.g., $E = 0$ for providing unnecessary information)
- Character efficiency $= \frac{\text{Minimal number of characters required for the task}}{\text{Number of characters entered in the UI}}$

[Jef Raskin: The Humane Interface, 2000]

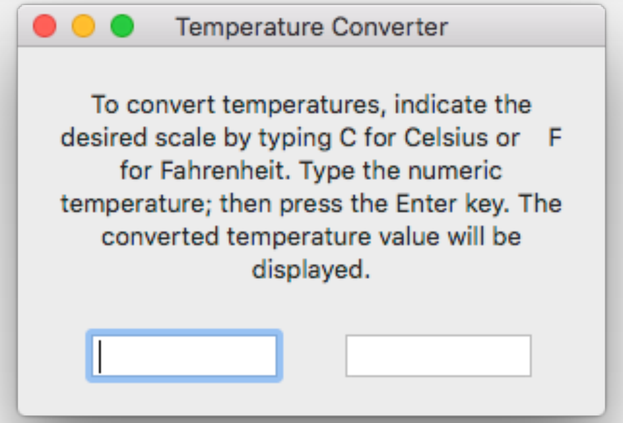
# Quantify Amount of Data

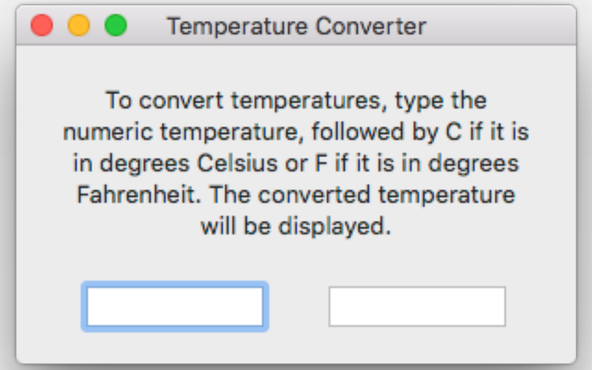
- Information is measured in bits
  - 1 bit represents choice between 2 alternatives
- n equally likely alternatives
  - Total information amount: log2(n)
  - Information per alternative: (1/n)log2(n)
- n alternatives with different probabilities p(i)
  - Information per alternative: p(i)log2(1/p(i))
  - Total amount = sum over all alternatives
- Consider situation as a whole
  - Probability of messages required
  - Information measures freedom of choice (information ≠ meaning)

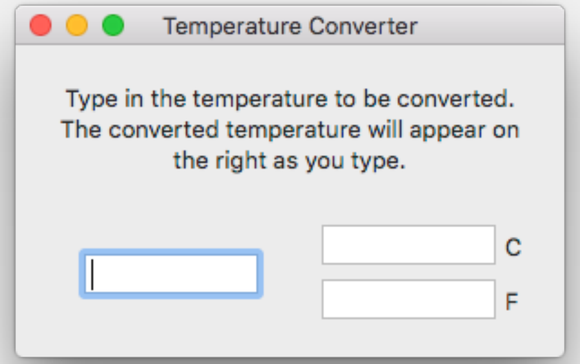
# Example: Temperature Converter

- Input assumptions (given)
  - 50% Fahrenheit, 50% Degree Celsius
  - 75% positive, 25% negative
  - only decimal input (no integer numbers)
  - All digits are equally likely
  - Only four characters input

# Example: Temperature Converter




- Keystroke efficiency
  - Type C or F, value, enter: M K K K K K M K ⇒ 3.9 sec (char. eff. 67 %)
  - Type value, then C or F: M K K K K M K ⇒ 3.7 sec (char. eff. 80%)
  - Bifurcated: M K K K K = 2.15 sec (char. eff. 100 %)

# Example: Temperature Converter

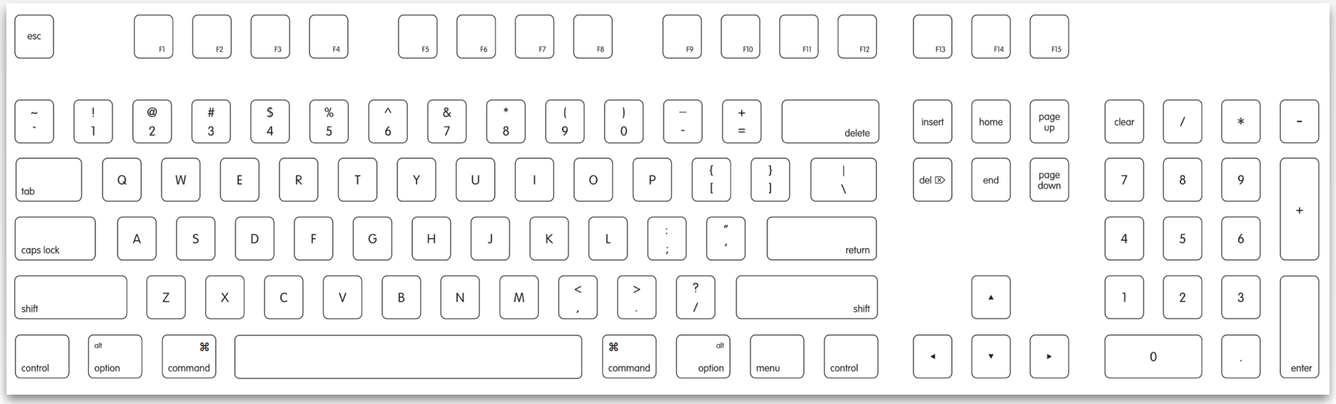
Information per alternative
$p(i)\log_2(1 / p(i))$

| Numbers | Prob. | Values | $p(i)$ | Information in bits | Overall (values x information in bits) |
|---|---|---|---|---|---|
| -.dd | 12.5 % | 100 | 0.00125 | 0.012 | 1.2 |
| -d.d | 12.5 % | 100 | 0.00125 | 0.012 | 1.2 |
| .ddd | 25 % | 1000 | 0.00025 | 0.003 | 3 |
| d.dd | 25 % | 1000 | 0.00025 | 0.003 | 3 |
| dd.d | 25 % | 1000 | 0.00025 | 0.003 | 3 |

⇒ Minimal info required for the task = 11.4 bits/message

⇒ Simple approach: $4 \log_2(12) \approx 14$ bits

# Example: Temperature Converter




- Information efficiency: $E = \dfrac{11.4 \text{ bits}}{\text{Info supplied by user}}$
  - 128 keys standard keyboard (5 bits/key): $E = 11.4 / (4 \times 5) \approx 55\%$
  - 16 keys numeric keypad: $E = 11.4 / (4 \times 4) \approx 70\%$
  - 12 keys dedicated keypad: $E = 11.4 / (4 \times 3.5) \approx 80\%$

