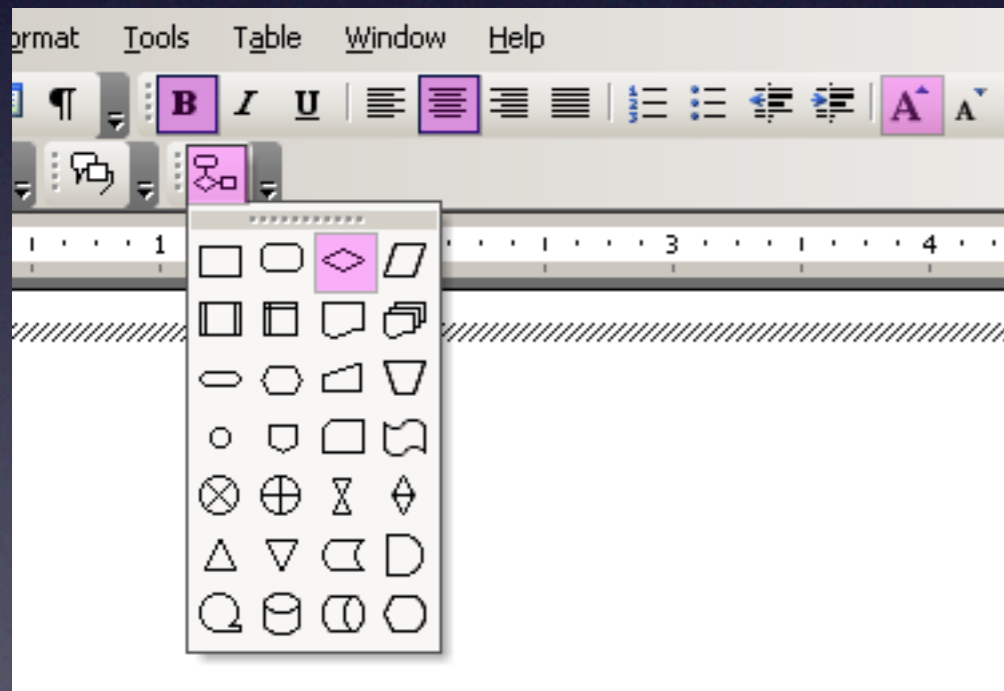
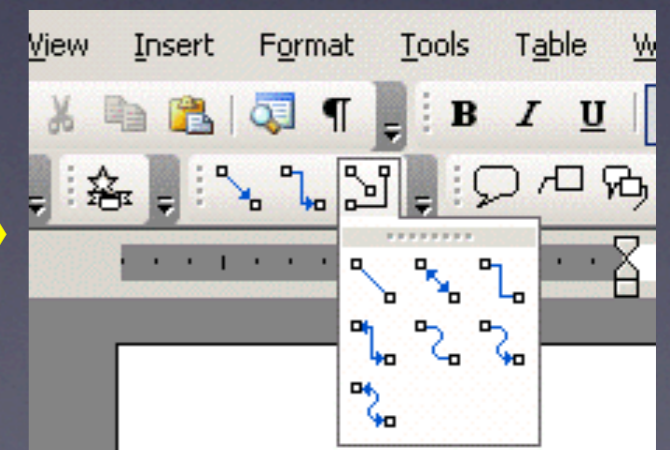
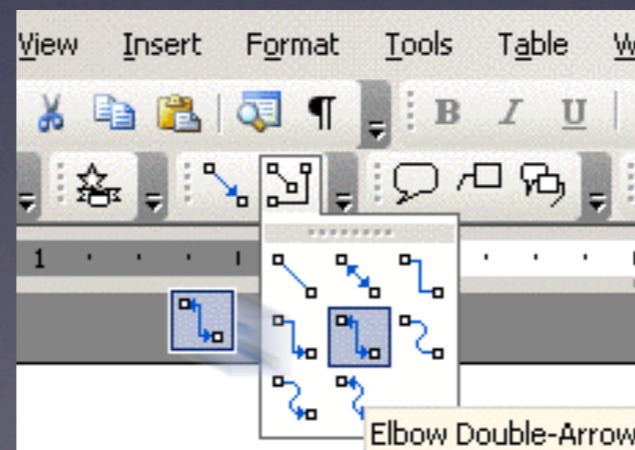


# Exploring the Design Space for Adaptive Graphical User Interfaces



Krzysztof Gajos  
Mary Czerwinski  
Desney Tan  
Daniel S. Weld

(University of Washington)  
(Microsoft Research)  
(Microsoft Research)  
(University of Washington)





# Scope

**Graphical User Interfaces** where the **system automatically** adapts the **presentation of the functionality**



# Scope

**Graphical User Interfaces** where the system **automatically** adapts the **presentation** of the **functionality**

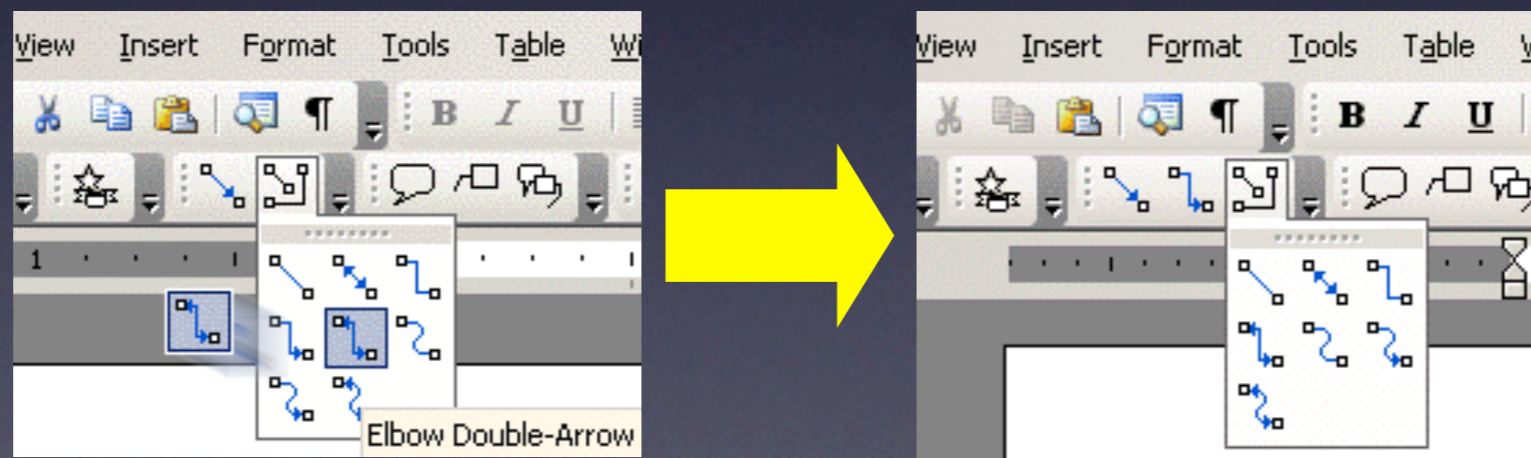


The Split Interface



# Scope

**Graphical User Interfaces** where the **system automatically** adapts the **presentation of the functionality**

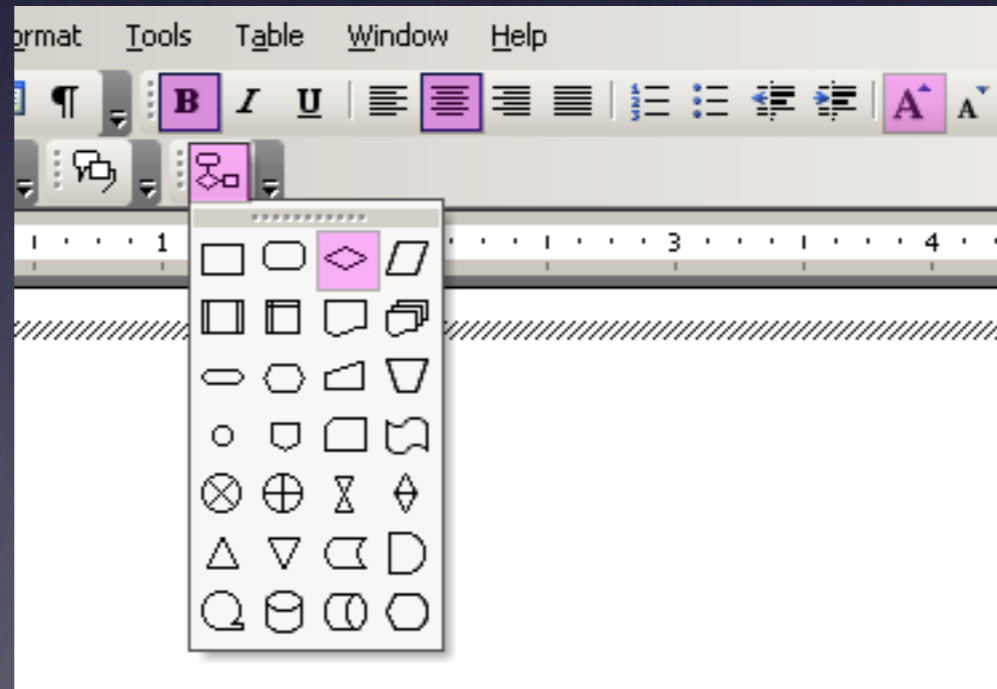


The Moving Interface



# Scope

**Graphical User Interfaces** where the **system automatically** adapts the **presentation** of the **functionality**



The Visual Popout Interface



# Scope

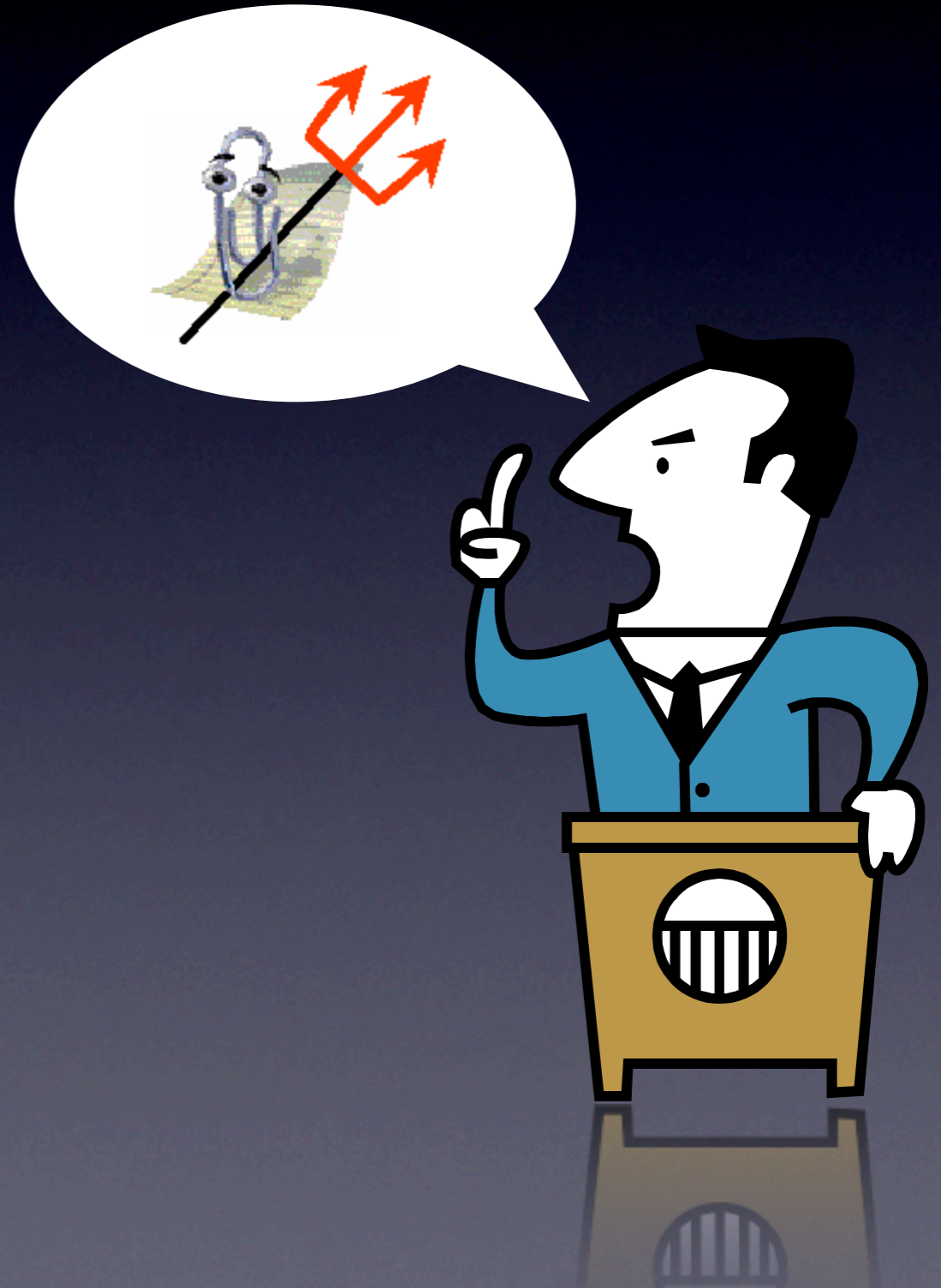
**Graphical User Interfaces** where the **system automatically** adapts the **presentation of the functionality**



# Motivation

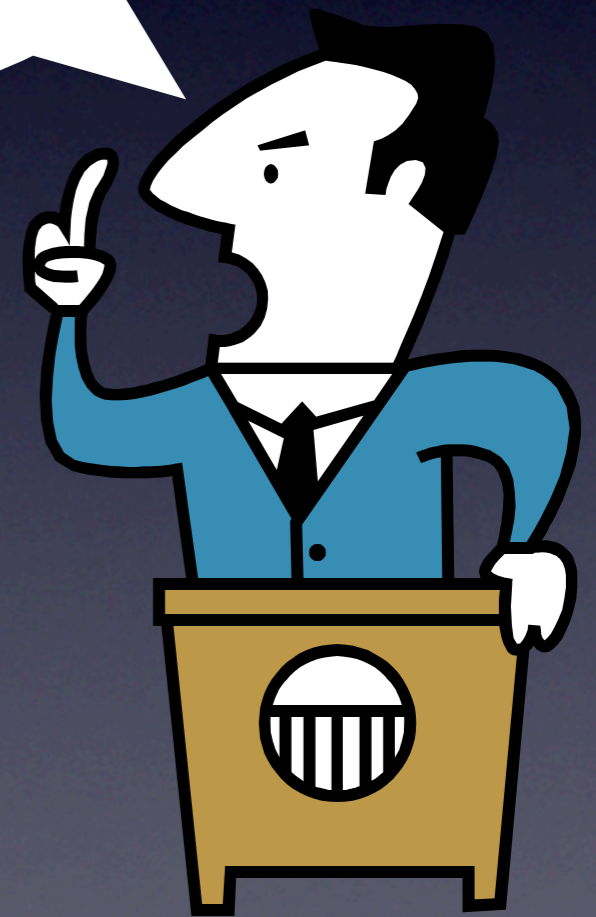
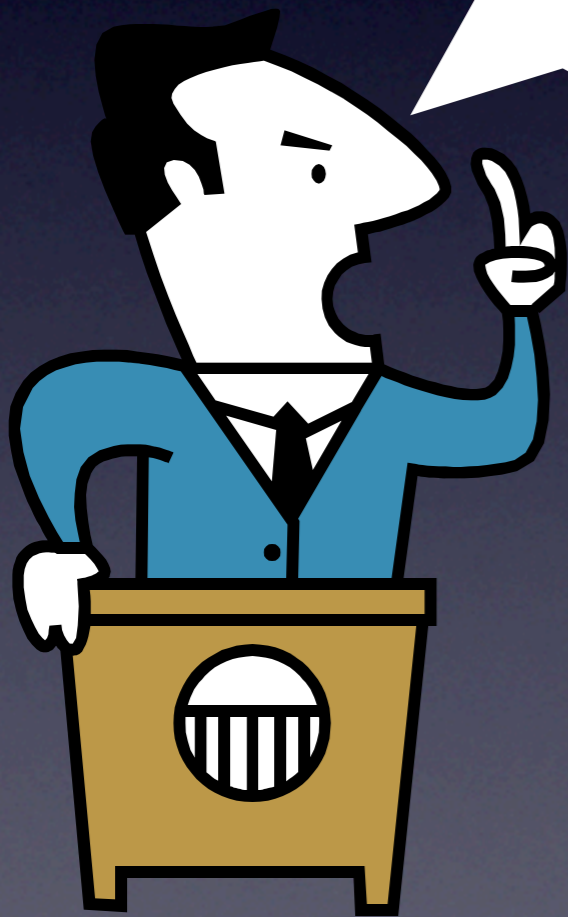
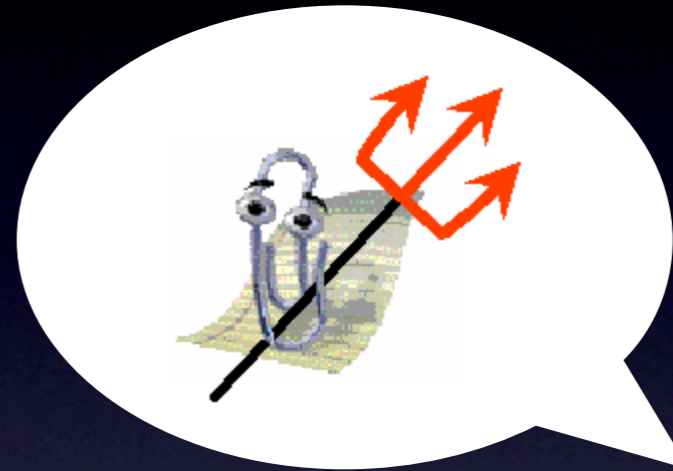