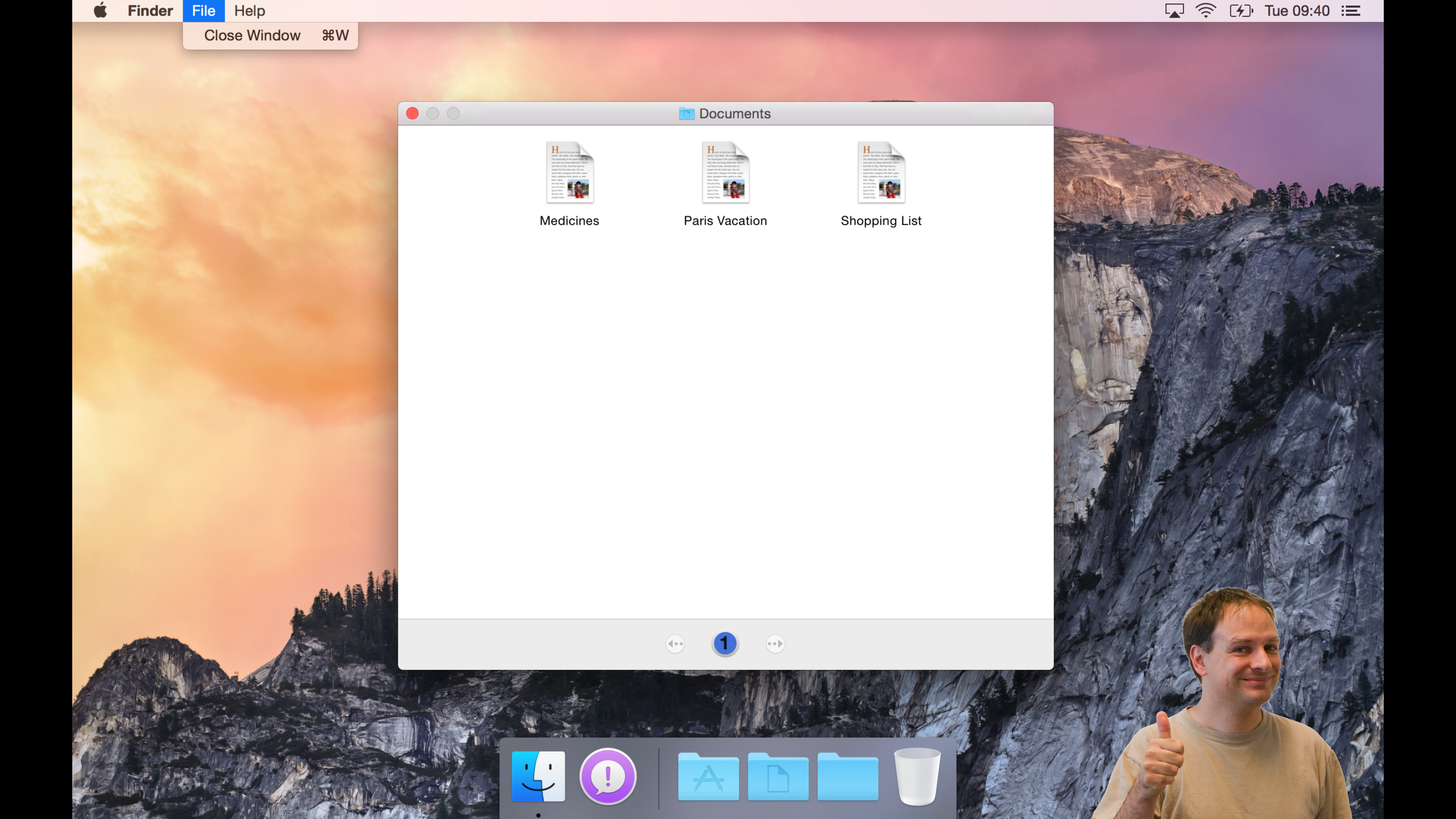
# Ten Golden Rules of Interface Design

# Ten Golden Rules of Interface Design

1. Keep the interface simple!
2. Speak the user's language!
3. Be consistent and predictable!
4. Provide feedback & be responsive!
5. Minimize memory load!
6. Avoid errors, help to recover, offer undo!
7. Design clear exits and closed dialogs!
8. Include help and documentation!
9. Address diverse user needs!
10. Hire a graphic designer!

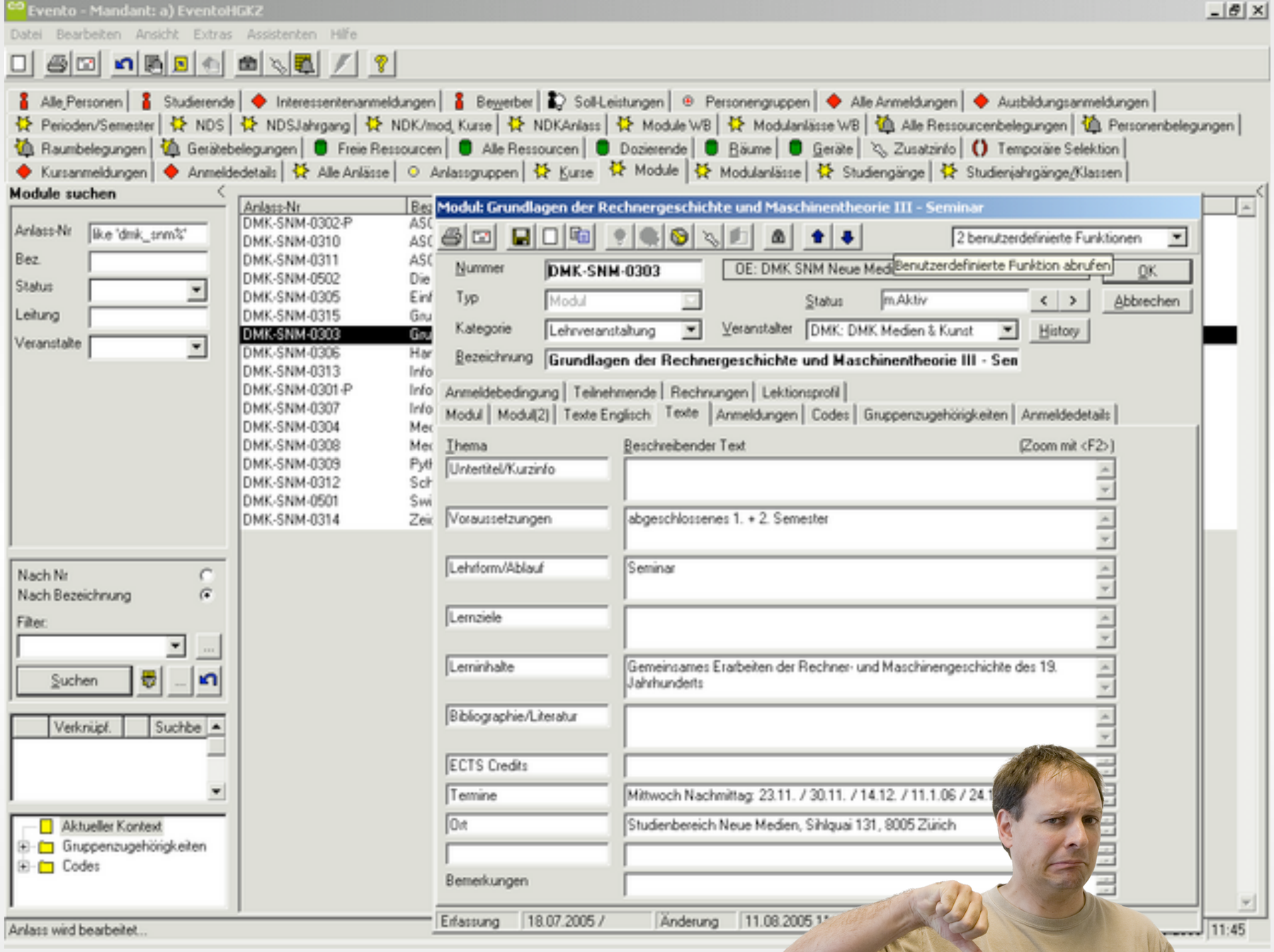
# 1. Keep the Interface Simple!

- Most important rule
- First design is often too complex & awkward
- Avoid feature creep
  - Some consumers will ask for more and more features
  - But usability must not suffer
  - Experience: 80% of users use only 20% of features (e.g., Word)
  - Honorable goal would be: Next version will have no new features, just be easier to use
  - If pressed, move feature sets out to sub-dialogs


Finder
File
Help
Close Window ⌘W
Tue 09:40
Documents
Medicines
Paris Vacation
Shopping List
1

# Example for Feature Creep: VCR


# Example: Simple Alarm Clock

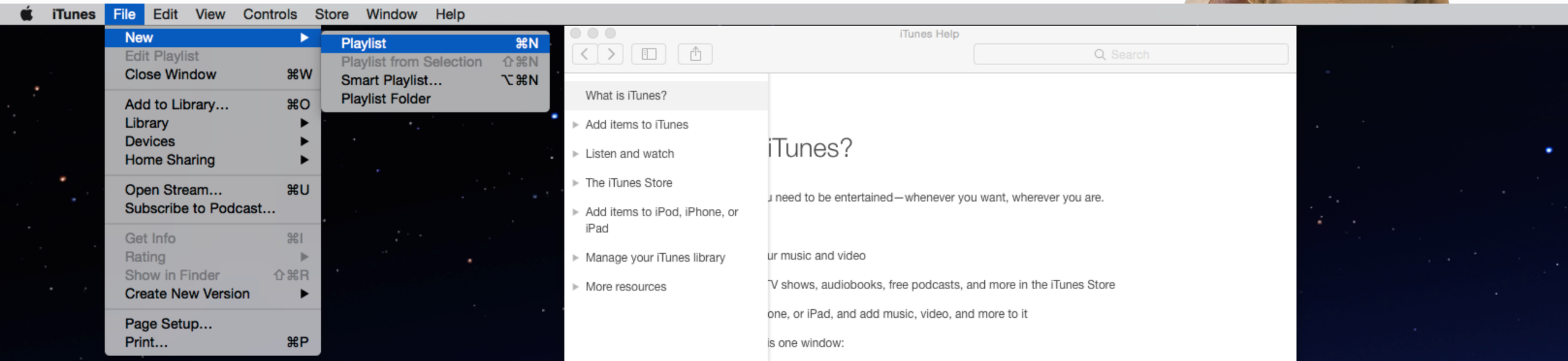
# 2. Speak the User's Language!

- Take words and concepts from the application domain, not technology
- Determine terminology during initial user interviews and task analysis
- Example: "File" means less to an architect who is new to computers than "drawing"
- Applies to words for objects, but also work processes and tasks (e.g., "order")

# Example: Telephone Book Menu


# Example: iTunes

- Talks about "music", "songs", "video", "movies", "playlists", not "files"
  - In menus, dialogs, and online help (⇒Rule 3: Consistency)
- Exceptions: E.g., "File" menu
  - Conflict with cross-application consistency

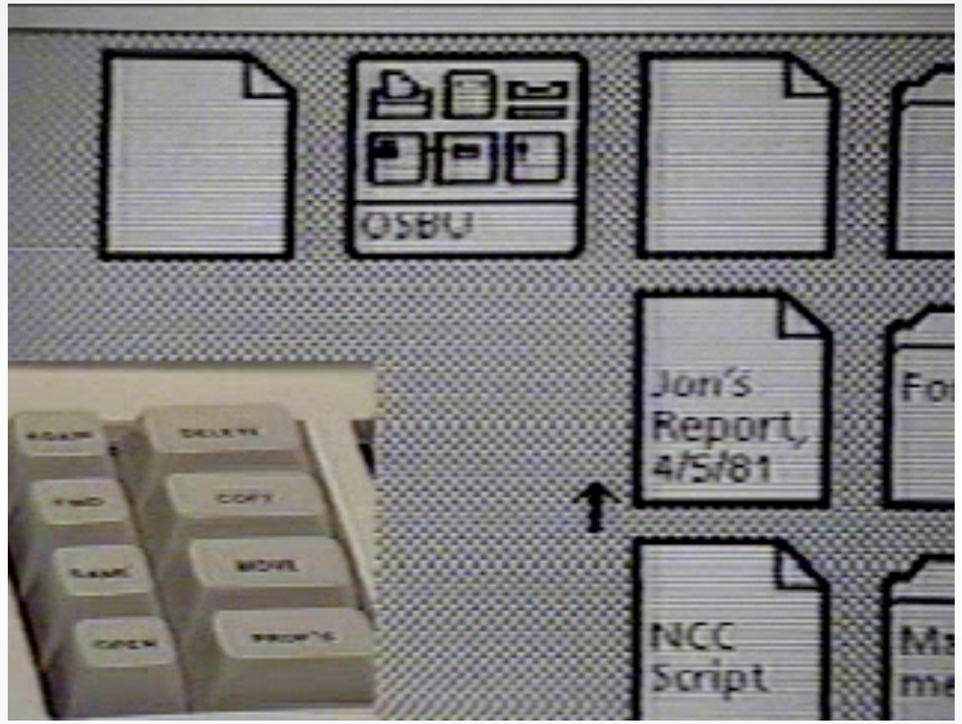


# 3. Be Consistent and Predictable!

- Consistency is needed across many levels:
  - Similar commands for similar situations
  - Consistent terminology in menus, dialogs, help pages, etc.
  - Consistent fonts, layout, color coding, upper/lower cases, etc. throughout the system
  - Only few obvious exceptions
    - No clear-text echo when entering passwords
    - Extra security check before erasing files, etc.

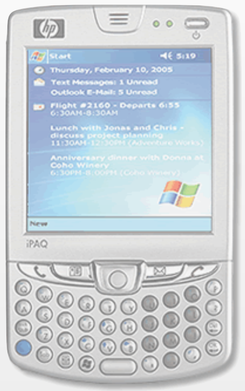
# Example: Xerox Star Command Buttons

- Same (physical) buttons to copy a file, a word in a text editor, an object in a graphics program, etc.
- Still true today (Cut/Copy/Paste)




# Consistency through Vertical Design

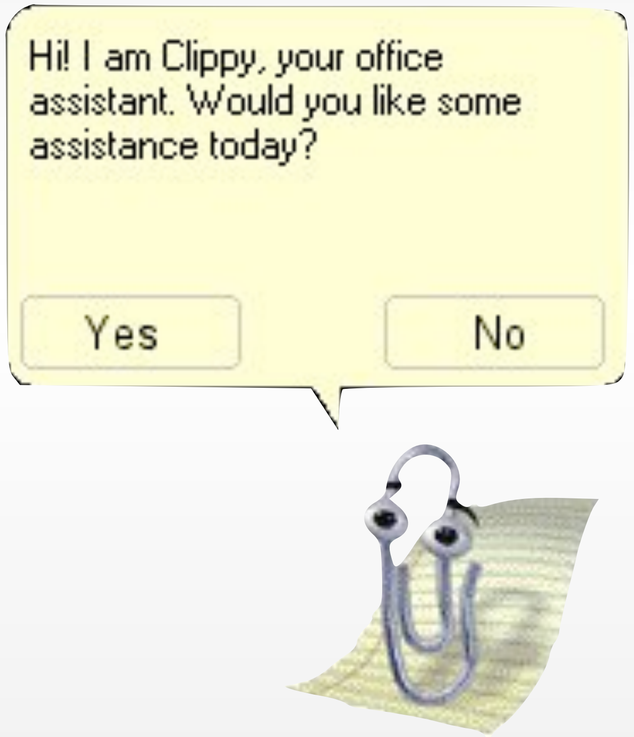




# Predictability

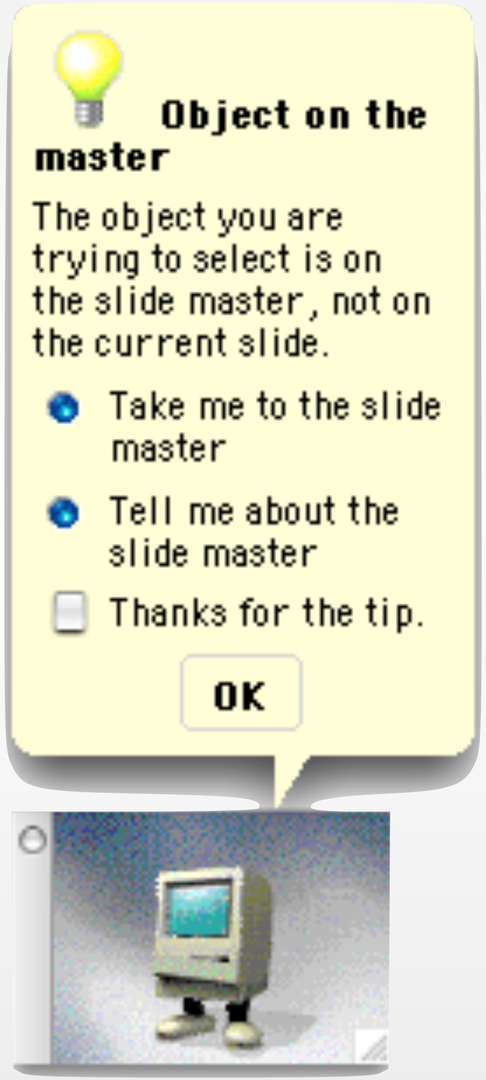
- Follow the "Principle of Least Surprise"
  - System should always react so that it minimizes the user's surprise (and therefore, confusion and irritation)
- Don't do unexpected things
  - …and don't make actions unexpectedly difficult ("…how do I print this in duplex?")
- Users (especially experts) like to be "in control"
  - They initiate actions, the system responds