# Motivation



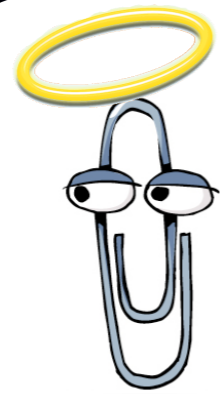


# Motivation

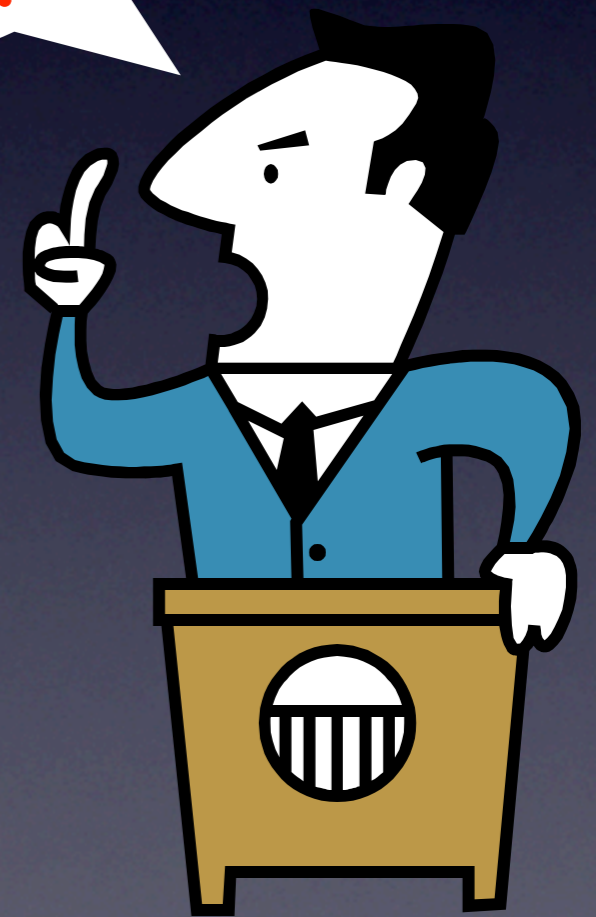
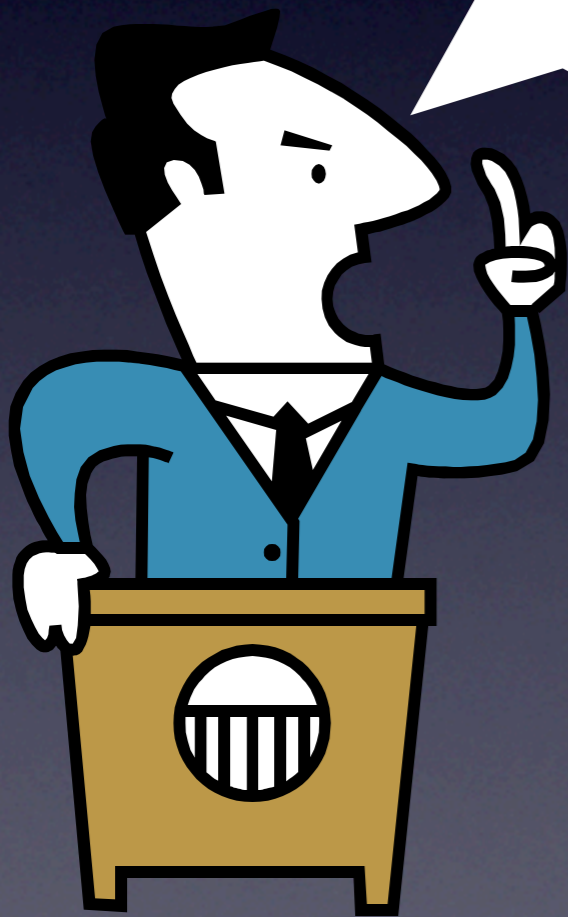




# Motivation



They  
disorient  
the user!

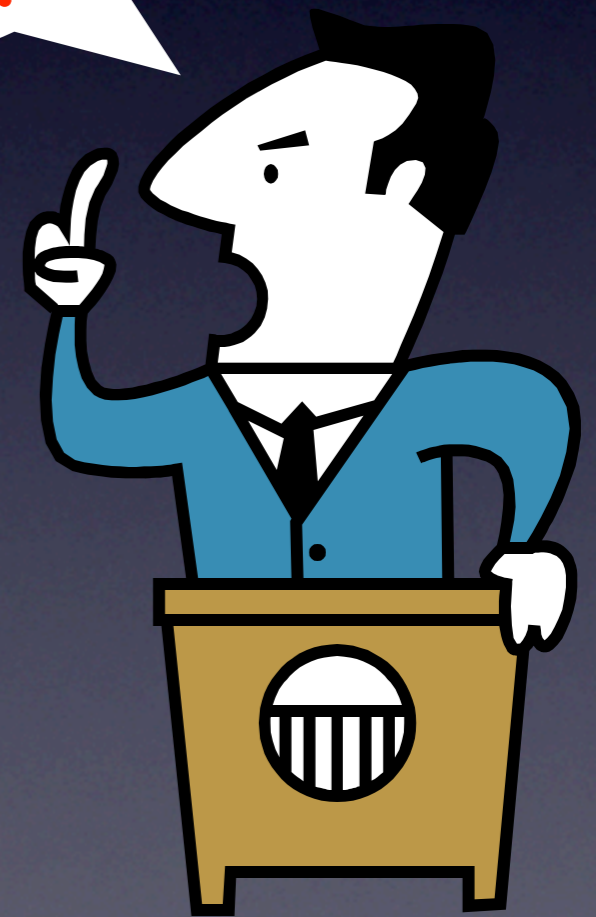
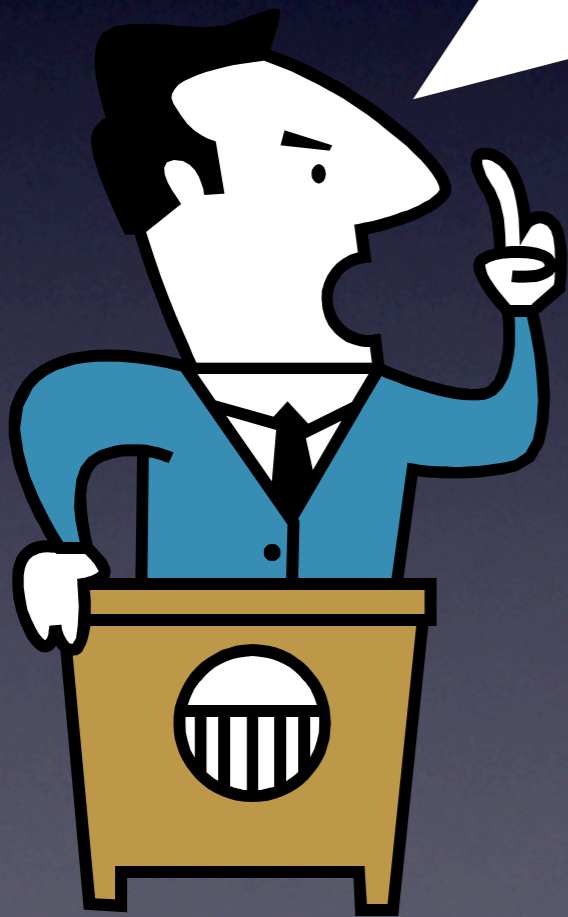




# Motivation

They optimize  
the UI for the  
individual!

They  
disorient  
the user!





# Prior Work

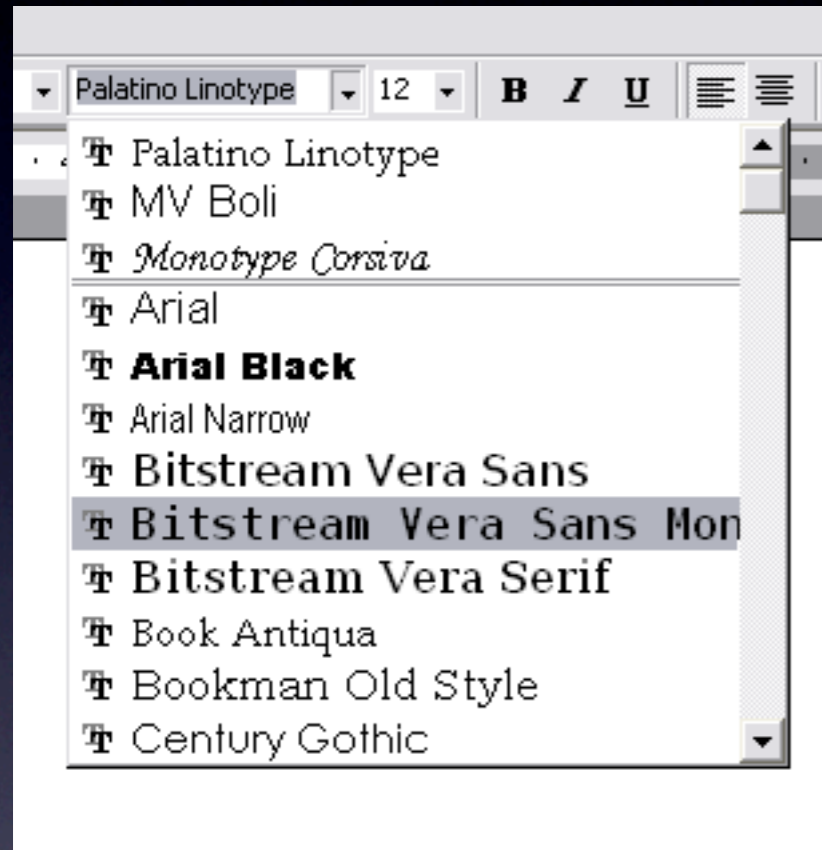


# Prior Work

- ↑ Greenberg and Witten [1985]
- ↕ Trevellyan and Browne [1987]
- ↓ Mitchell and Shneiderman [1989]
- ↑ Sears and Shneiderman [1994]
- ? McGrenere, Baecker and Booth [2002]
- ↓ Findlater and McGrenere [2004]
- ↔ Tsandilas and shraefel [2005]



# Commercial Deployments





# Commercial Deployments

This screenshot shows the font and symbol menus of Microsoft Word 2003. The font menu is open, showing a list of fonts with 'Palatino Linotype', 'MV Boli', and 'Monotype Corsiva' highlighted by a red box. Below it, the 'Symbol' dialog box is open, showing a grid of symbols. The 'Euro' symbol (€) is highlighted in the grid. A red box highlights the 'Recently used symbols' section at the bottom of the dialog, which includes the Euro symbol, Pound symbol (£), Yen symbol (¥), Copyright symbol (©), Registered trademark symbol (®), Trademark symbol (™), Plus-minus symbol (±), Not equal symbol (≠), Less than or equal to symbol (≤), Greater than or equal to symbol (≥), Division symbol (÷), Multiplication symbol (×), Infinity symbol (∞), Greek letter mu (μ), Greek letter alpha (α), and Greek letter beta (β). The 'Character code' field shows '20AC' and the 'from' dropdown is set to 'Unicode (hex)'. The 'Insert' button is visible at the bottom.

This screenshot shows the Windows XP desktop environment. The user's name 'kgajos' is visible in the top right corner. The Start menu is open, showing a list of programs and folders. A red box highlights the 'All Programs' list, which includes: Internet (Mozilla Firefox), E-mail (Mozilla Thunderbird), Presenter 2.0, DeckBuilder 2.0, Microsoft Office Word 2003, iTunes, Adobe Reader 7.0, and Microsoft Office PowerPoint 2003. The desktop background is a light blue color. The taskbar at the bottom shows the Start button, several application icons, and the system tray with the Log Off and Turn Off Computer buttons.



# Our Goal

Uncover the **factors** and **relationships** that influence users' **satisfaction** and actual **performance** when using adaptive UIs



# Road Map

- ✓ Introduce and motivate the problem
- Video**
- Experiment 1: qualitative results
- Experiment 2: quantitative results
- Synthesis
- Conclusions



**Mapping the Design Space  
for Adaptive User Interfaces:  
The Good, the Bad, and the Ugly**







Potential  
Benefit

Potential  
Disorientation



# The Split Interface



Potential  
Benefit

Potential  
Disorientation

Medium

Low



Potential Benefit

Potential Disorientation

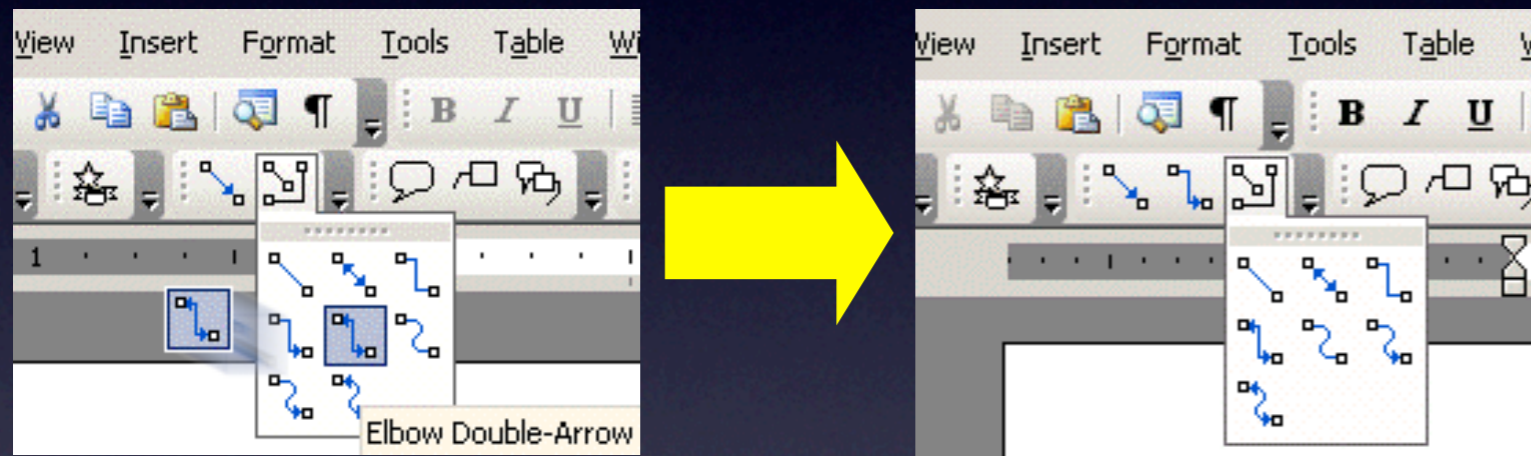
## The Split Interface



Medium

Low

## The Moving Interface



High

Medium



Potential Benefit

Potential Disorientation

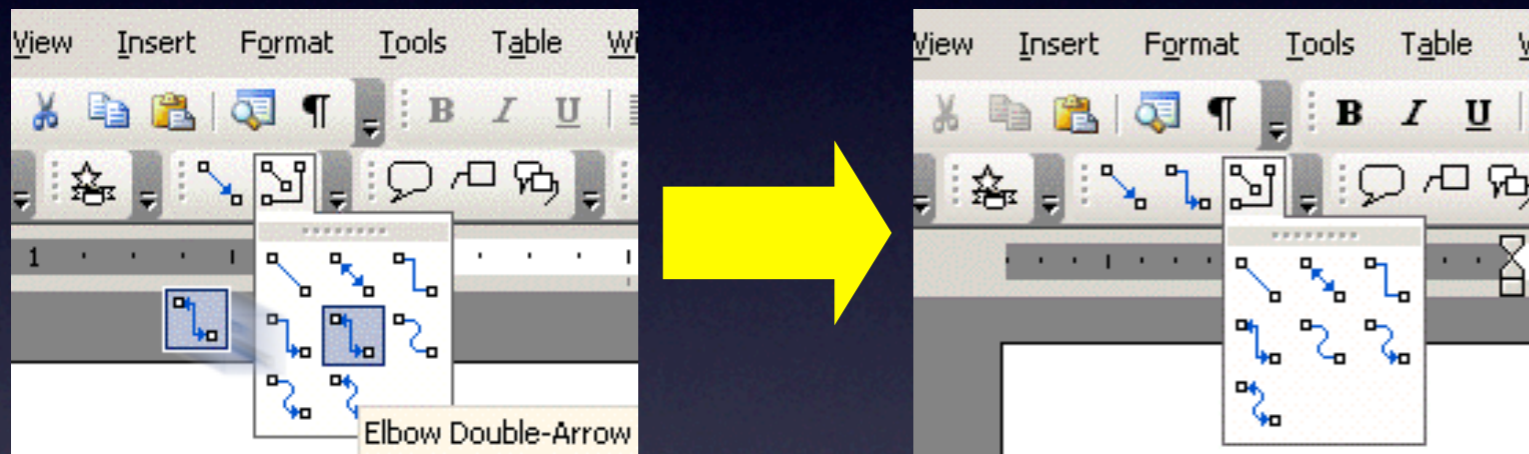
## The Split Interface



Medium

Low

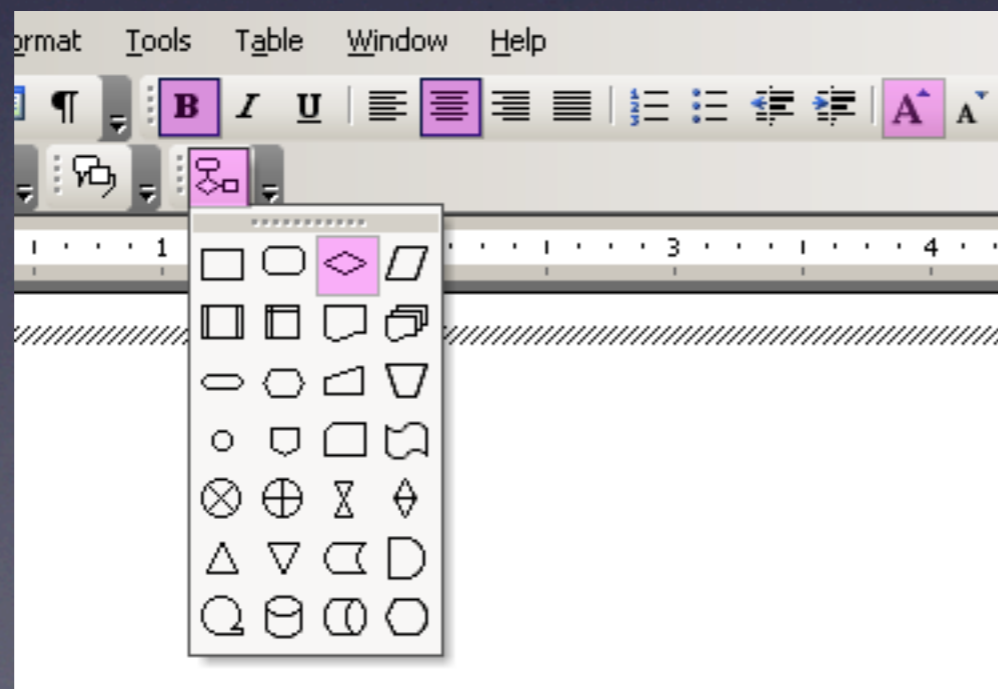
## The Moving Interface



High

Medium

## The Visual Popout Interface



Low

Low



# Experiment 1

**Goal:** collect informative **subjective** data



# Participants

- 26 volunteers (10 female)
- aged 25 to 55 (mean=46)
- moderate to high experience using computers (as indicated by a validated screener)
- intermediate to expert users of MS Office (as indicated by a validated screener)
- participants received software gratuity