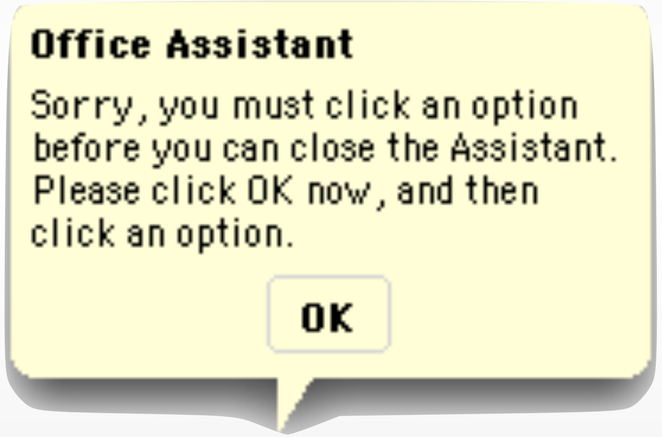
# Principle of Least Surprise





# PowerPoint Office Assistant





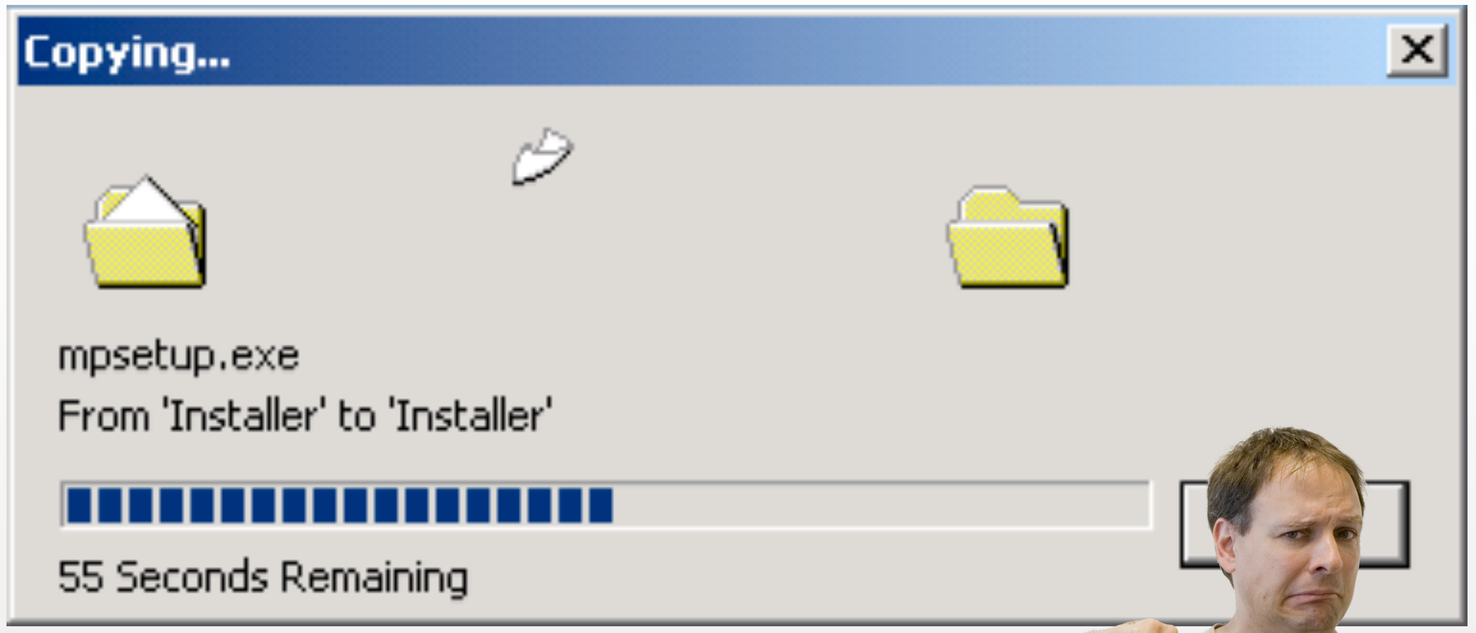

# Timeouts are Evil!

# 4. Provide Feedback & Be Responsive!

- Recall the Seven Stages Of Action
  - Complete & continuous feedback bridges Gulf of Evaluation
- Each user action requires some feedback
  - Subtle for small/short/frequent actions (e.g., key press, menu selection)
  - More noticeable for main/long/infrequent actions (e.g., saving or deleting files)
  - Icons in GUIs simplify visualizing object state and actions: direct manipulation
- Nothing is more frustrating for the user than "Where am I?" or "What is it doing now?"

# Example: Windows 2000 Progress Dialog for Copying Files

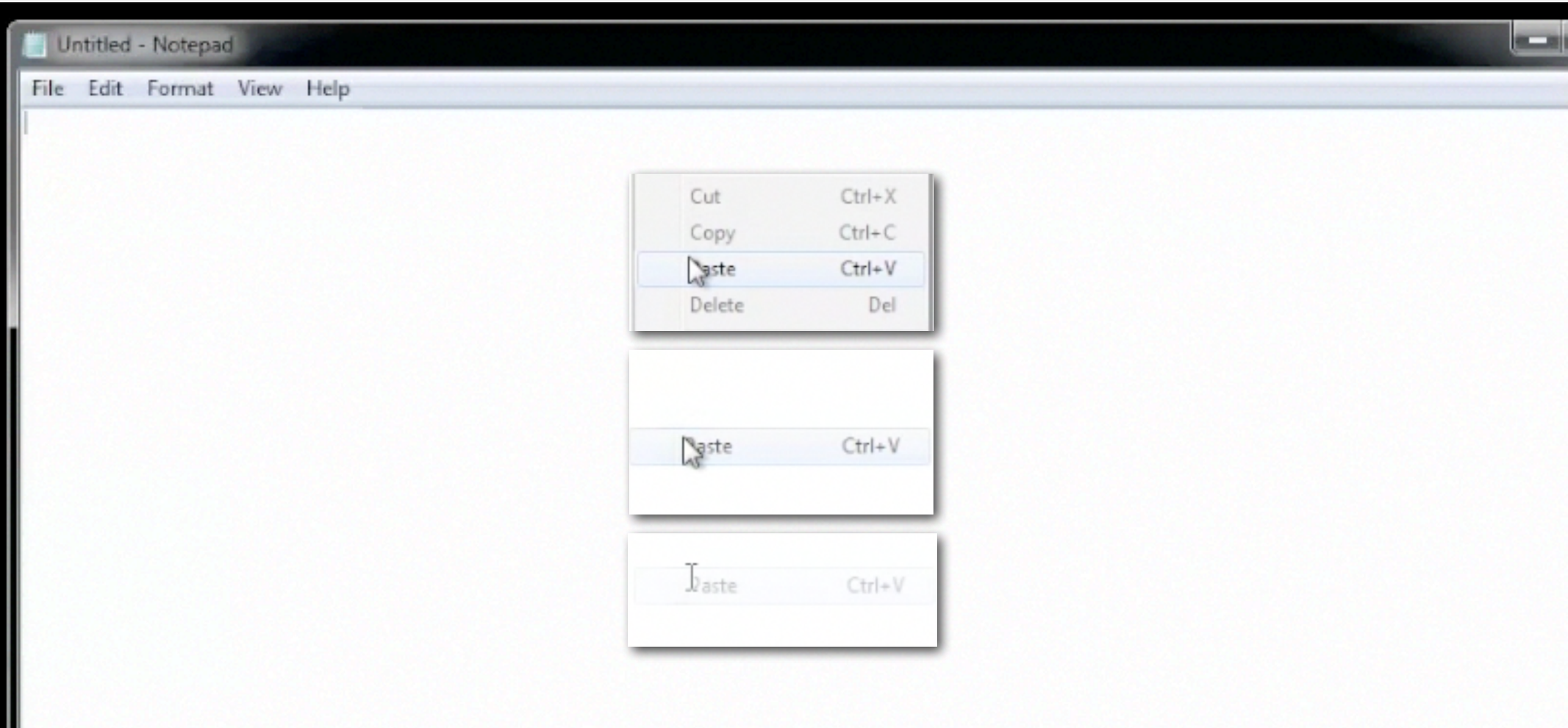
- What's wrong with this picture?



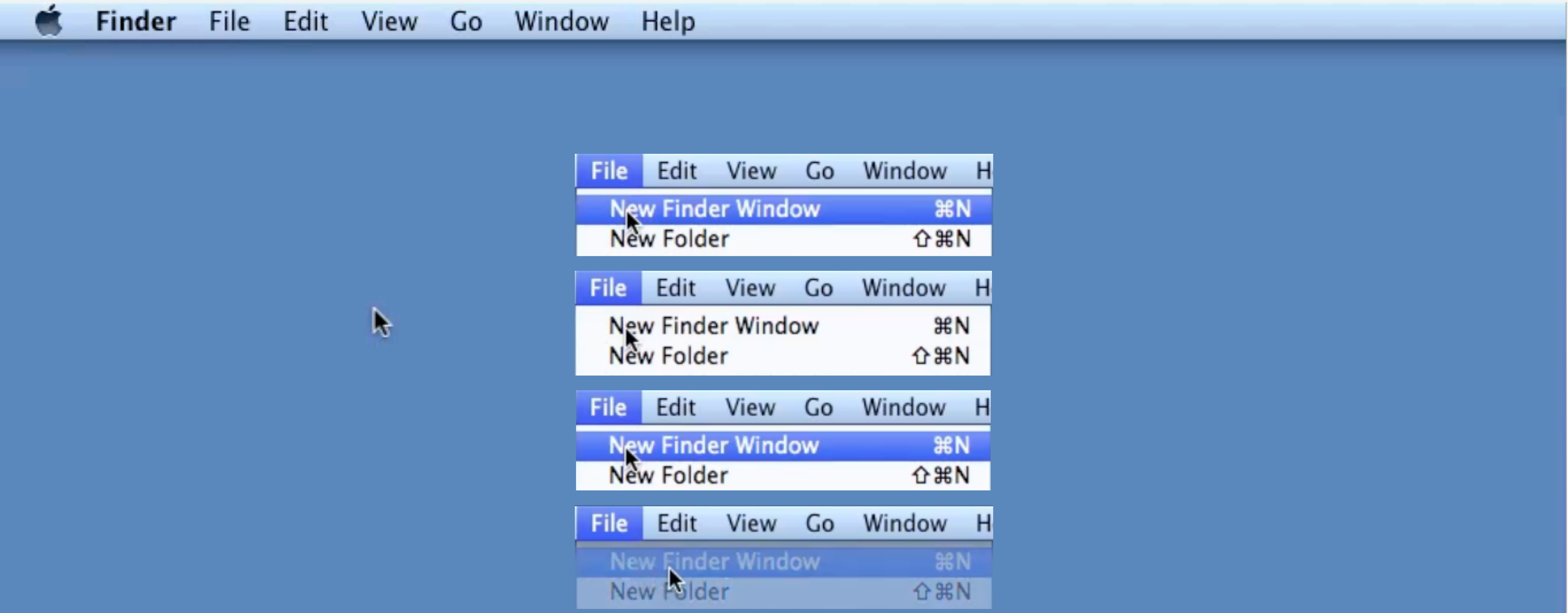
# Example: Menu Selection

- What happens when you select a menu item?

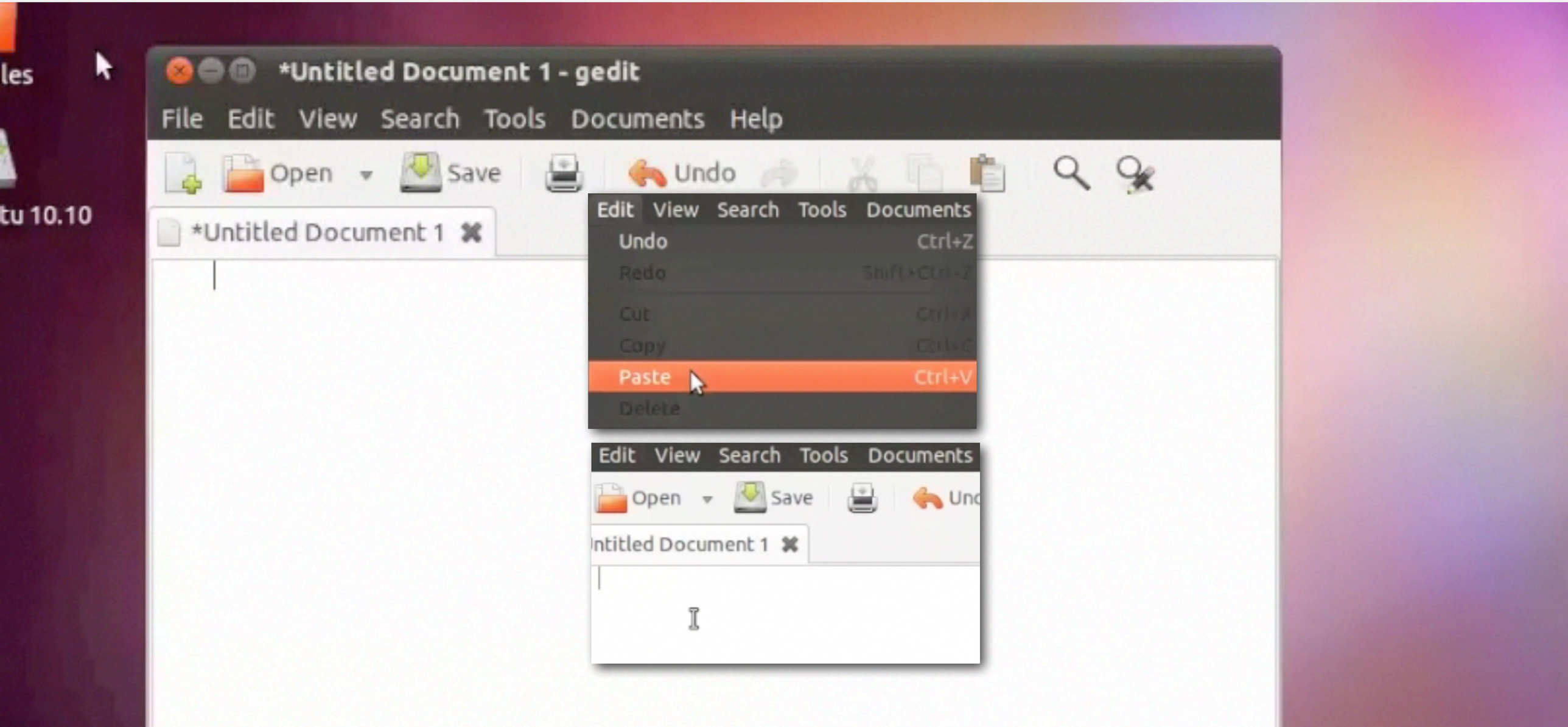
# Windows 7 Menu



# Mac OS X Menu


Finder File Edit View Go Window Help
File Edit View Go Window H
New Finder Window ⌘N
New Folder ⇧⌘N
File Edit View Go Window H
New Finder Window ⌘N
New Folder ⇧⌘N
File Edit View Go Window H
New Finder Window ⌘N
New Folder ⇧⌘N
File Edit View Go Window H
New Finder Window ⌘N
New Folder ⇧⌘N

# GNOME

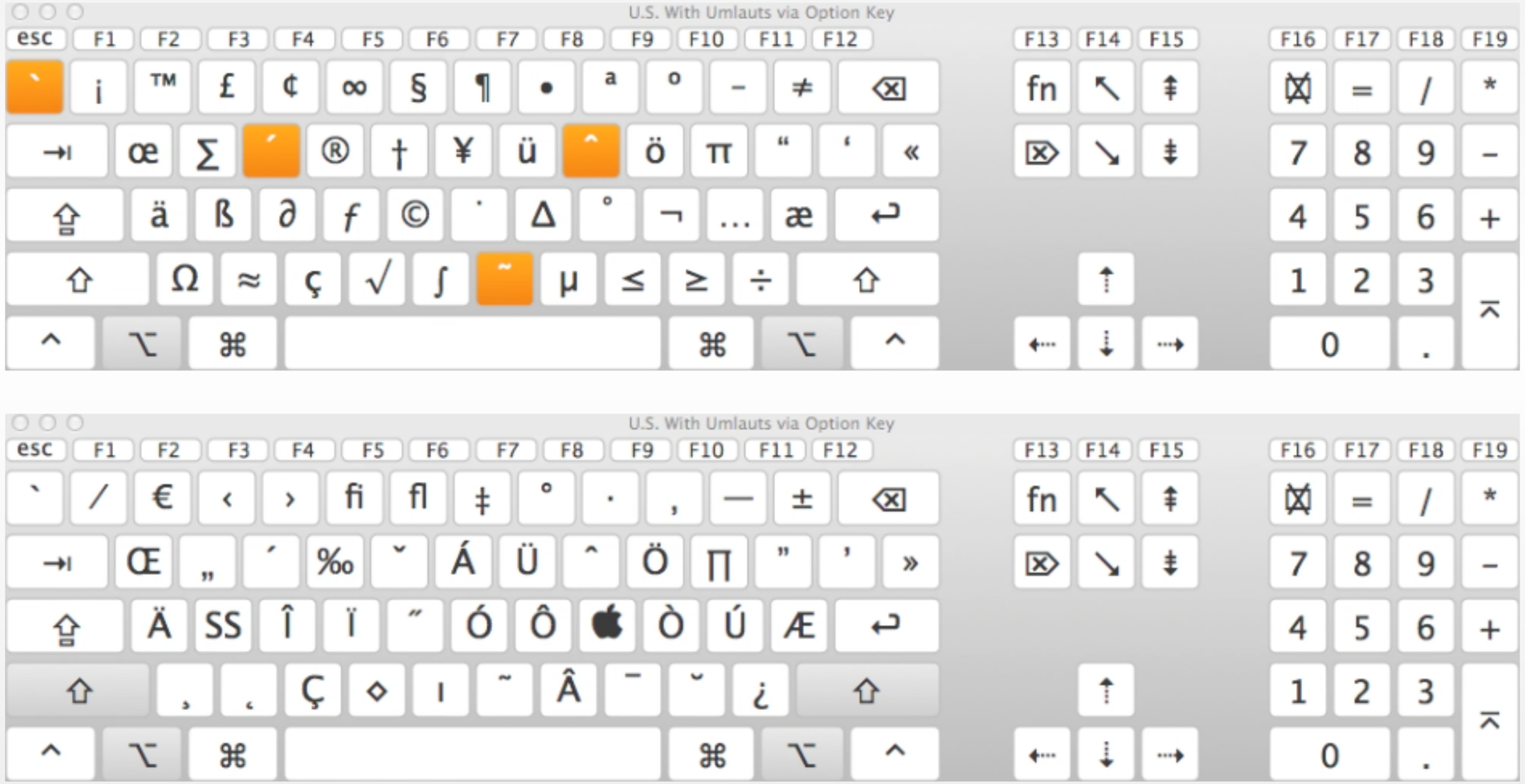

*Untitled Document 1 - gedit
File Edit View Search Tools Documents Help
Open
Save
Undo
*Untitled Document 1
Edit View Search Tools Documents
Undo Ctrl+Z
Redo
Cut
Copy
Paste Ctrl+V
Delete
Edit View Search Tools Documents
Open
Save
Undo
*Untitled Document 1

# Haptic Feedback

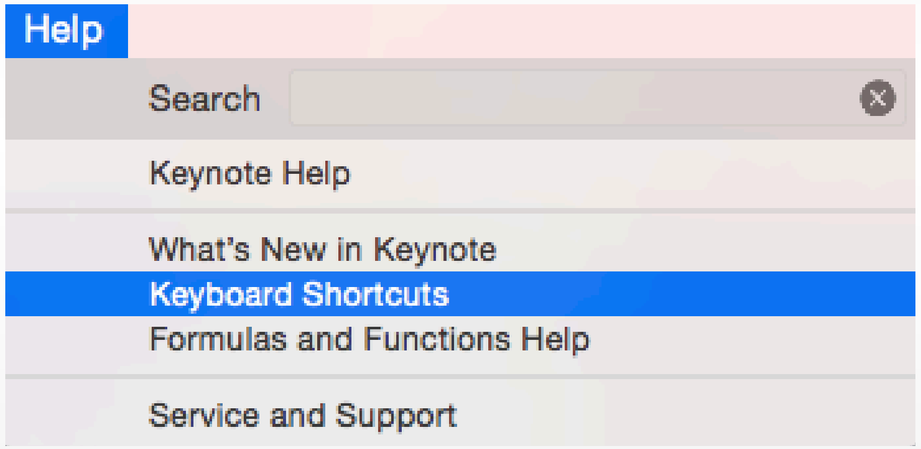
# 5. Minimize Memory Load!