# Tasks

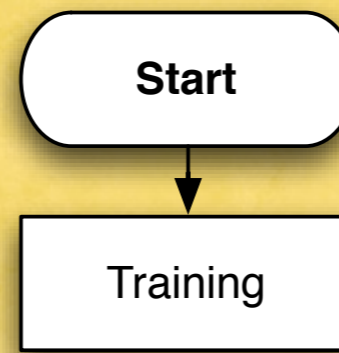
- Three classes of editing tasks:
  - Flow chart edits
  - Text edits
  - Combined text and graphical edits



# Procedures

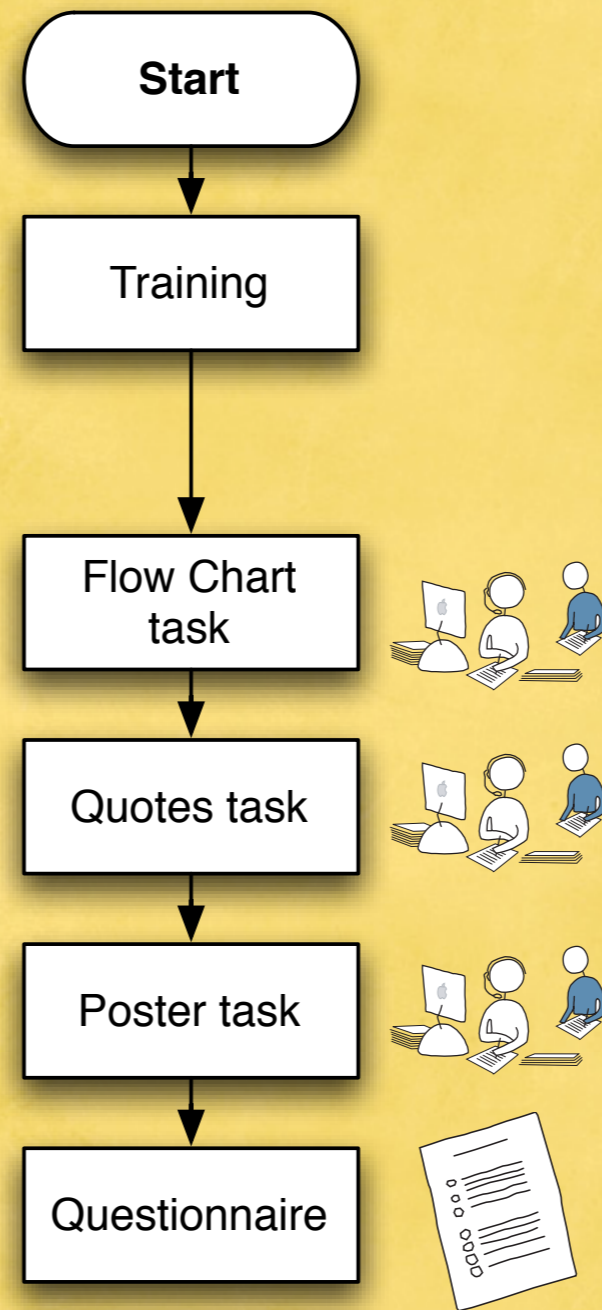


# Procedures



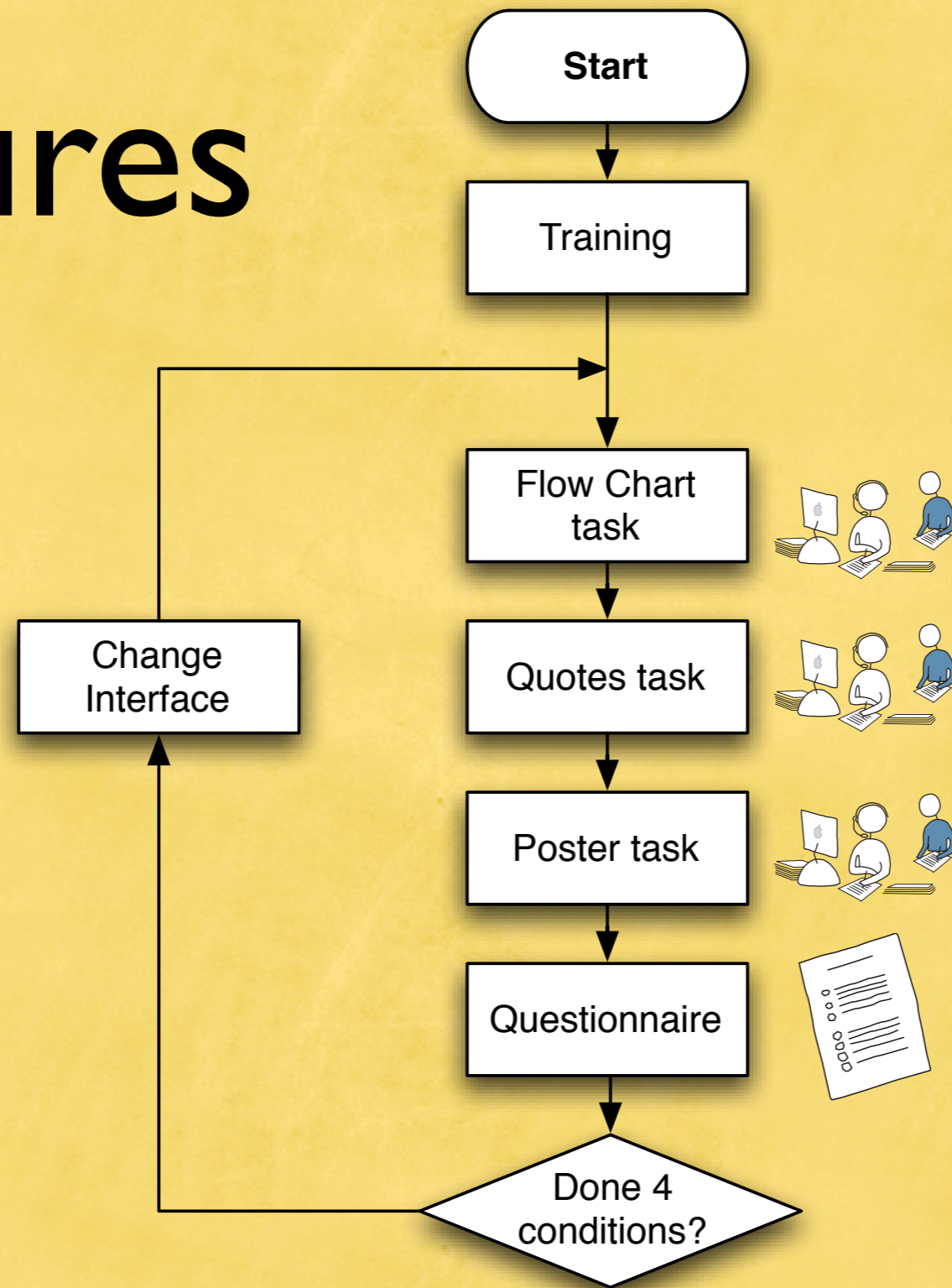


# Procedures



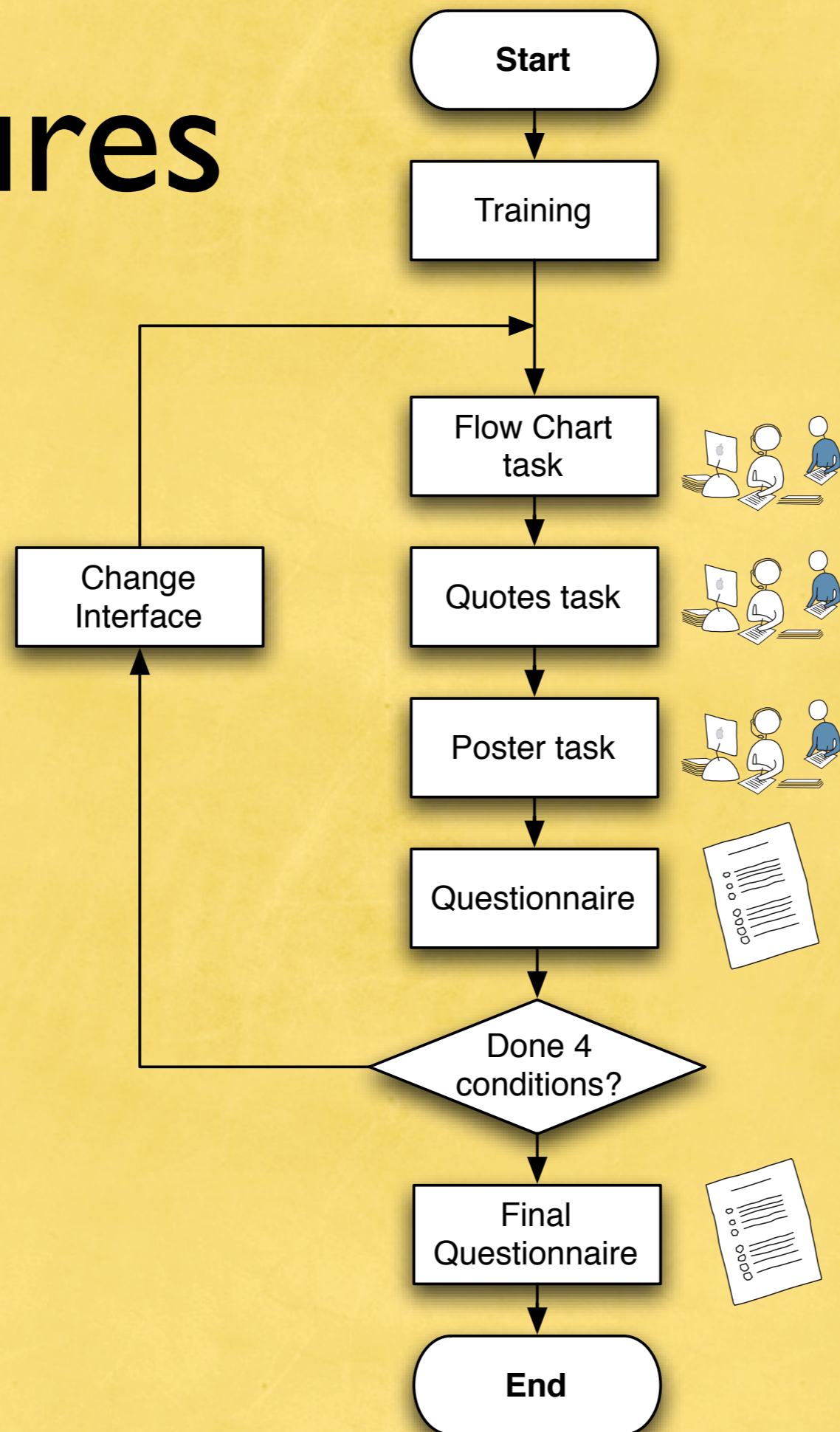


# Procedures





# Procedures





# Results: Ranking

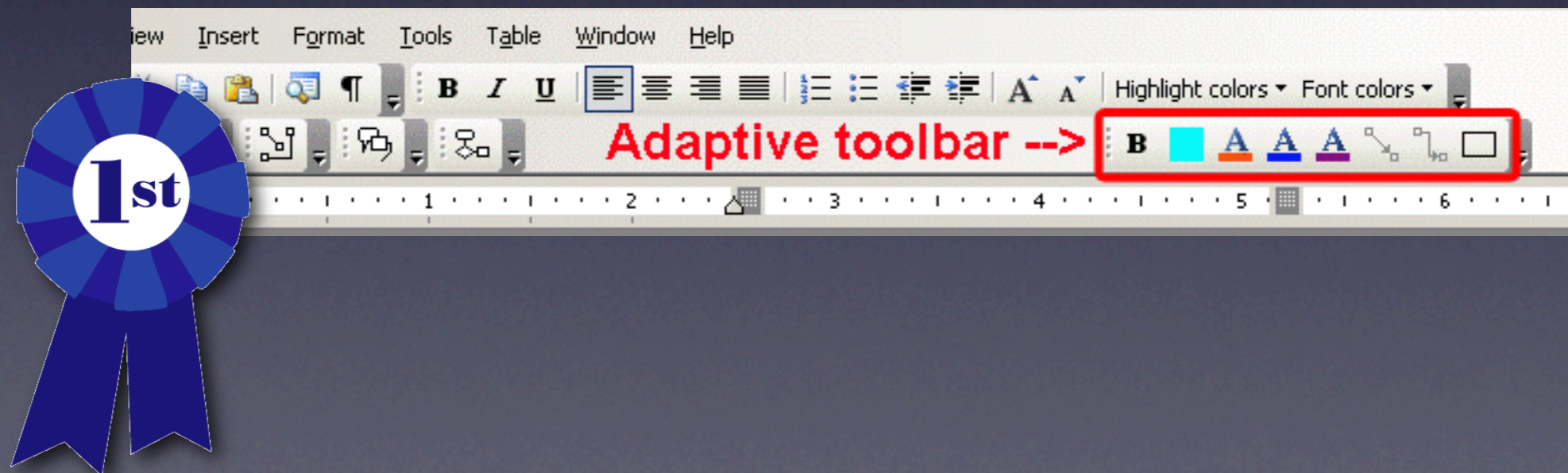
Users ranked the **Split Interface** the highest ( $p < 0.001$ )





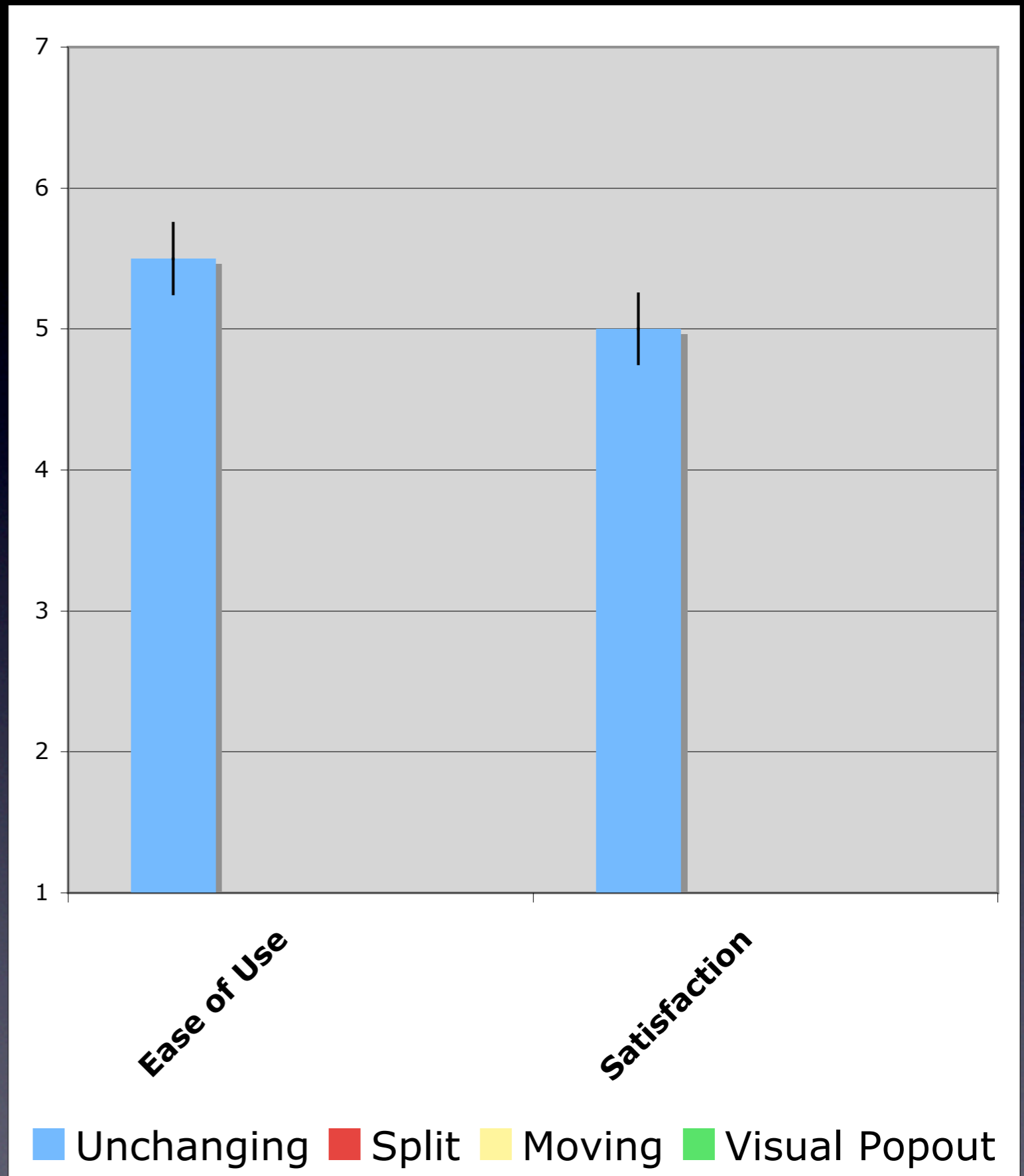
# Results: Ranking

Users ranked the **Split Interface** the highest ( $p < 0.001$ )