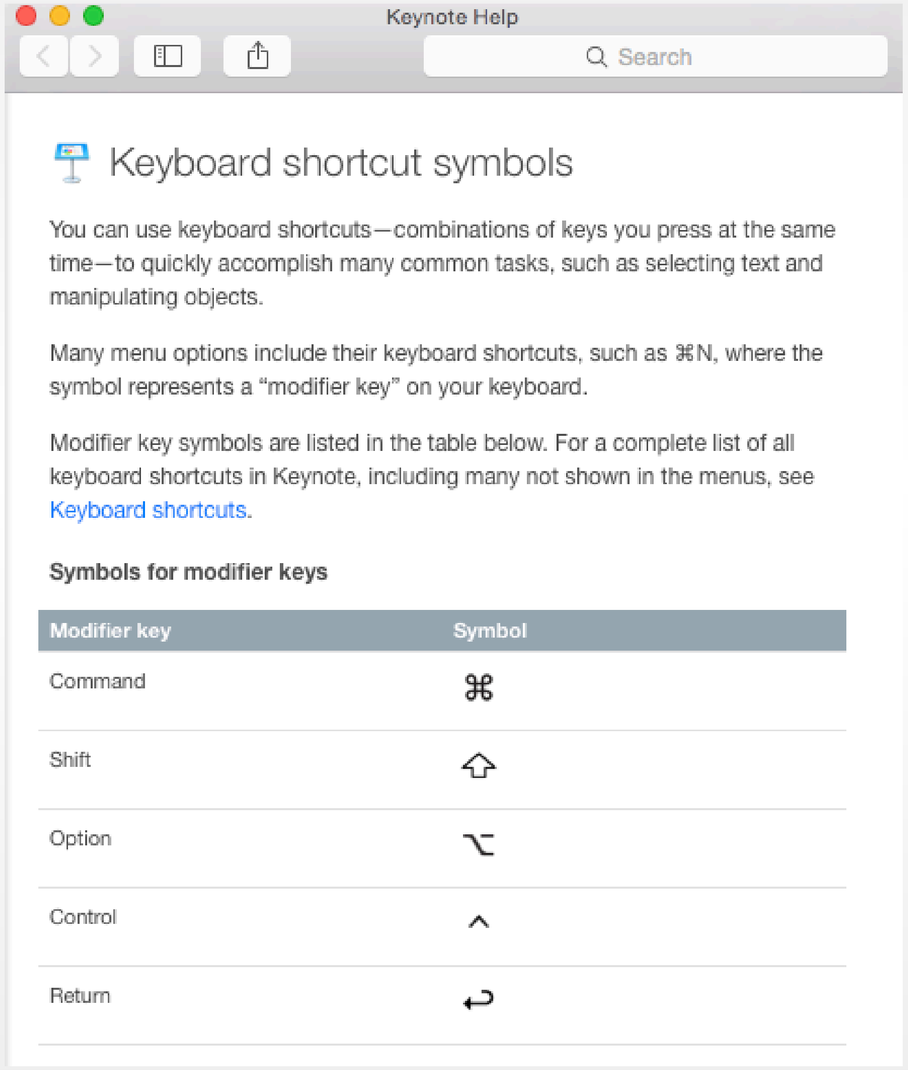
- Short-term memory: limited capacity (ca. 7 ± 2 chunks)
- Avoid situations where prior dialog information has to be reproduced from memory
  - E.g., user should not have to type anything in twice.
- Display information so it's easy to parse (Gestalt laws)
- Provide obvious access to help pages for codes, abbreviations, etc.
- It's easier to minimize memory load with GUIs than command line interfaces
  - "Read & Select" instead of "Remember & Type"

# Keyboard Viewer



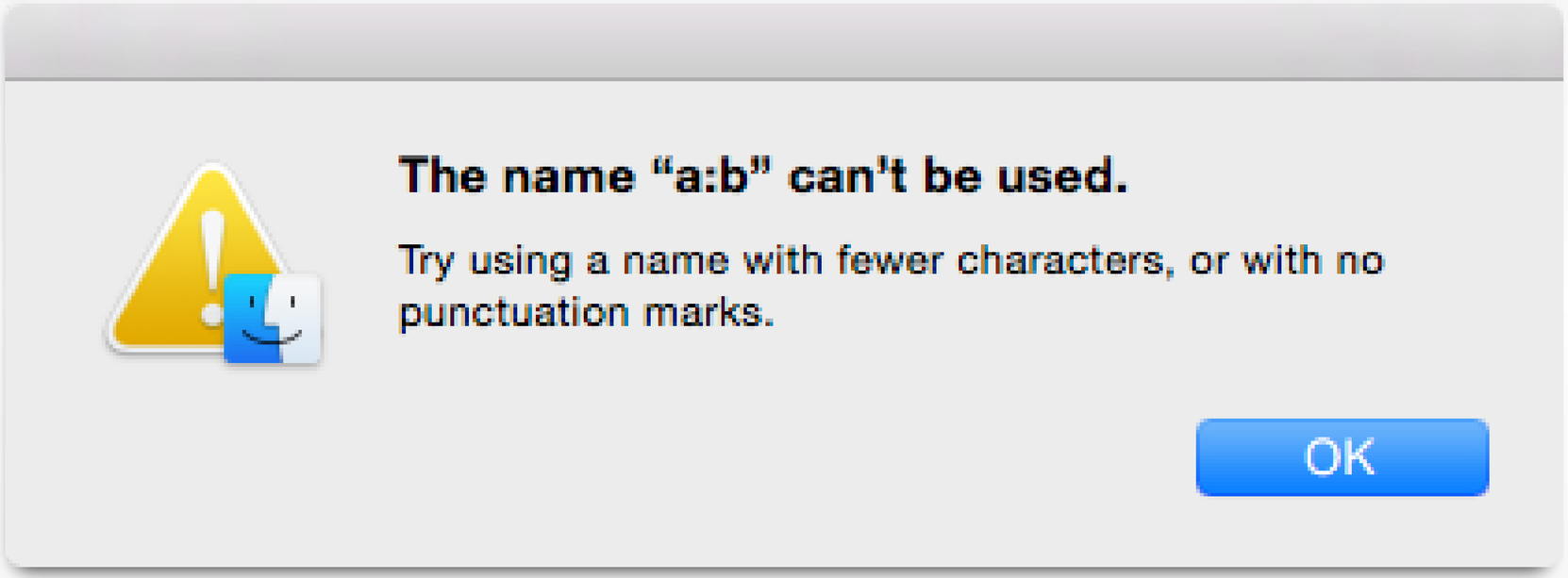
# Keyboard Shortcut List



# 6. Avoid Errors, Help to Recover!

- Errors lead to stress
  - So offer simple, constructive, concrete, helpful, and comfortable instructions to recover
  - System state should not change through wrong input, or should be easy to restore
- Best: Design system so mistakes cannot be made in the first place. Examples:
  - Selection instead of (mis)typing
  - Cannot type letters in numerical data fields
  - Arcade game machines have virtually no error messages!
  - Automatic correction of illegal characters in file names


# 6. Avoid Errors, Help to Recover!

- Offer undo
  - As many actions as possible should be reversible
  - Lowers anxiety because users know errors are correctable
  - Encourages users to try out new functions
  - Ideal: multiple undo, and at multiple levels


Photoshop File Edit Image Layer Select Filter Analysis 3D View Window Help
jan-good-design.png @ 25% (Good Design, R...
HISTORY
jan-good-design.png
Open
Type Tool
Move
Free Transform
Move
Move
25%
Doc: 5.65M/5.99M

# 7. Design Clear Exits & Closed Dialogs!

- Three most common questions of users during a dialog:
  - Where am I?
  - What can I do here?
  - How do I get back to where I was?
- Clear exits ("Back", "Quit") help with Question 3
- Closed dialogs:
  - Provide feeling of having completed a step
  - Allows user to relax, "take a breath", frees the mind for the next step

amazon.com

Hello, C WACHARAMANOTHAM. We have recommendations for you. (Not C?)

C's Amazon.com | Today's Deals | Gifts & Wish Lists | Gift Cards | Your Account | Help

Shop All Departments | Search | All Departments | GO | Cart | Wish List

# Thank you, your order has been placed.

An e-mail confirmation has been sent to you.

Order Number: **104-1969352-5141057**

- 1 item will be shipped to Chatchavan Wacharamanotham by Amazon.com. Estimated delivery **January 18, 2011 - February 7, 2011**

› Review or edit your order

## Next time use Express Checkout with PayPhrase

Buy on Amazon and across the web with a simple phrase.