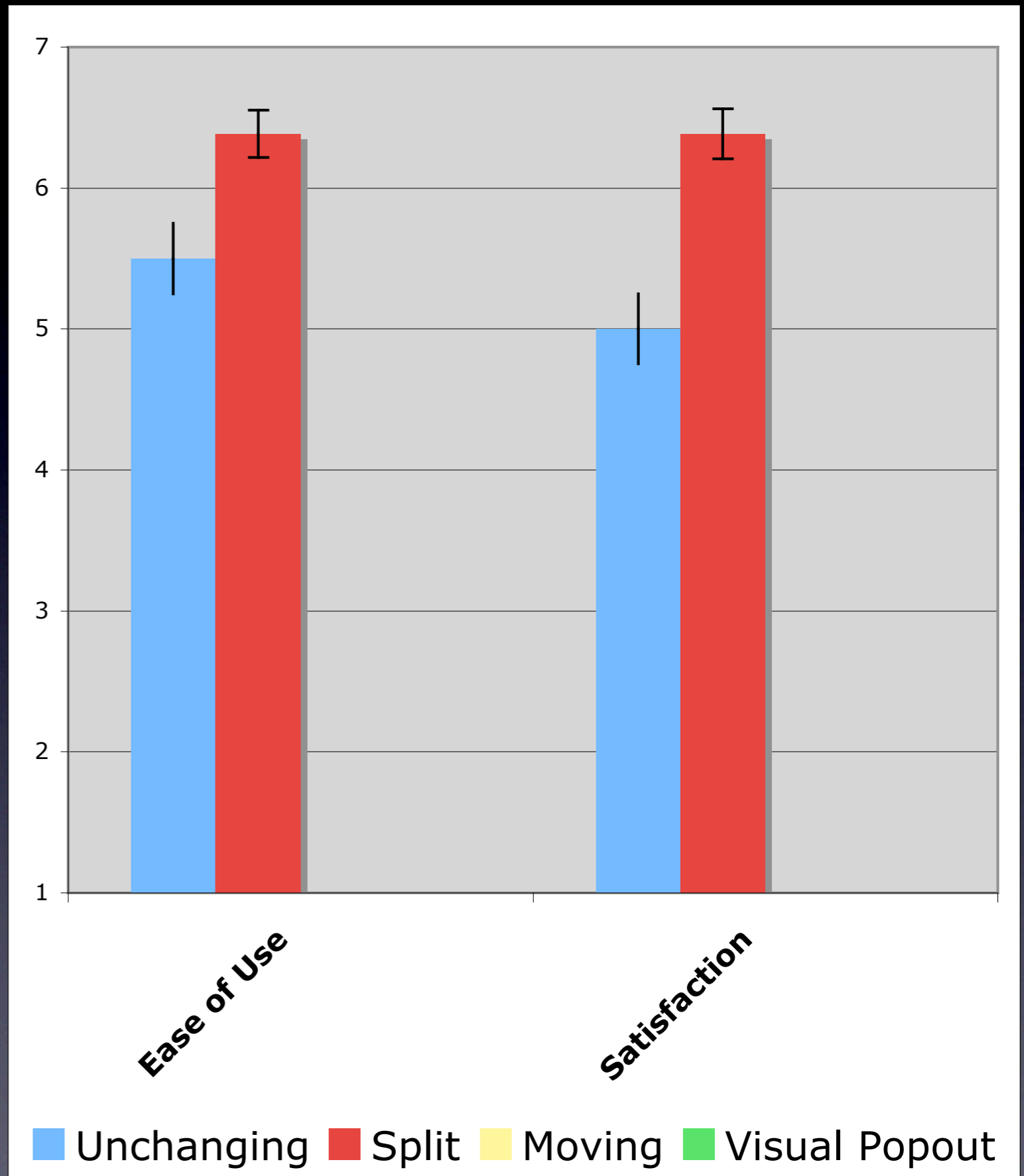


# General Satisfaction



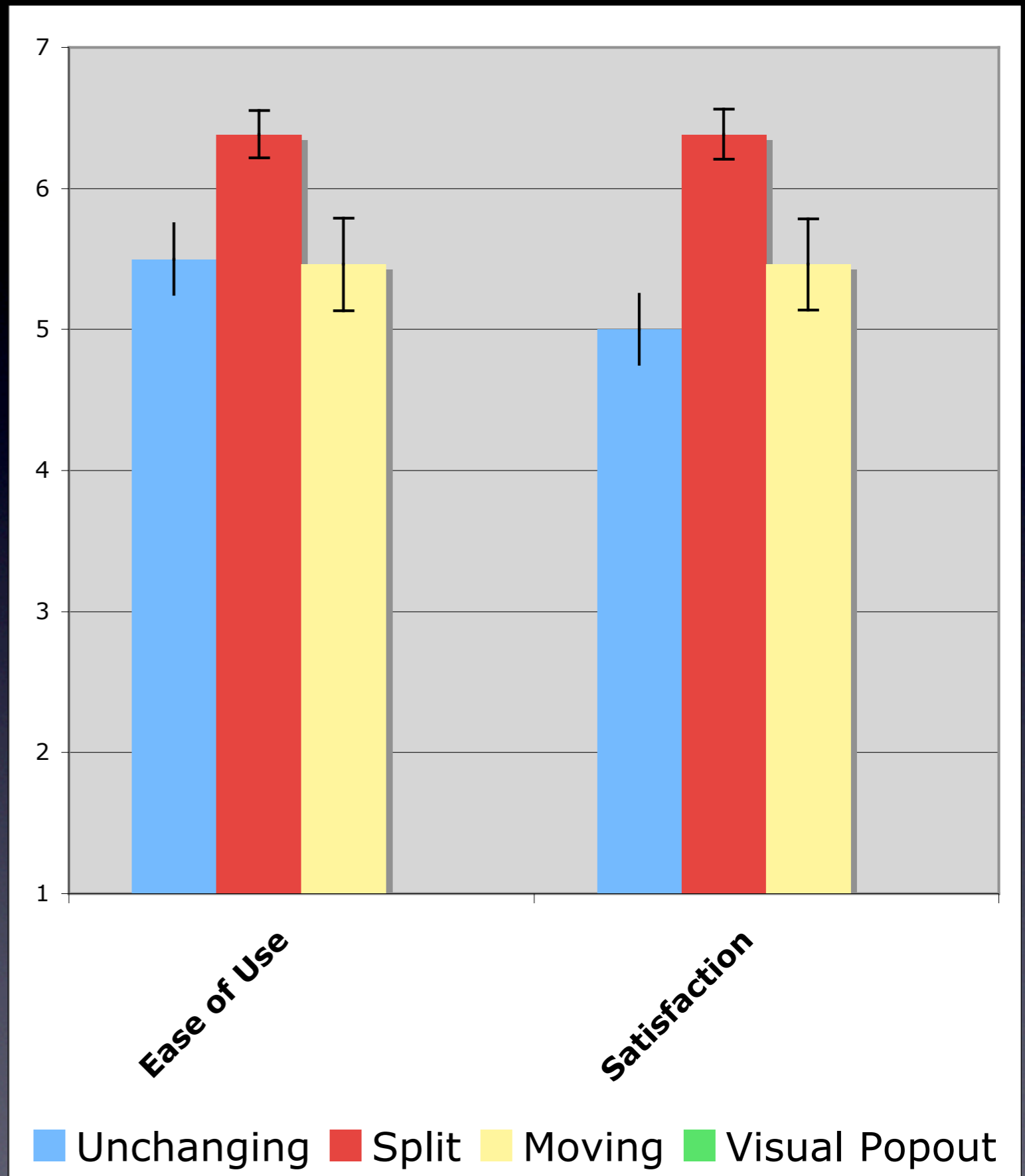


# General Satisfaction



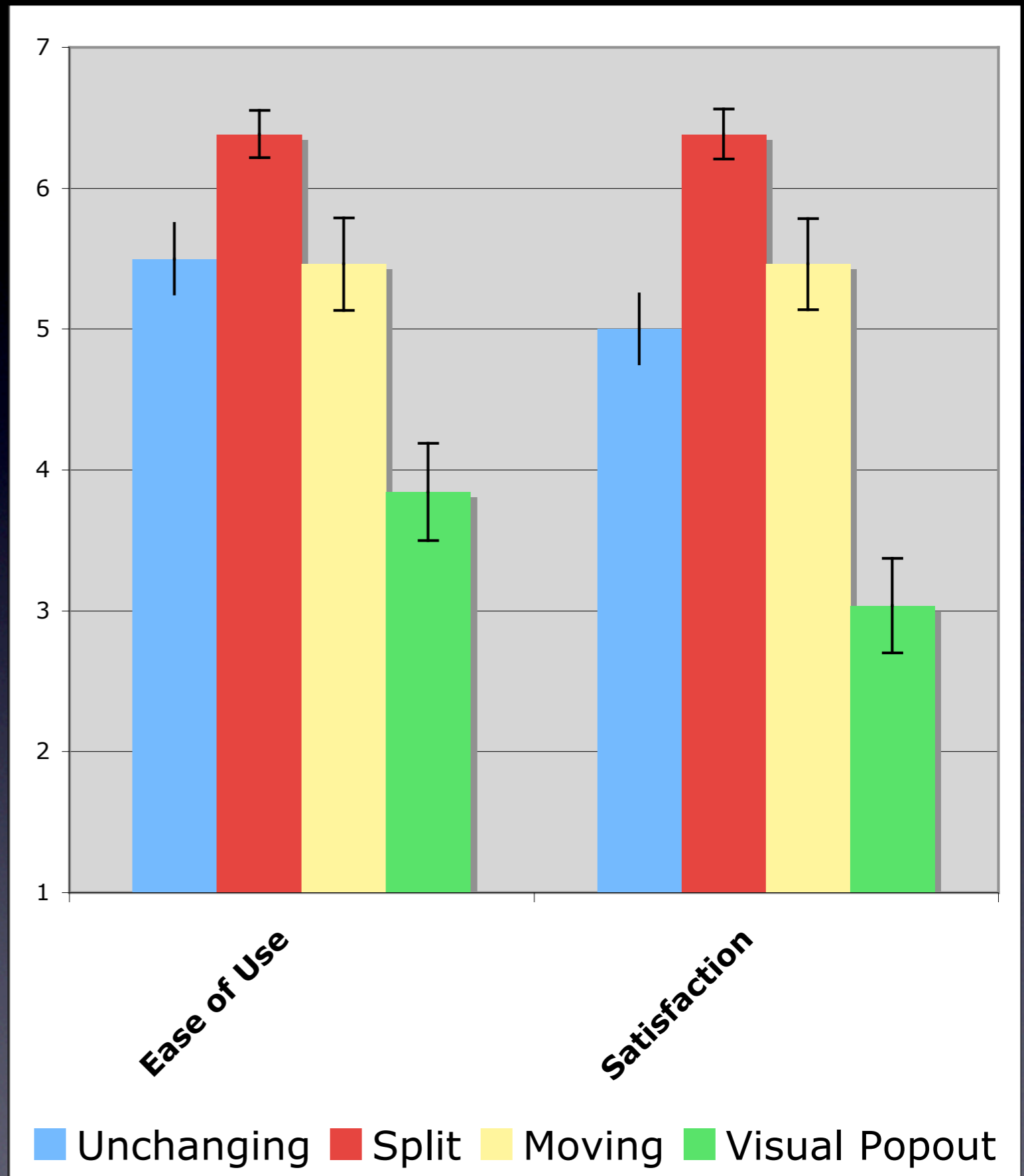


# General Satisfaction



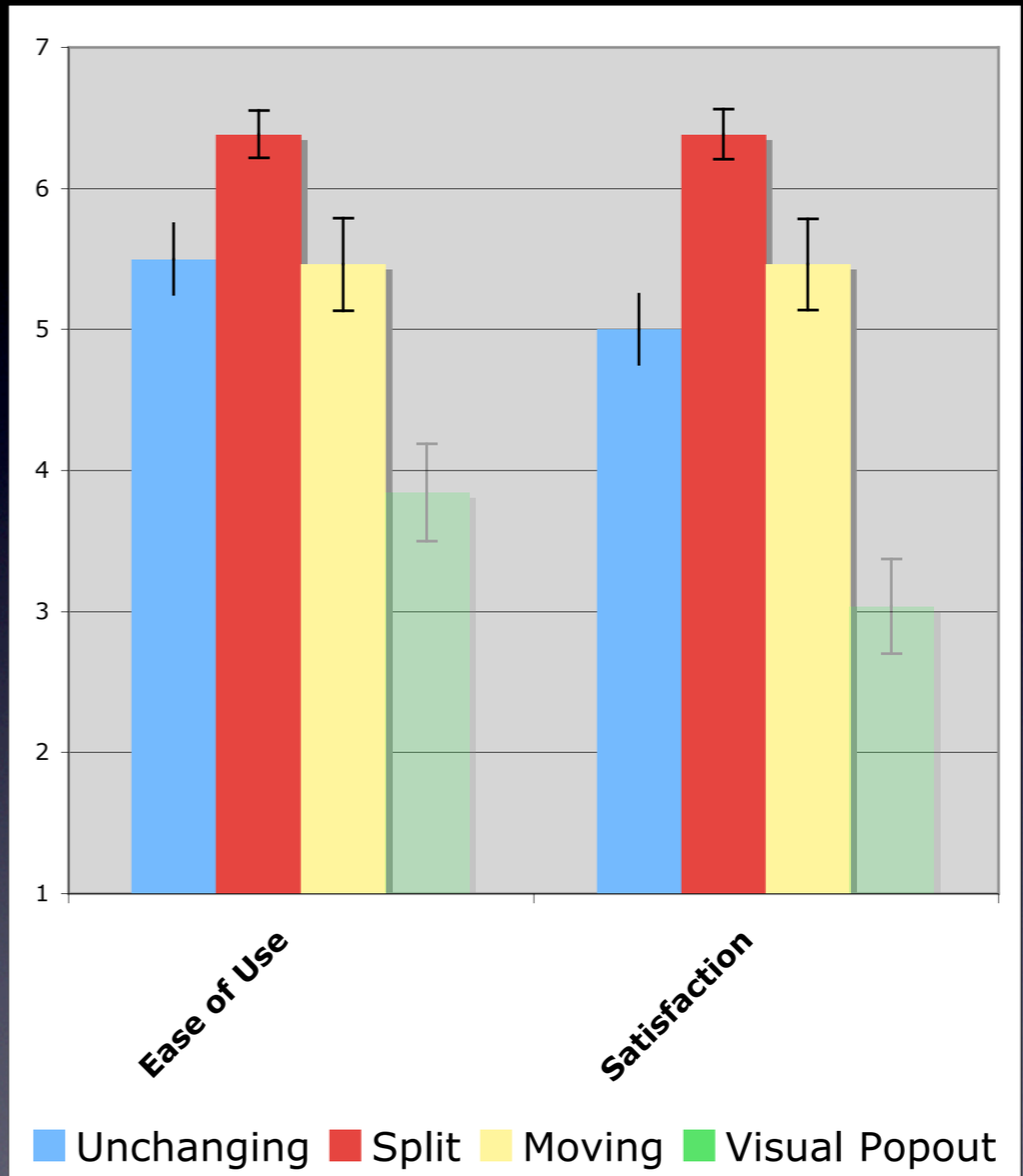


# General Satisfaction

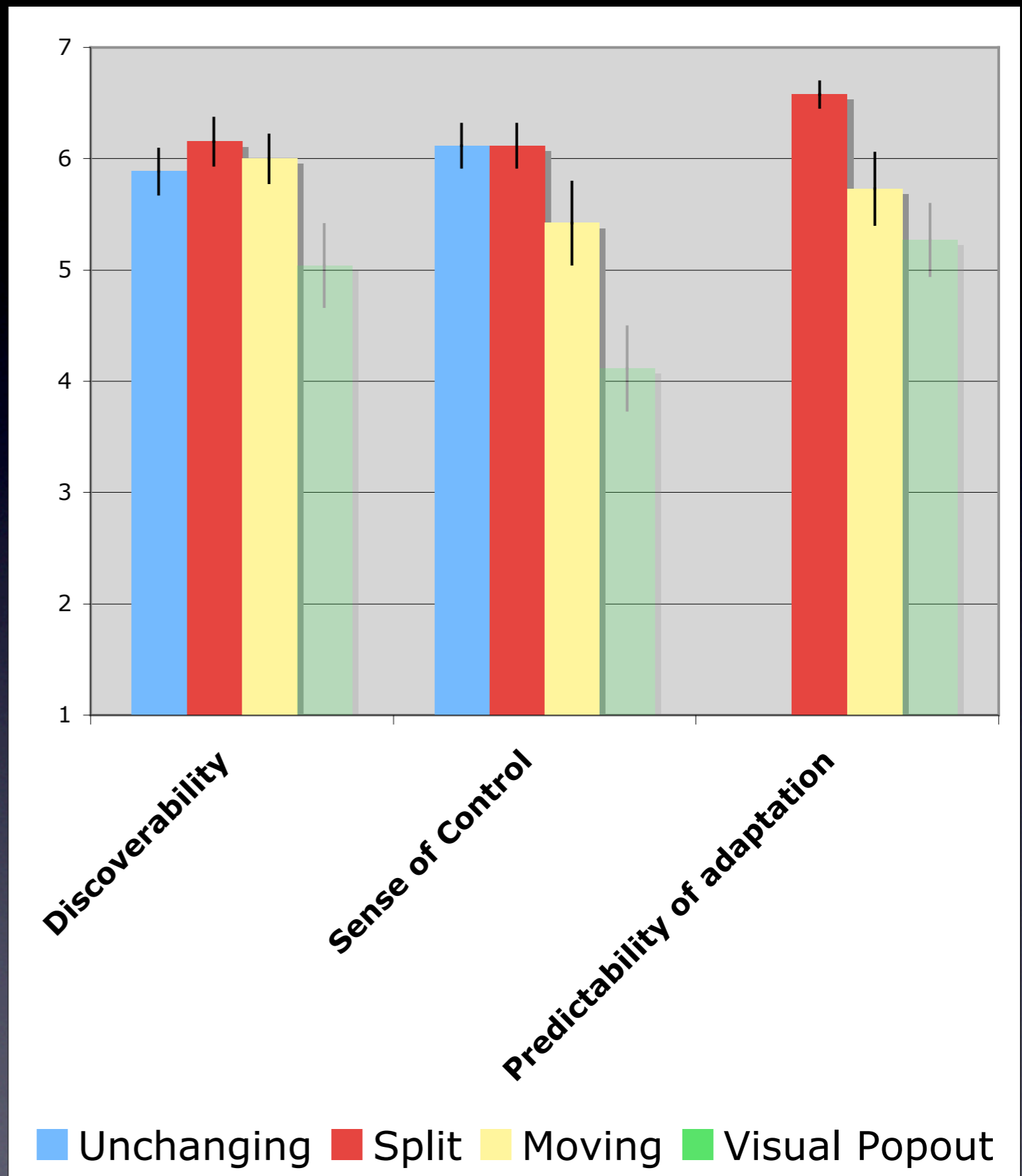




# General Satisfaction

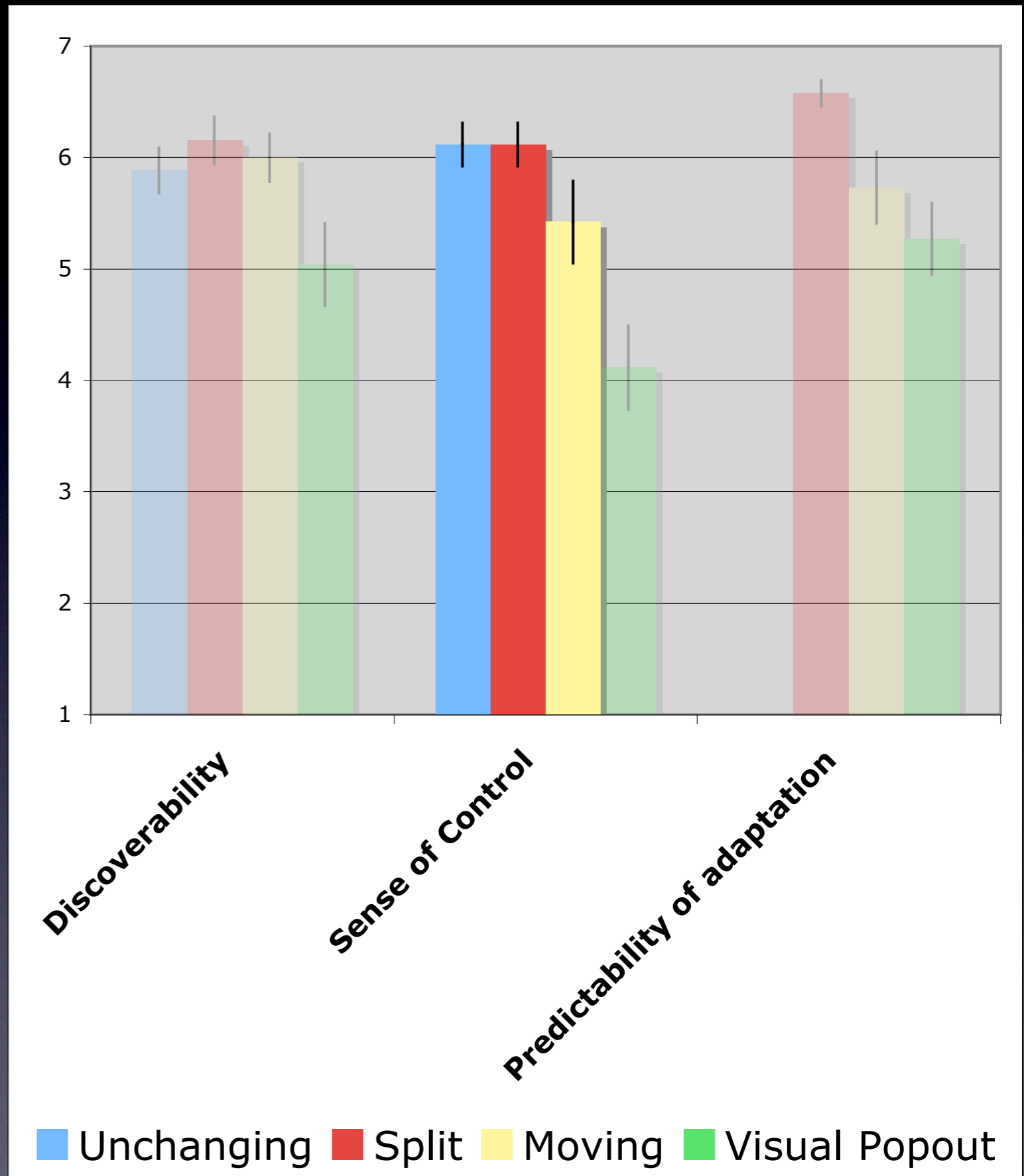


# Usability





# Usability



# Subjective Cost and Benefit



# Subjective Cost and Benefit

- **Subjective cost**  
based on:
  - Mental demand
  - Physical Demand
  - Frustration
  - Confusion due to adaptation



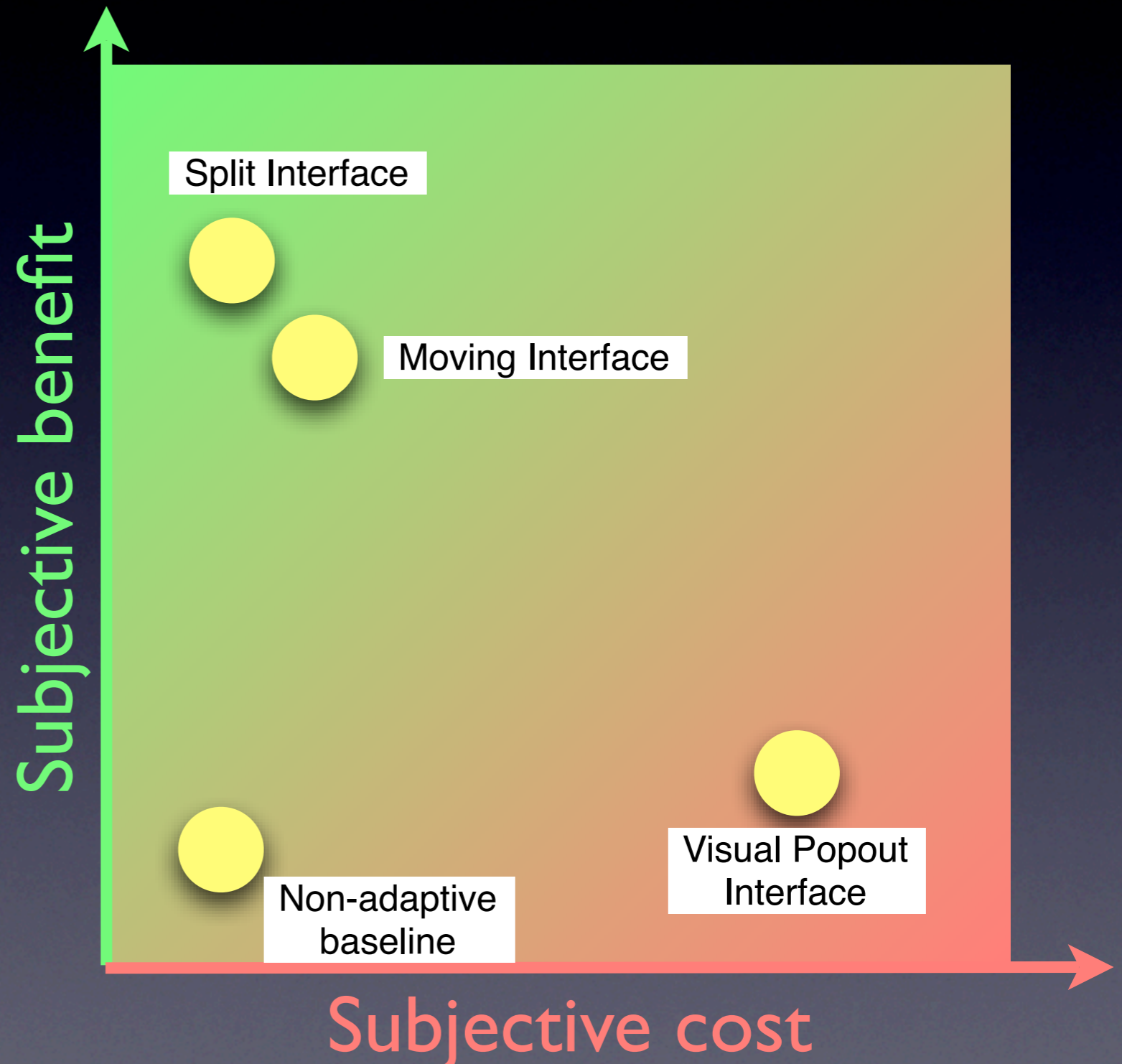
# Subjective Cost and Benefit

- **Subjective cost**  
based on:
  - Mental demand
  - Physical Demand
  - Frustration
  - Confusion due to adaptation
- **Subjective benefit**  
based on:
  - Performance
  - Efficiency due to adaptation



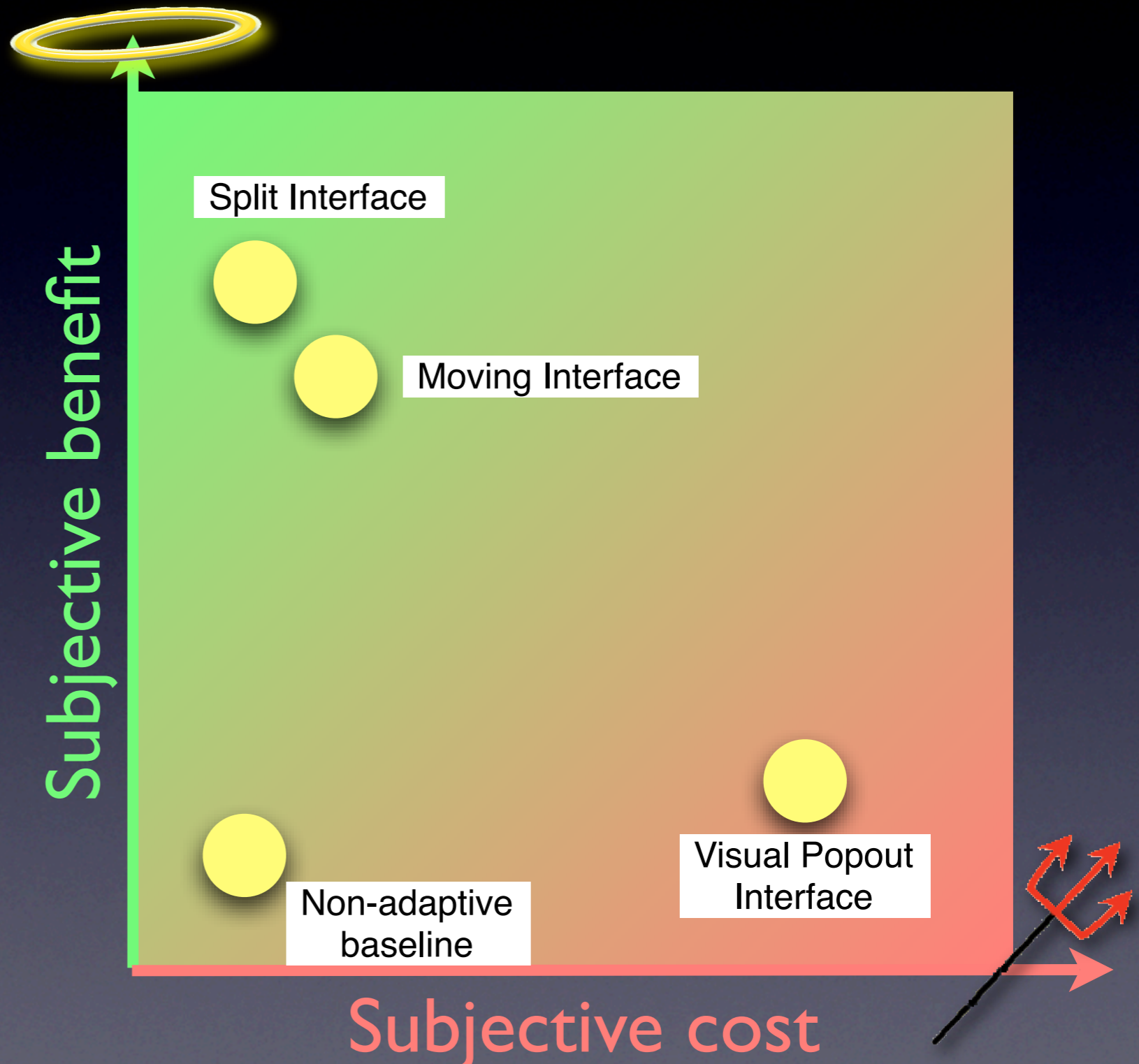
# Subjective Cost and Benefit

- **Subjective cost** based on:
  - Mental demand
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- **Subjective benefit** based on:
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# Subjective Cost and Benefit

- **Subjective cost** based on:
  - Mental demand
  - Physical Demand
  - Frustration
  - Confusion due to adaptation
- **Subjective benefit** based on:
  - Performance
  - Efficiency due to adaptation





# User Comments

Split Interface

Moving Interface

Visual Popout  
Interface

Split Interface	Moving Interface	Visual Popout Interface

# User Comments

Split Interface

Moving Interface

Visual Popout  
Interface

- stability
- semantic  
grouping



# User Comments

Split Interface

Moving Interface

Visual Popout  
Interface

- stability
- semantic  
grouping

- discoverability

# User Comments

Split Interface

Moving Interface

Visual Popout  
Interface

- stability
- semantic  
grouping

- discoverability



# User Comments

Split Interface

Moving Interface

Visual Popout  
Interface

- stability
- semantic  
grouping

- discoverability

- poor  
discoverability

# User Comments

Split Interface

Moving Interface

Visual Popout  
Interface

- stability
- semantic  
grouping

- discoverability

- poor  
discoverability

- instability



# User Comments

Split Interface

Moving Interface

Visual Popout  
Interface

- stability
- semantic  
grouping

- discoverability

- poor  
discoverability

- instability

- anti-saliience



# Road Map

- ✓ Introduce and motivate the problem
- ✓ Video
- ✓ Experiment 1: qualitative results
- Experiment 2: quantitative results**
- Synthesis
- Conclusions



# Experiment 2

## Goals:

Collect accurate **performance** data

Investigate how the **accuracy** of the adaptive algorithm affects how adaptation is used