**Choose your PayPhrase:** “C's Surprising Doors”

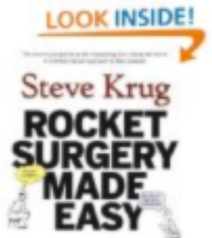
(Use this suggestion, see others, or enter your own)

**Orders will ship to:** Chatchavan Wacharamanotham, Lehrstuhl In...
**Orders will be paid using:** VISA ****-

Create your PayPhrase

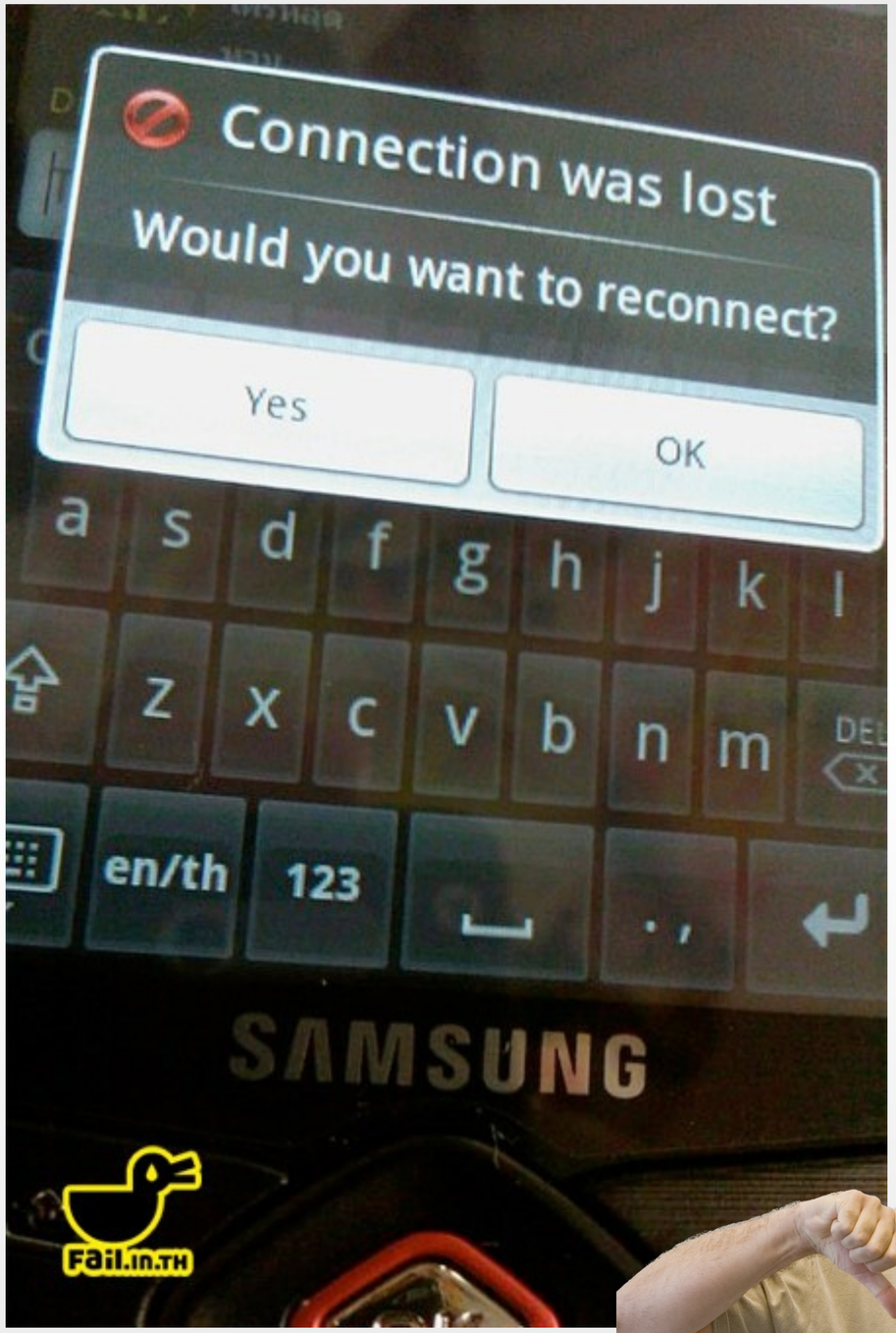
A Payphrase is an easy-to-remember shortcut to shipping and payment information in your Amazon.com account. Use it on Amazon.com and across the web. (Learn more)

## Recommendations Based on Your Order









Connection was lost
Would you want to reconnect?
Yes
OK
SAMSUNG
Fail.in.TH

# 8. Include Help and Documentation!

- Hierarchy of help systems, with increasing breadth and decreasing ease-of-access:
  - Dynamic Descriptors, such as Tooltips (but let users disable them!)
  - Online tutorials and references
  - Printed documentation (but…)
- More active help can be useful:
  - Assistants and Wizards
  - But danger: system takes over initiative, which breaks Rule 3 (predictability)

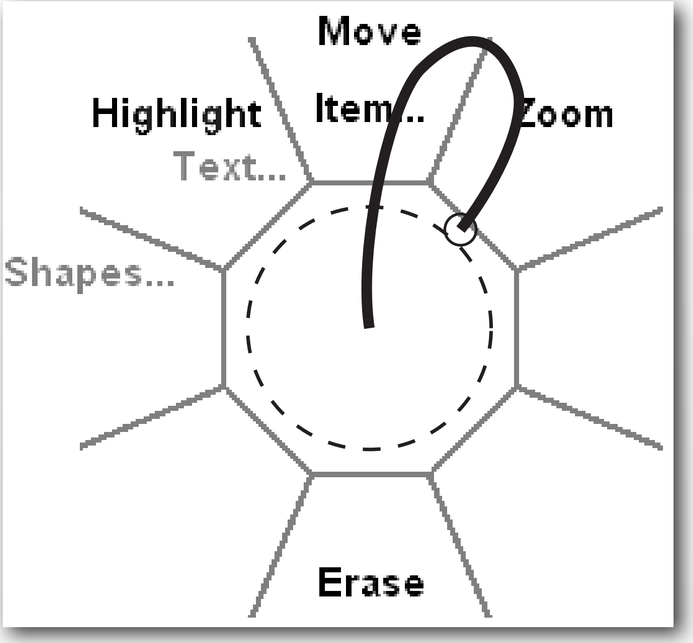
**Users don't read manuals!**

# 9. Address Diverse User Needs!

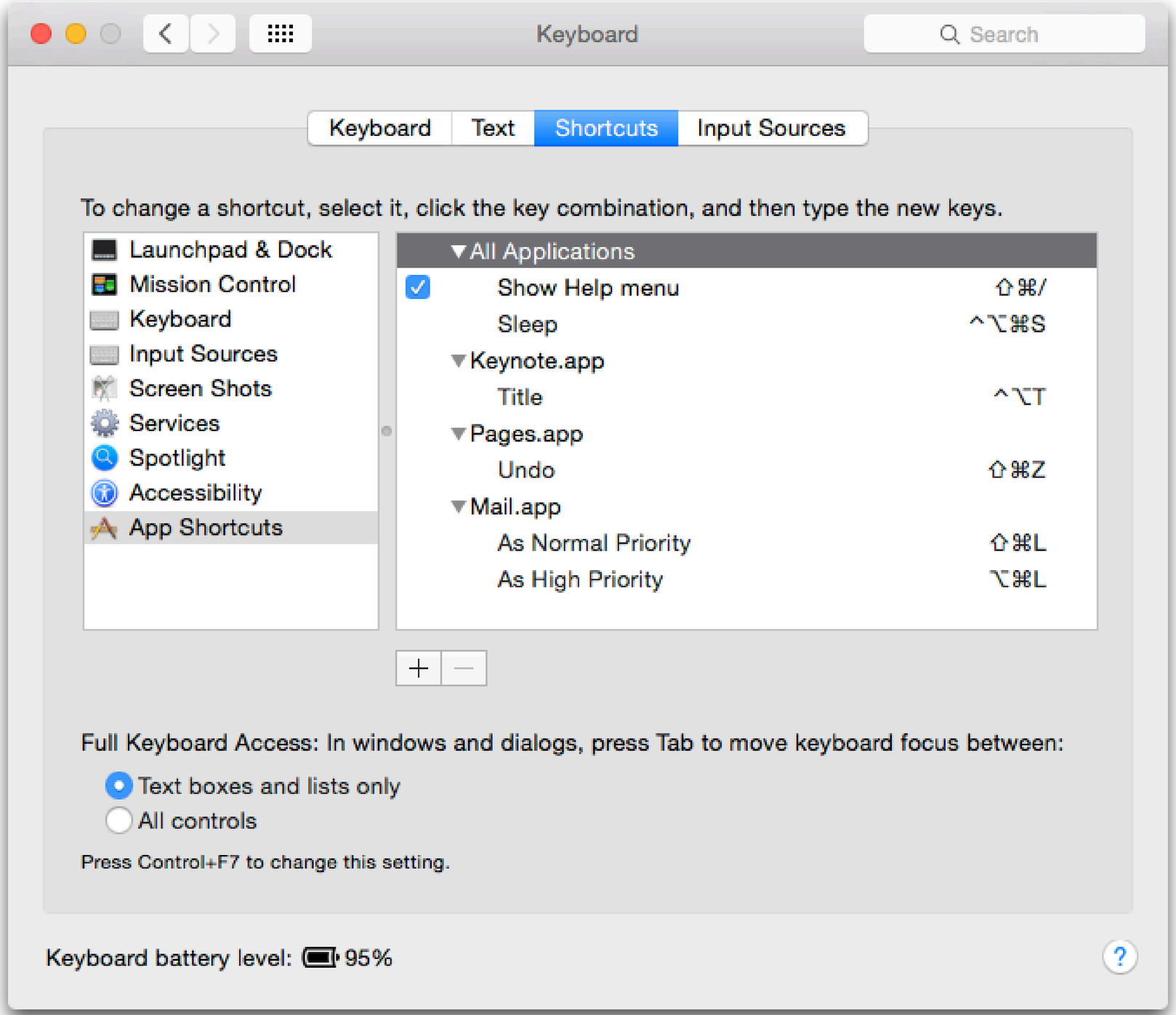
- Novices want more explanations
- Frequent users want less fussy and faster interaction
  - They value (configurable) keyboard shortcuts, macro recording, programmability, and quick responses without unnecessary feedback (for them)
- Different age ranges have different interface expectations
- Technology affinity ("enjoying to play with gadgets") varies widely among people
- But conflict: If in doubt, Rule 1 ("Keep the interface simple") is more important! May have to focus on a user group