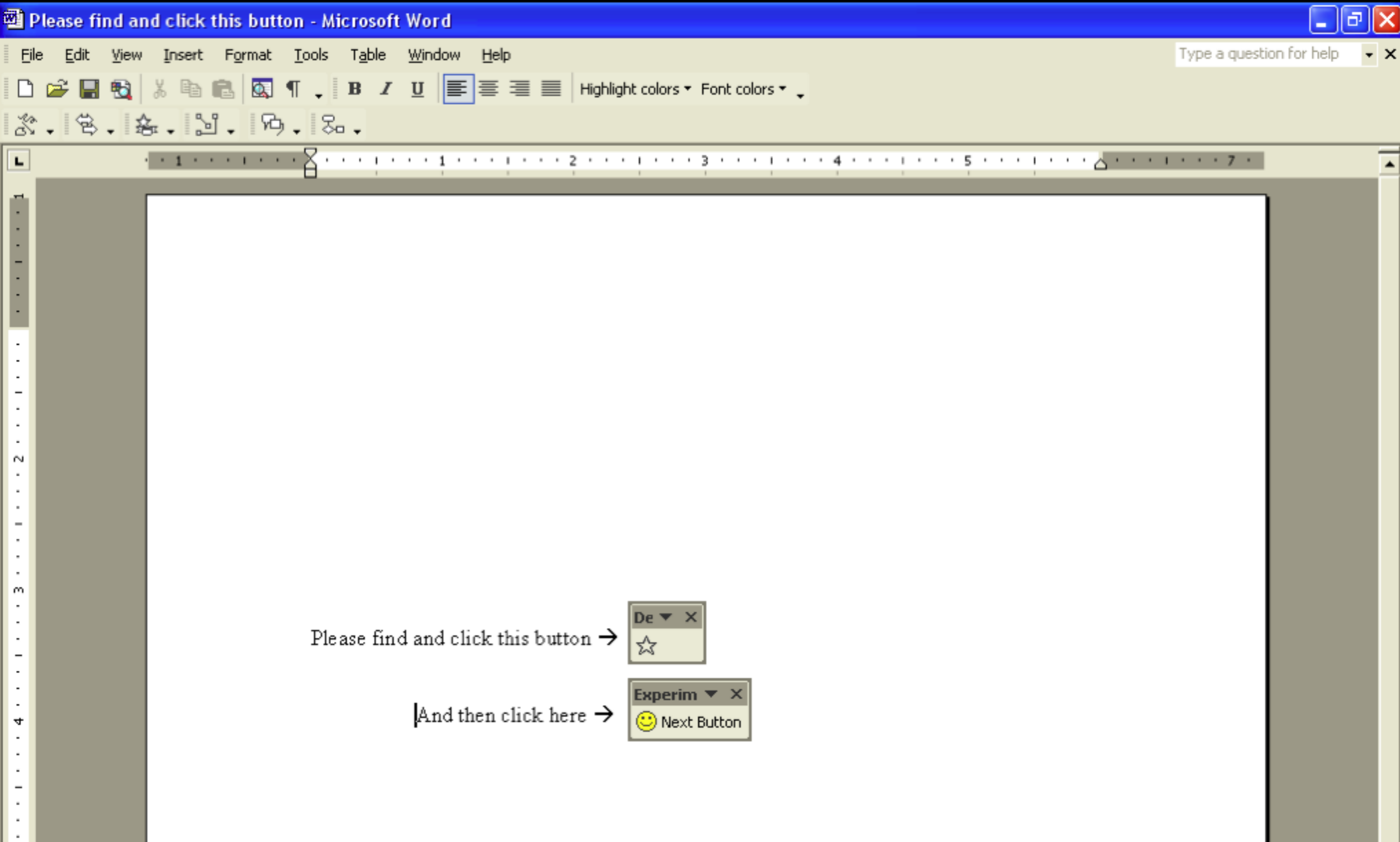


# Participants

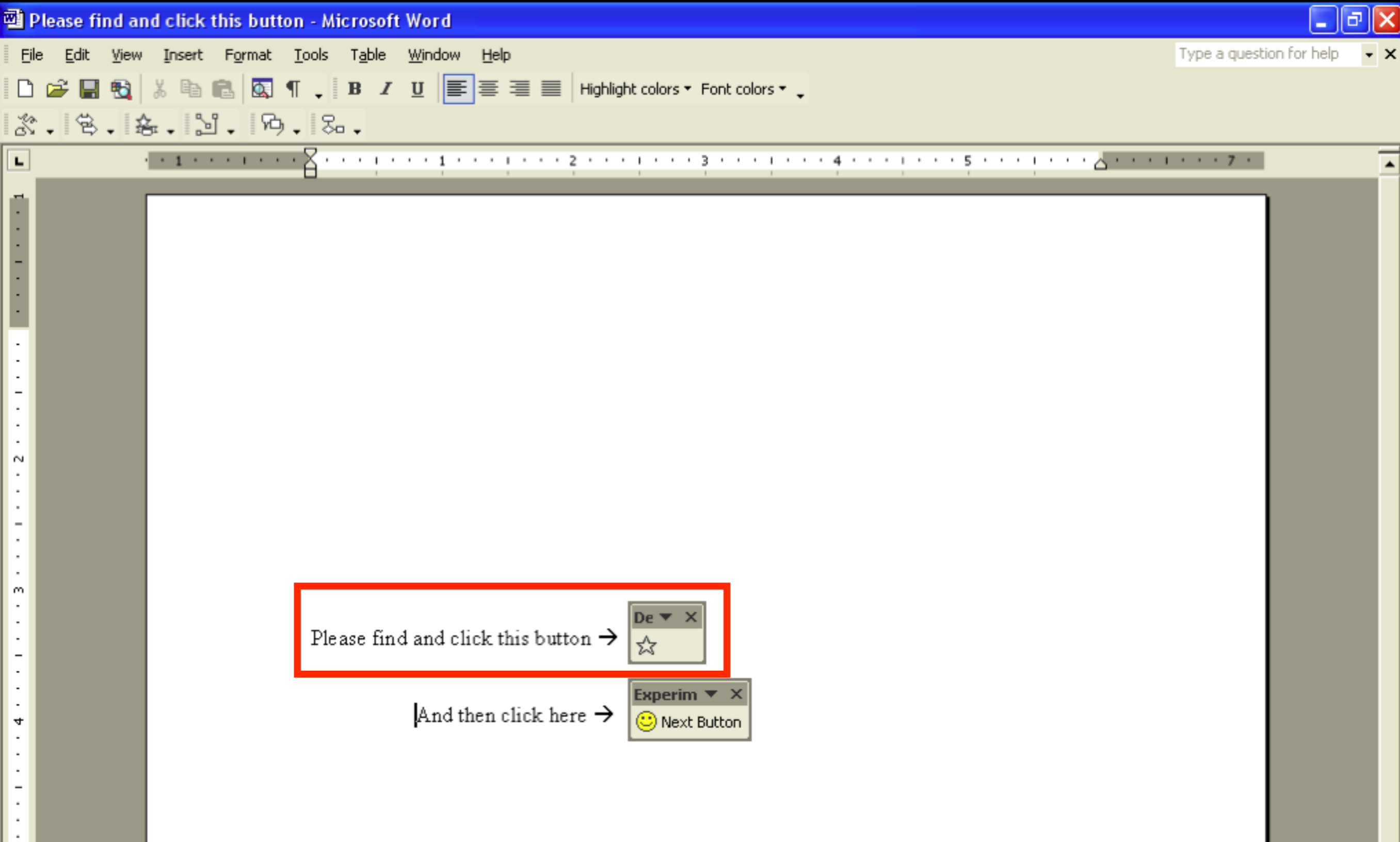
- 8 research colleagues (2 female)
- aged 25 to 58 (mean=36)
- high experience using computers
- expert users of MS Office
- participants received two meal vouchers as gratuity



# Tasks



# Tasks





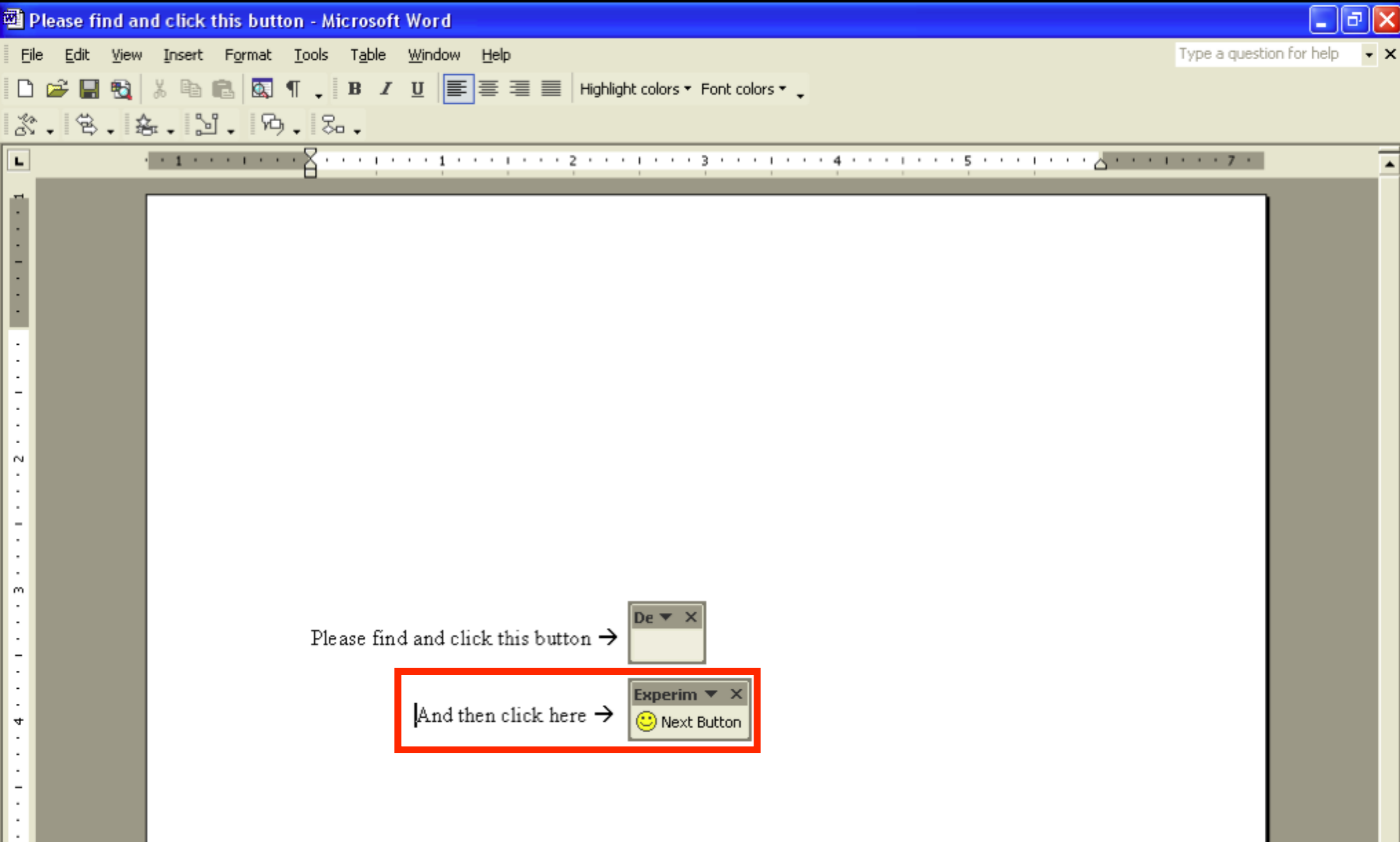
# Tasks

The image shows a screenshot of the Microsoft Word interface. The window title is "Please find and click this button - Microsoft Word". The menu bar includes File, Edit, View, Insert, Format, Tools, Table, Window, and Help. The ribbon shows the Insert tab, with the Shapes gallery expanded to show various shapes. A red box highlights the Shapes gallery, which contains several star and ribbon shapes. Below the ribbon, there is a ruler showing line numbers 1 through 7. In the main document area, there is a text instruction: "Please find and click this button →" followed by a button with a star icon. Below this, there is another instruction: "And then click here →" followed by a button with a smiley face icon and the text "Next Button".

Please find and click this button →

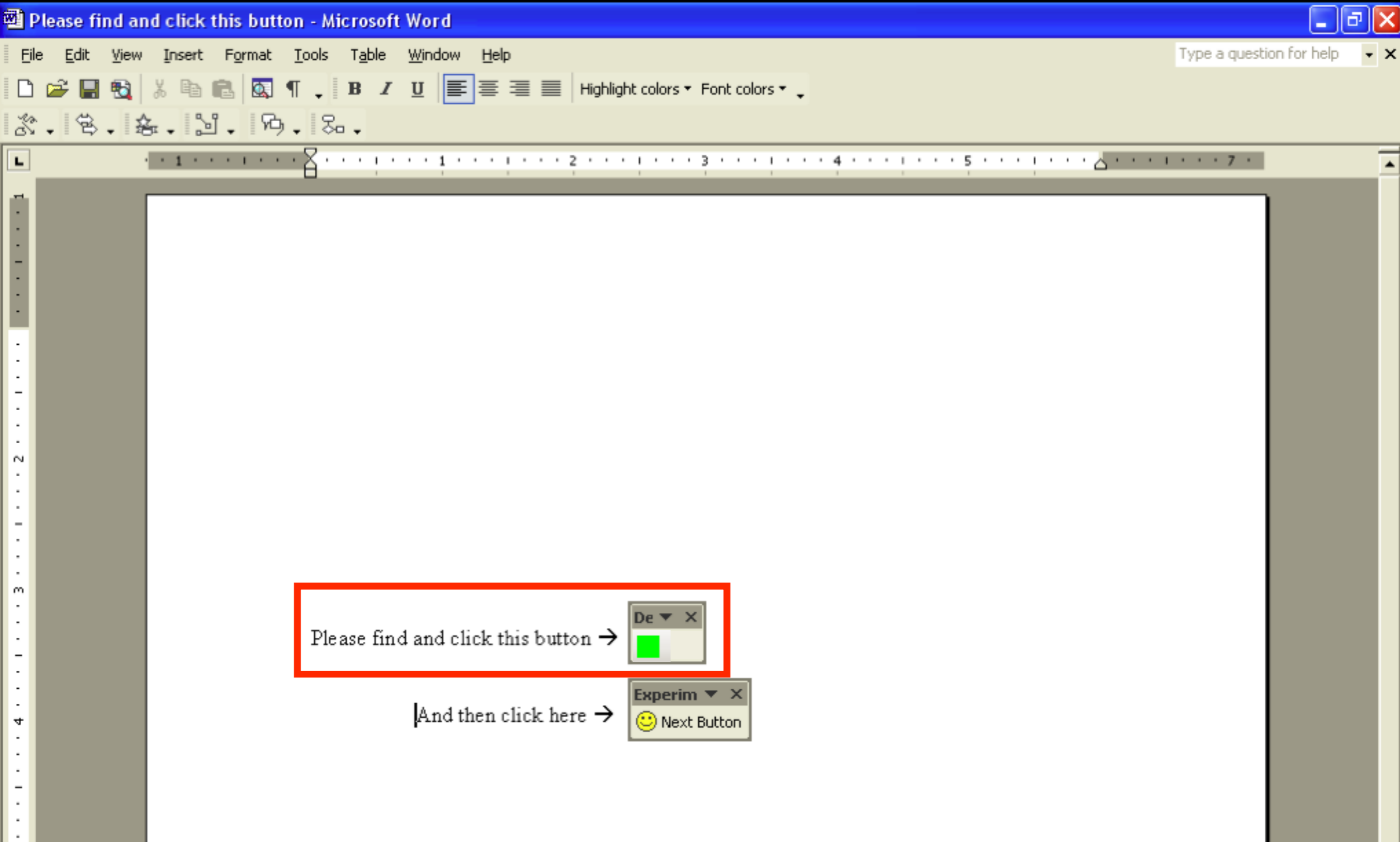
And then click here →

# Tasks





# Tasks



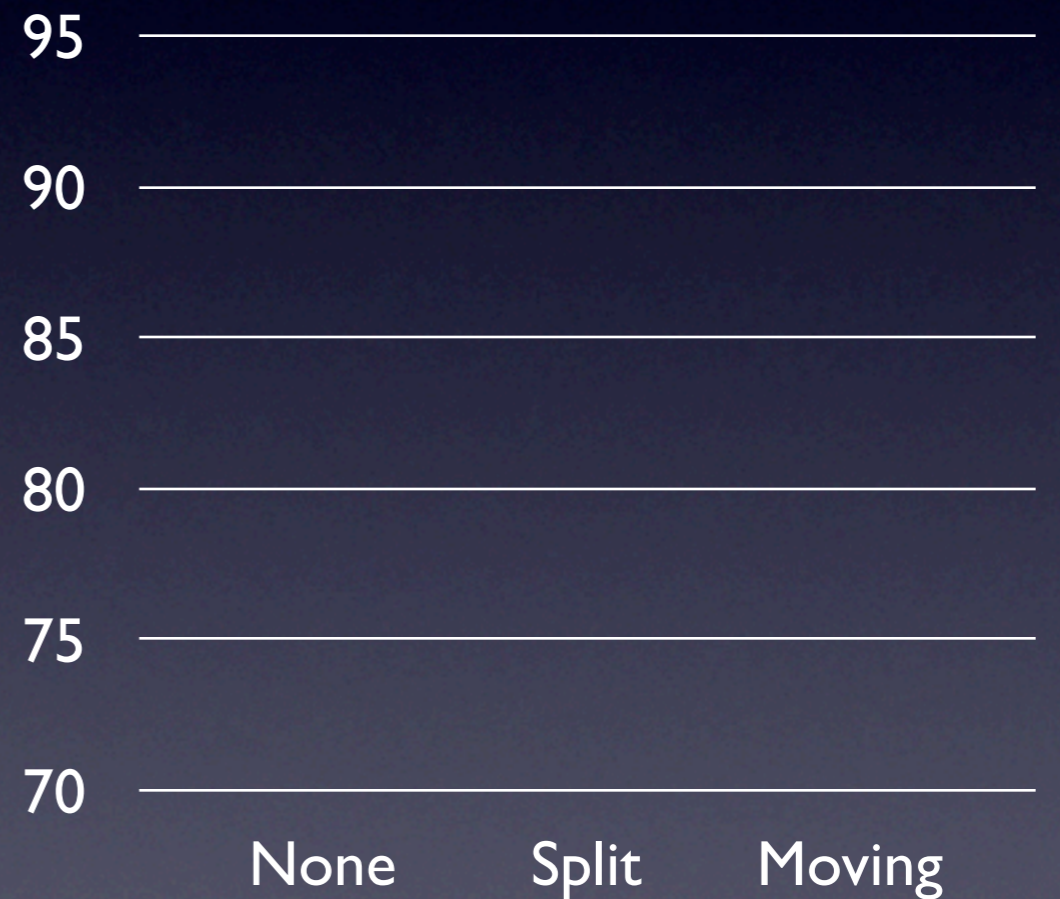
# Procedures

- Introduction and a brief training on a non-adaptive version of the interface
- Each participant used each of the three interfaces (Unchanging, Split and Moving) at two different accuracy levels (30% and 70%)



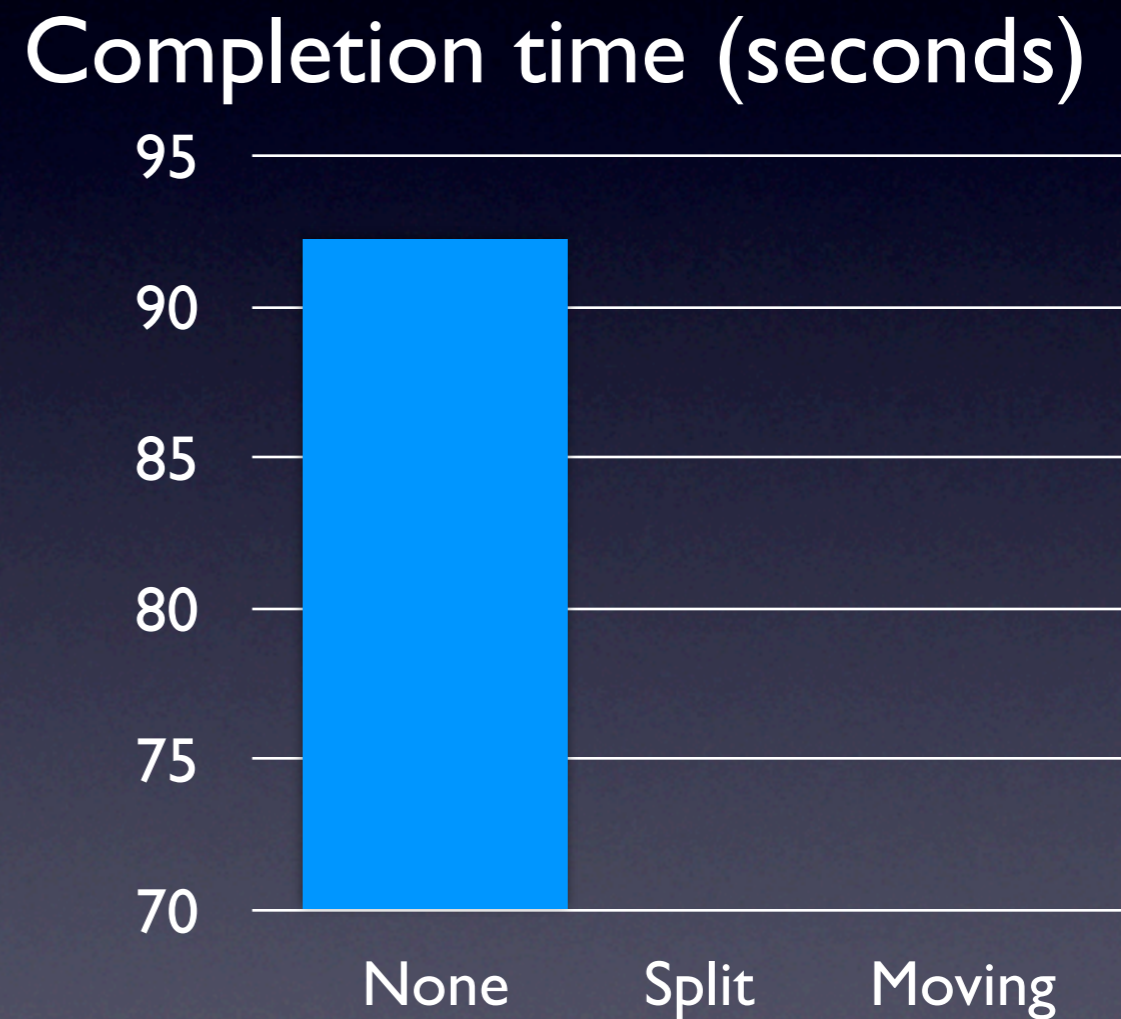
# Performance Vs. Adaptation Type

Completion time (seconds)





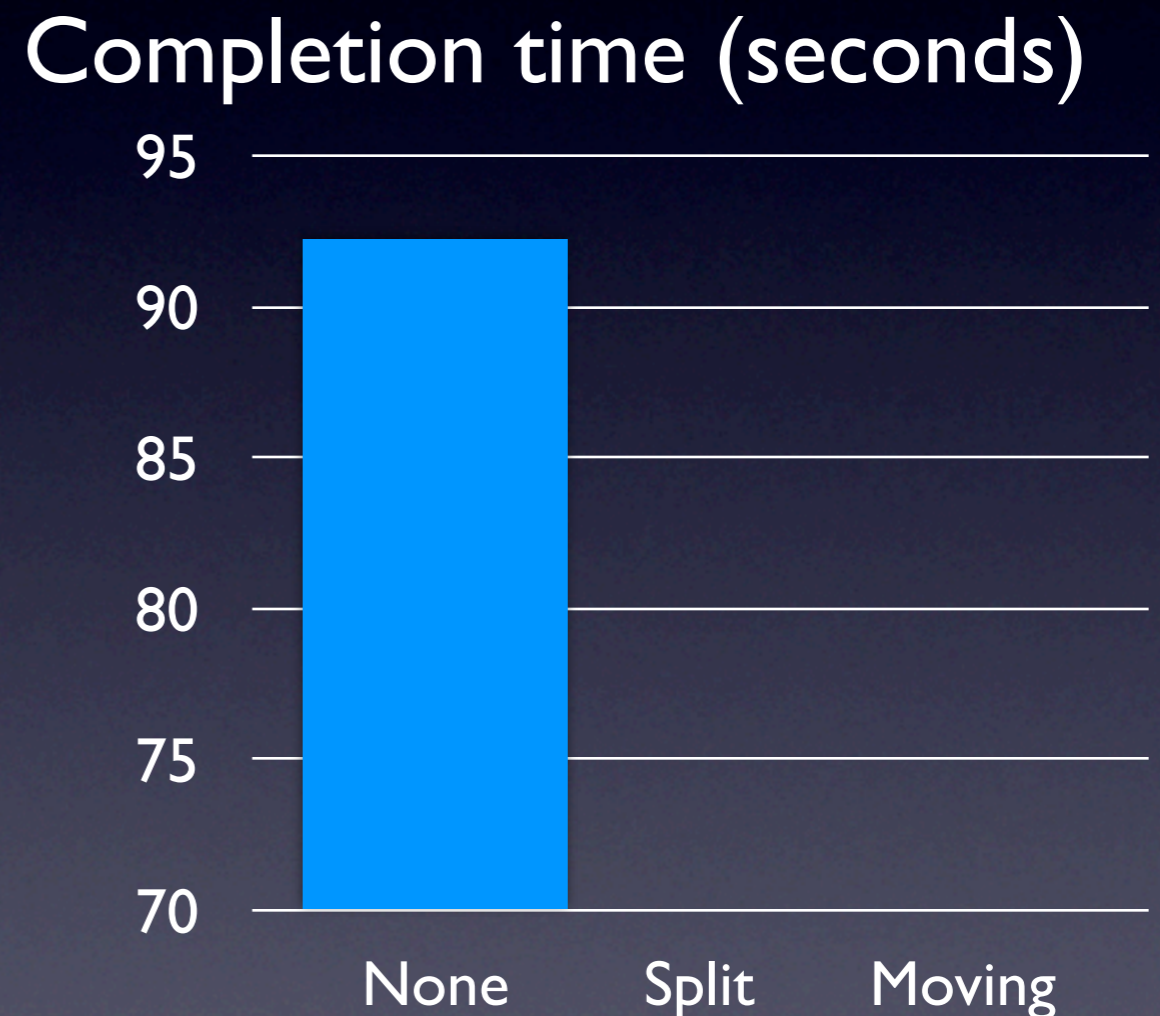
# Performance Vs. Adaptation Type





# Performance Vs. Adaptation Type

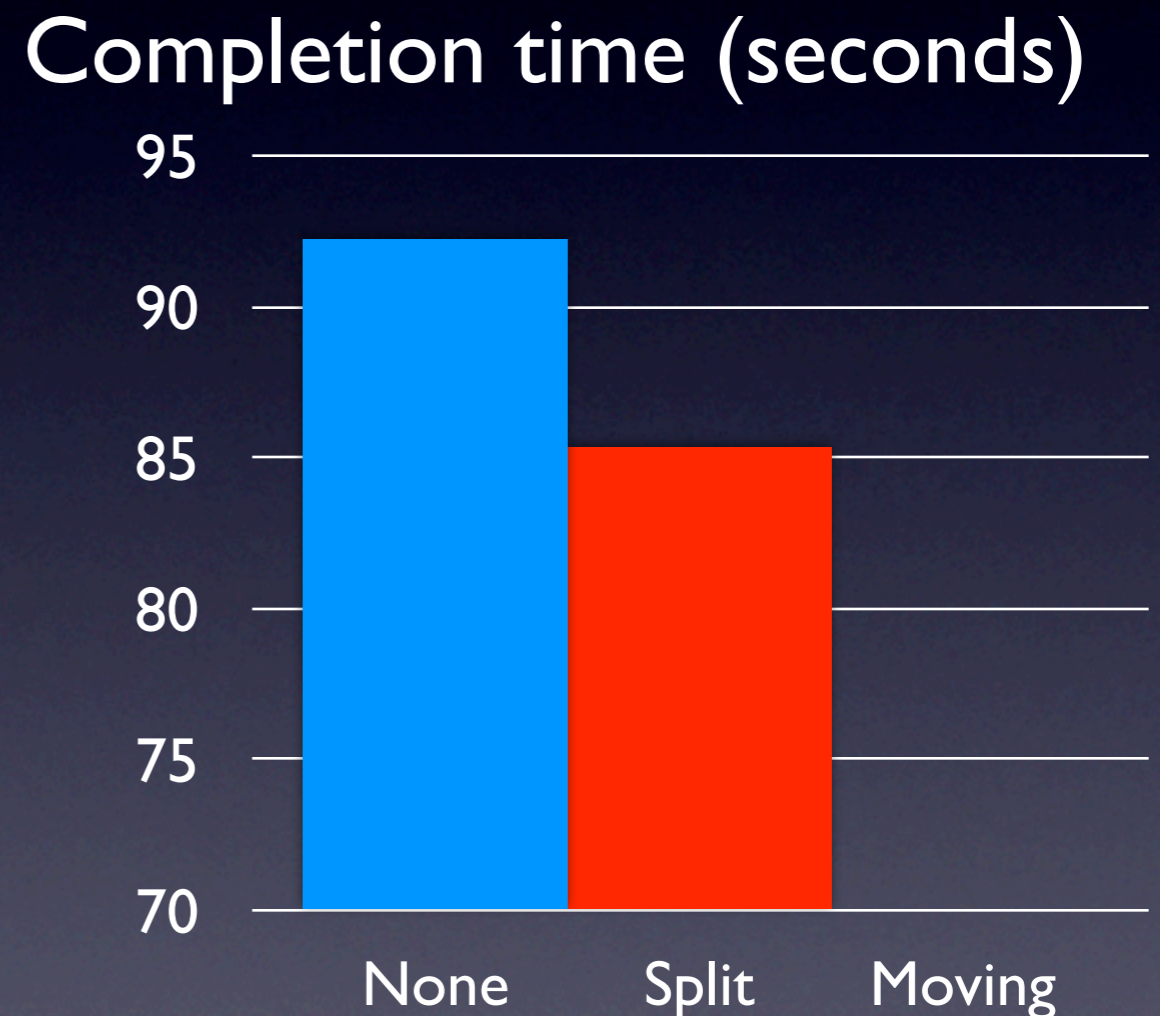
- Participants were significantly **faster** using Split Interface than Non-adaptive baseline ( $p < 0.003$ )





# Performance Vs. Adaptation Type

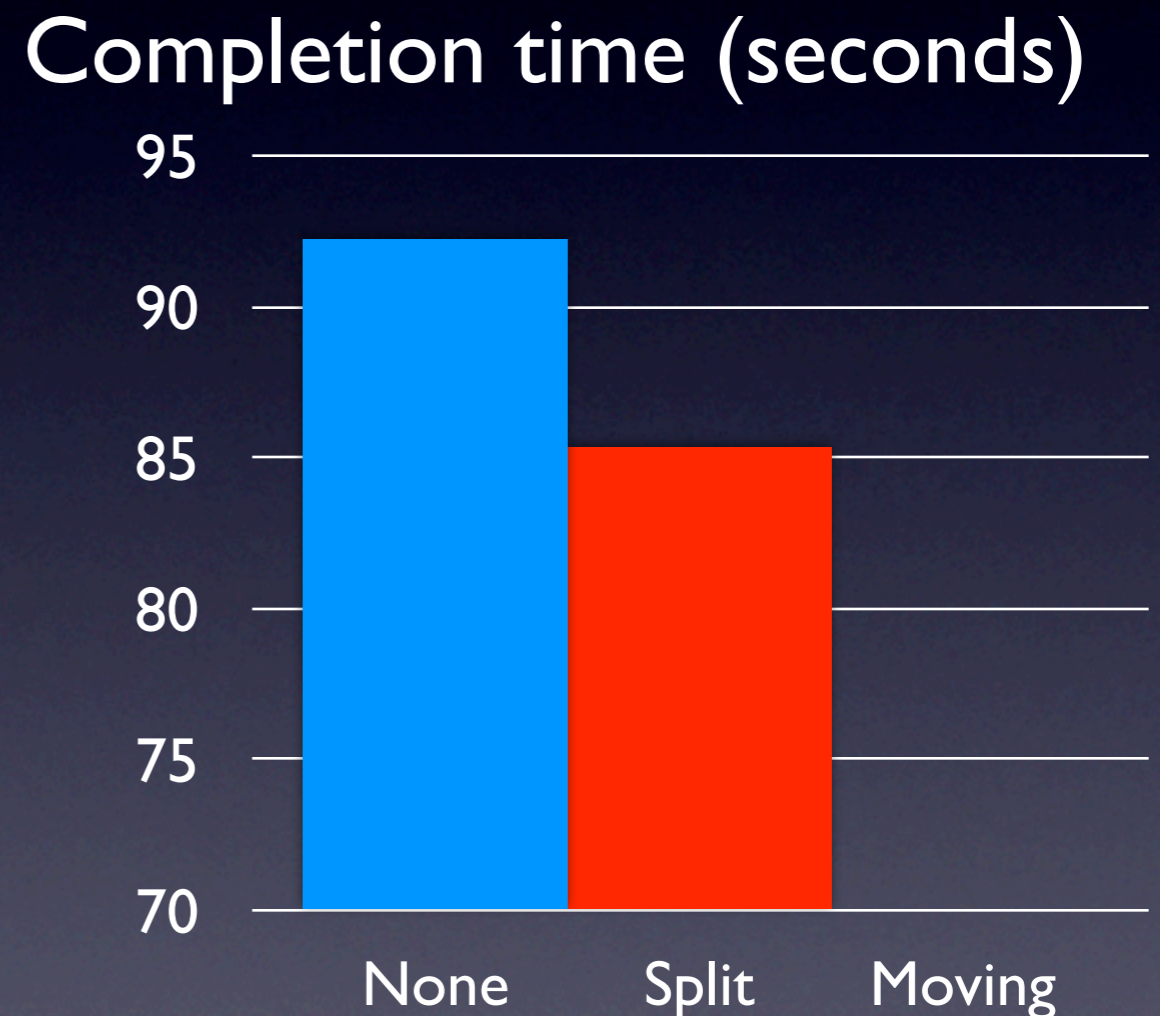
- Participants were significantly **faster** using Split Interface than Non-adaptive baseline ( $p < 0.003$ )





# Performance Vs. Adaptation Type

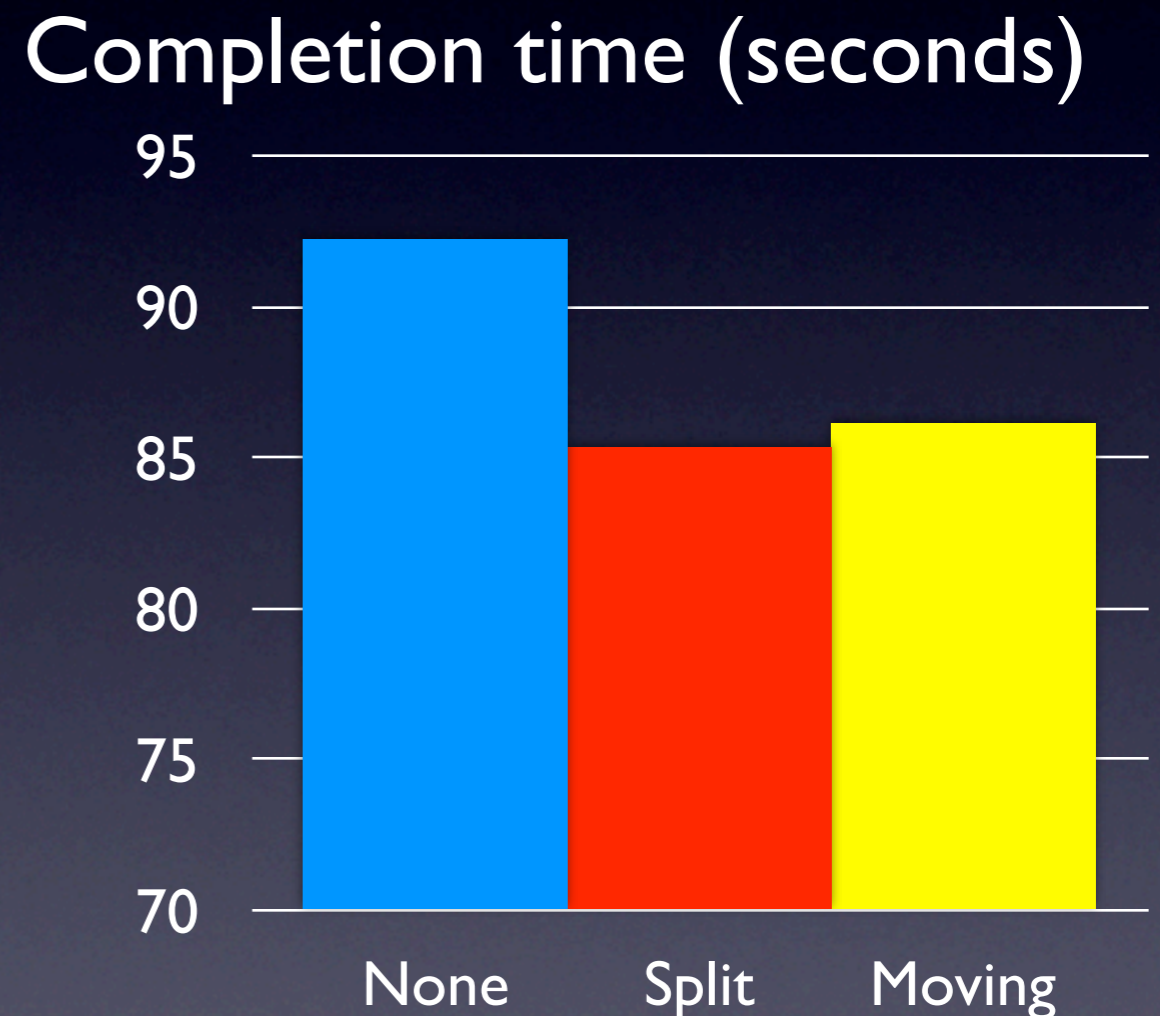
- Participants were significantly **faster** using Split Interface than Non-adaptive baseline ( $p < 0.003$ )
- Participants were **marginally faster** using Moving Interface than Non-adaptive baseline ( $p < 0.073$ )