# Example: PostBrainstorm

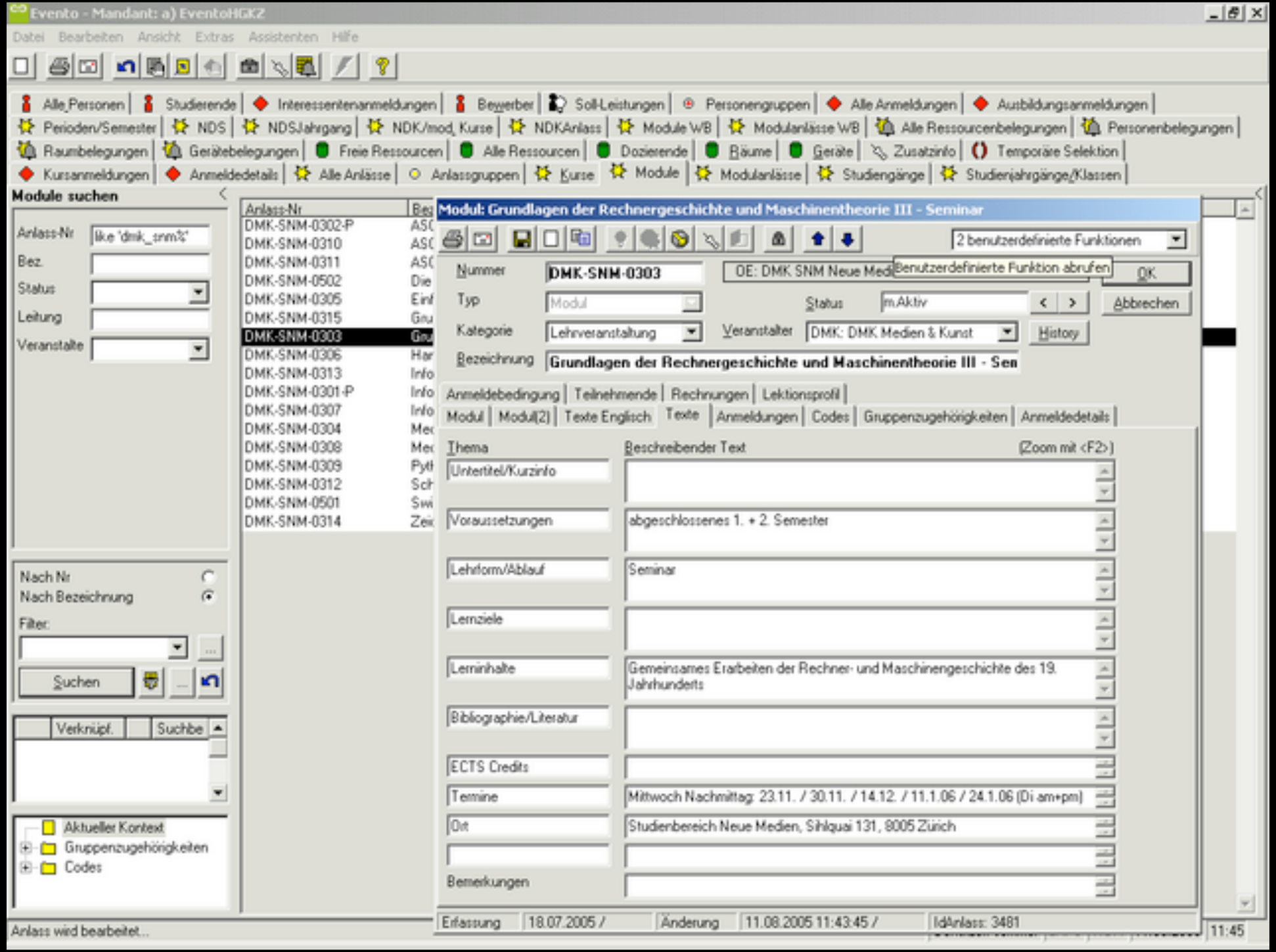
- New users get popup menu
- Experienced users remember the gestures to select frequent commands from the menu
- The menu does not even pop up when the gesture is done rapidly
- But: If you ever forget the gesture, just wait for a fraction of a second, and you can revert to using the popup menu
- The result: Fluid and reversible transition from menu selection to gesture commands




[F. Guimbretière, Stanford, UIST 2000]


Keyboard
Search
Keyboard
Text
Shortcuts
Input Sources
To change a shortcut, select it, click the key combination, and then type the new keys.
Launchpad & Dock
Mission Control
Keyboard
Input Sources
Screen Shots
Services
Spotlight
Accessibility
App Shortcuts
All Applications
Show Help menu ⇧⌘/
Sleep ^⌥⌘S
Keynote.app
Title ^⌥T
Pages.app
Undo ⇧⌘Z
Mail.app
As Normal Priority ⇧⌘L
As High Priority ⌥⌘L
Full Keyboard Access: In windows and dialogs, press Tab to move keyboard focus between:
Text boxes and lists only
All controls
Press Control+F7 to change this setting.
Keyboard battery level: 95%

# 10. Hire a Graphic Designer!


Evento - Mandant: a) EventoHGKZ
Datei Bearbeiten Ansicht Extras Assistenten Hilfe
Alle Personen | Studierende | Interessentenanmeldungen | Bewerber | Soll-Leistungen | Personengruppen | Alle Anmeldungen | Ausbildungsanmeldungen
Perioden/Semester | NDS | NDSJahrgang | NDK/mod. Kurse | NDKAnlass | Module WB | Modulanlässe WB | Alle Ressourcenbelegungen | Personenbelegungen
Raumbelegungen | Gerätebelegungen | Freie Ressourcen | Alle Ressourcen | Dozierende | Räume | Geräte | Zusatzinfo | Temporäre Selektion
Kursanmeldungen | Anmeldedetails | Alle Anlässe | Anlassgruppen | Kurse | Module | Modulanlässe | Studiengänge | Studienjahrgänge/Klassen
Module suchen
Anlass-Nr
like 'dmk_snm%'
Bez.
Status
Leitung
Veranstalte
Nach Nr
Nach Bezeichnung
Filter:
Suchen
Verknüpf.
Suchbe
Aktueller Kontext
Gruppenzugehörigkeiten
Codes
Anlass-Nr
DMK-SNM-0302-P
DMK-SNM-0310
DMK-SNM-0311
DMK-SNM-0502
DMK-SNM-0305
DMK-SNM-0315
DMK-SNM-0303
DMK-SNM-0306
DMK-SNM-0313
DMK-SNM-0301-P
DMK-SNM-0307
DMK-SNM-0304
DMK-SNM-0308
DMK-SNM-0309
DMK-SNM-0312
DMK-SNM-0501
DMK-SNM-0314
Modul: Grundlagen der Rechnergeschichte und Maschinentheorie III - Seminar
2 benutzerdefinierte Funktionen
Benutzerdefinierte Funktion abrufen
Nummer
DMK-SNM-0303
OE: DMK SNM Neue Medi
OK
Typ
Modul
Status
mAktiv
Abbrechen
Kategorie
Lehrveranstaltung
Veranstalter
DMK: DMK Medien & Kunst
History
Bezeichnung
Grundlagen der Rechnergeschichte und Maschinentheorie III - Sen
Anmeldebedingung | Teilnehmende | Rechnungen | Lektionsprofil
Modul | Modul(2) | Texte Englisch | Texte | Anmeldungen | Codes | Gruppenzugehörigkeiten | Anmeldedetails
Thema
Beschreibender Text
(Zoom mit <F2>)
Untertitel/Kurzinfo
Voraussetzungen
abgeschlossenes 1. + 2. Semester
Lehrform/Ablauf
Seminar
Lernziele
Lerninhalte
Gemeinsames Erarbeiten der Rechner- und Maschinengeschichte des 19. Jahrhunderts
Bibliographie/Literatur
ECTS Credits
Termine
Mittwoch Nachmittag: 23.11. / 30.11. / 14.12. / 11.1.06 / 24.1.06 (Di am+pm)
Ort
Studienbereich Neue Medien, Sihlquai 131, 8005 Zürich
Bemerkungen
Erfassung
18.07.2005 /
Änderung
11.08.2005 11:43:45 /
IdAnlass: 3481
Anlass wird bearbeitet...
11:45


PENNY
MARKT
HOHE QUALITÄT ZUM NIEDRIGSTEN PREIS!
Seit 11.10.
PREISSTURZ!

# Ten Golden Rules of Interface Design

1. Keep the interface simple!
2. Speak the user's language!
3. Be consistent and predictable!
4. Provide feedback & be responsive!
5. Minimize memory load!
6. Avoid errors, help to recover, offer undo!
7. Design clear exits and closed dialogs!
8. Include help and documentation!
9. Address diverse user needs!
10. Hire a graphic designer!