# Performance Vs. Adaptation Type

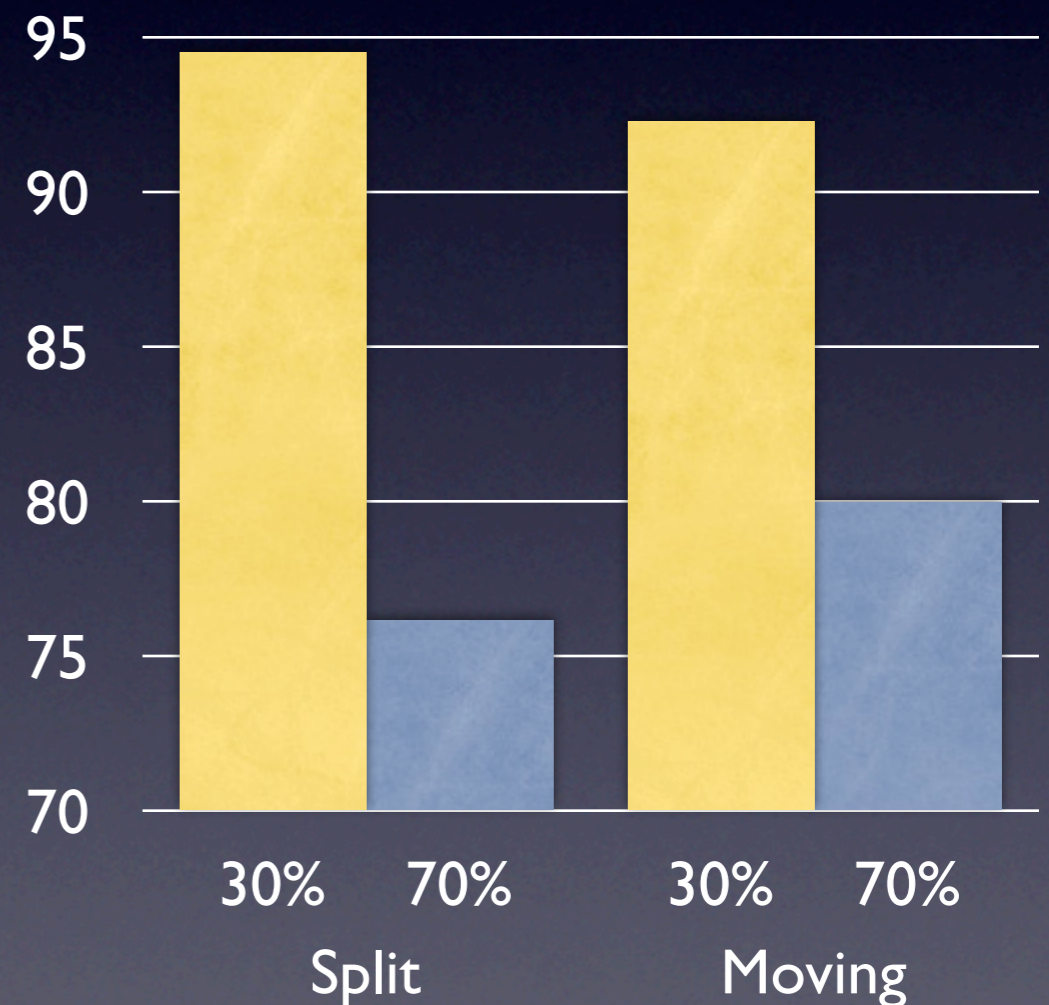
- Participants were significantly **faster** using Split Interface than Non-adaptive baseline ( $p < 0.003$ )
- Participants were **marginally faster** using Moving Interface than Non-adaptive baseline ( $p < 0.073$ )



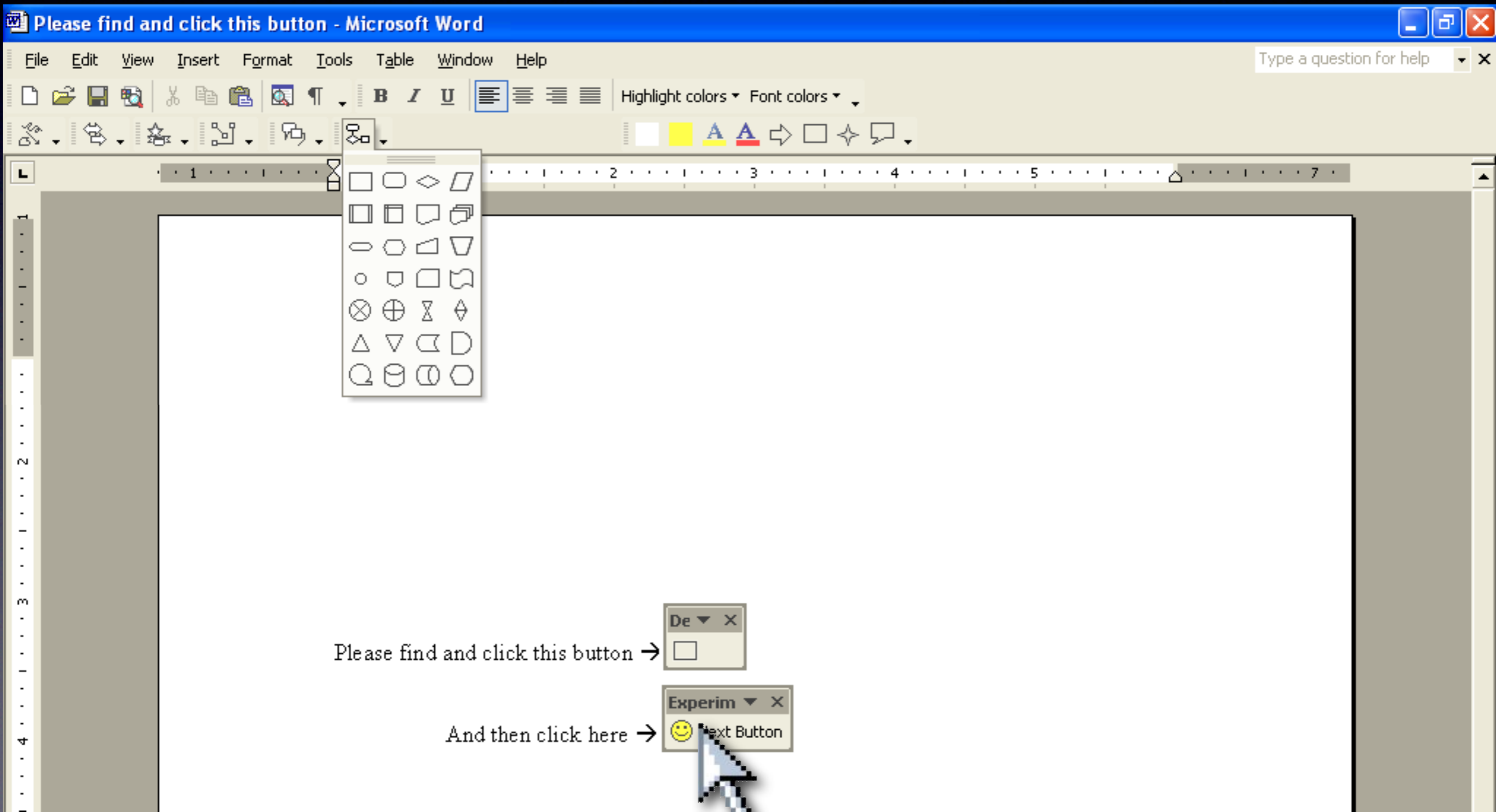


# Performance Vs. Accuracy

- Both adaptive interfaces resulted in faster performance at the higher (70%) accuracy level than at the lower (30%) level ( $p < 0.001$ )

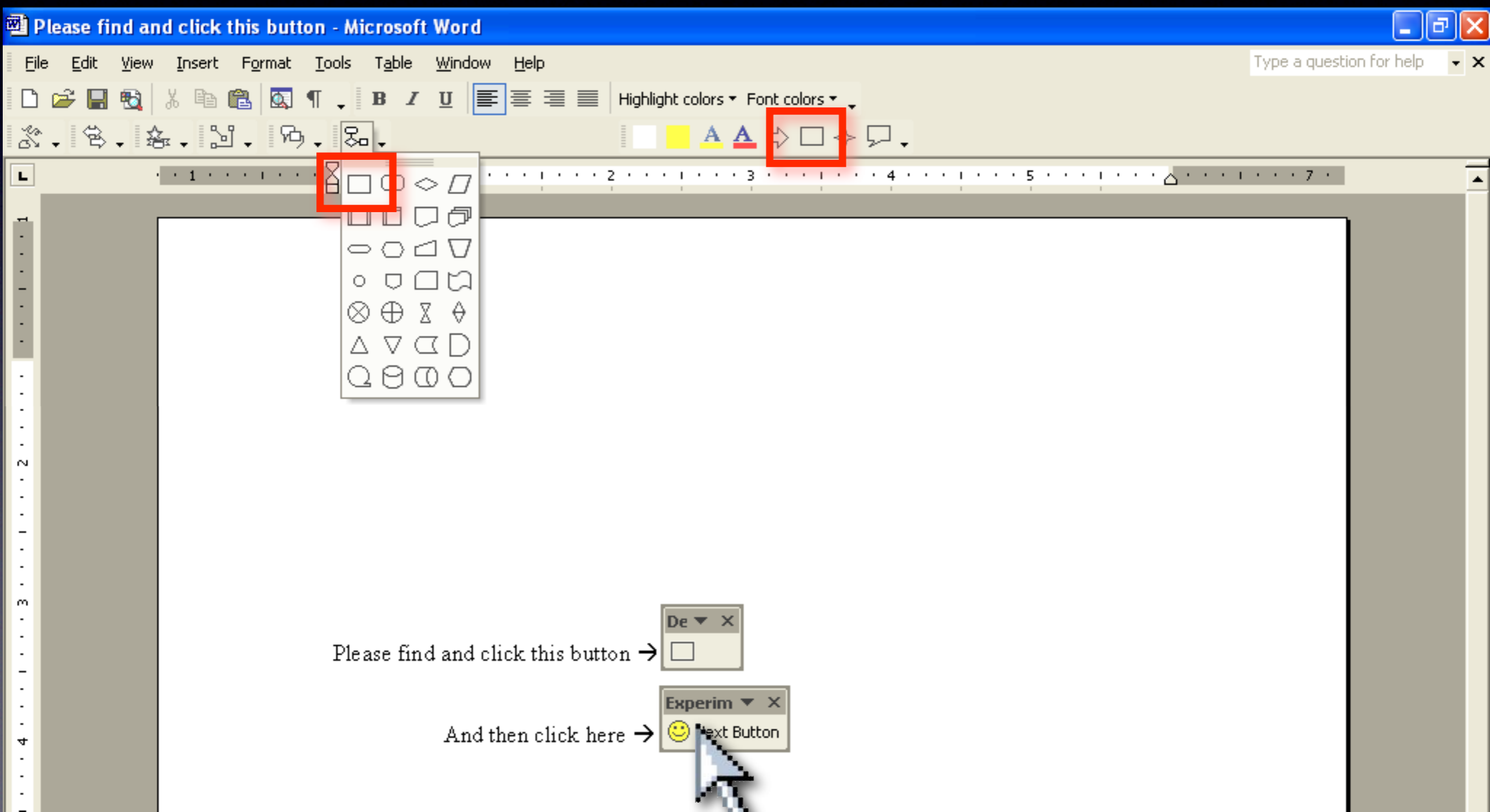


# Frequency of Use Vs. Accuracy

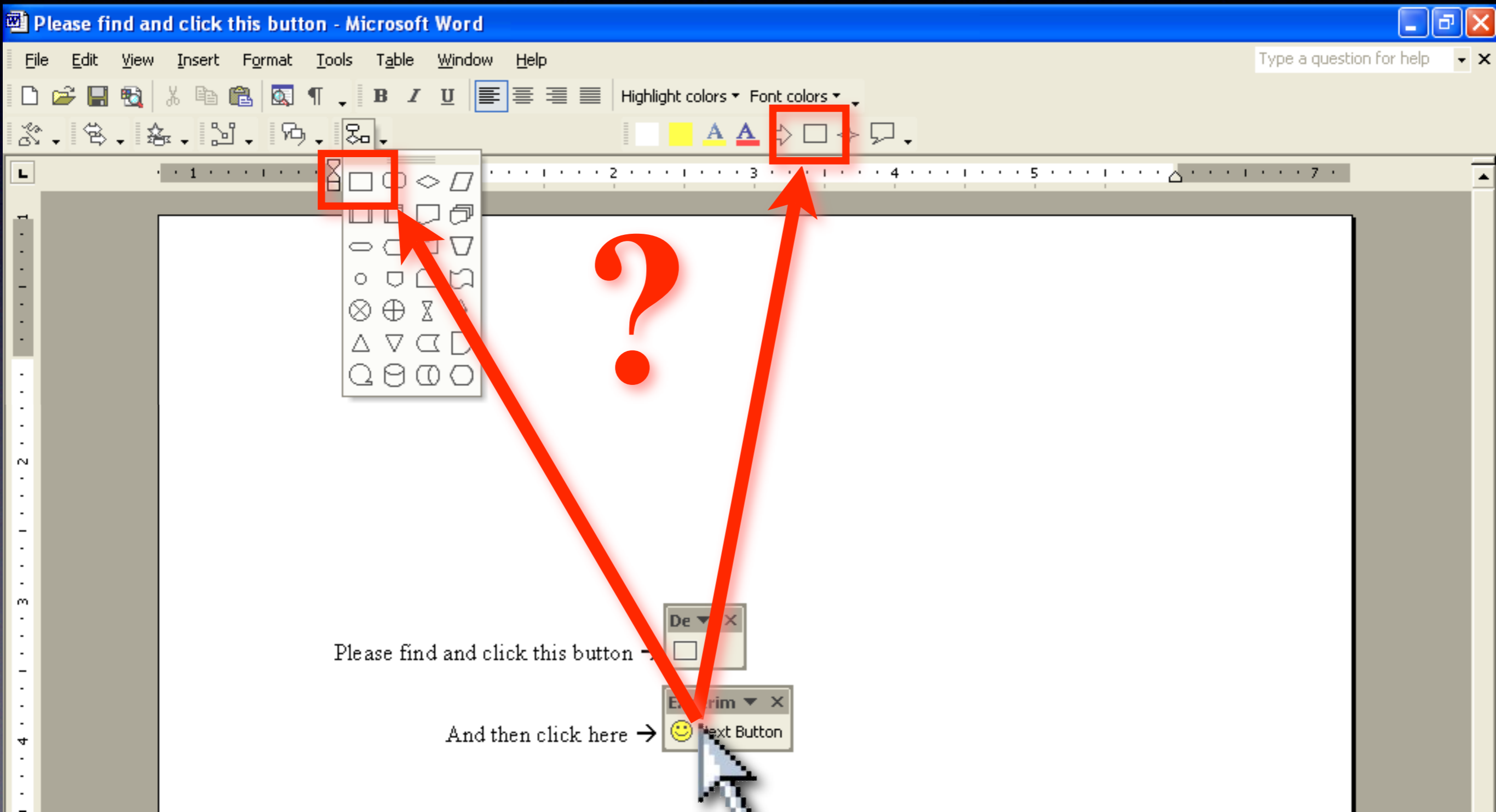




# Frequency of Use Vs. Accuracy



# Frequency of Use Vs. Accuracy





# Frequency of Use Vs. Accuracy

The image shows a screenshot of the Microsoft Word interface. The title bar reads "Please find and click this button - Microsoft Word". The menu bar includes File, Edit, View, Insert, Format, Tools, Table, Window, and Help. The ribbon shows the Insert tab with the Shapes gallery open. Two red boxes highlight the "Rectangle" button in the ribbon and the "Rectangle" button in the Shapes gallery. Two red arrows point from these boxes to a "Next Button" in the document. The "Next Button" is a yellow smiley face icon with the text "Next Button" below it. A mouse cursor is clicking on the "Next Button".

19%

81%

30% accuracy

Please find and click this button →

And then click here →

Next Button

# Frequency of Use Vs. Accuracy

The image shows a screenshot of the Microsoft Word interface with several annotations. Two red boxes highlight the 'Text Button' icon in the ribbon and its corresponding icon in the 'Shapes' dropdown menu. Two red arrows originate from a 'Text Button' tooltip at the bottom of the screen, pointing to these two locations. The annotations include the following percentages and accuracy values:

- 7% (green text) associated with the 'Text Button' icon in the ribbon.
- 19% (black text) associated with the 'Text Button' icon in the 'Shapes' dropdown menu.
- 93% (green text) associated with the 'Text Button' icon in the ribbon.
- 81% (black text) associated with the 'Text Button' icon in the 'Shapes' dropdown menu.
- 70% accuracy (green text) associated with the 'Text Button' icon in the ribbon.
- 30% accuracy (black text) associated with the 'Text Button' icon in the 'Shapes' dropdown menu.

The document text includes the instruction: "Please find and click this button →" followed by a square icon, and "And then click here →" followed by a smiley face icon and a tooltip for the "Text Button".



# User Comments

**Split Interface**

**Moving Interface**

# User Comments

Split Interface

Moving Interface

- discoverability



# User Comments

Split Interface

Moving Interface

- poor discoverability

- discoverability

# User Comments

Split Interface

Moving Interface

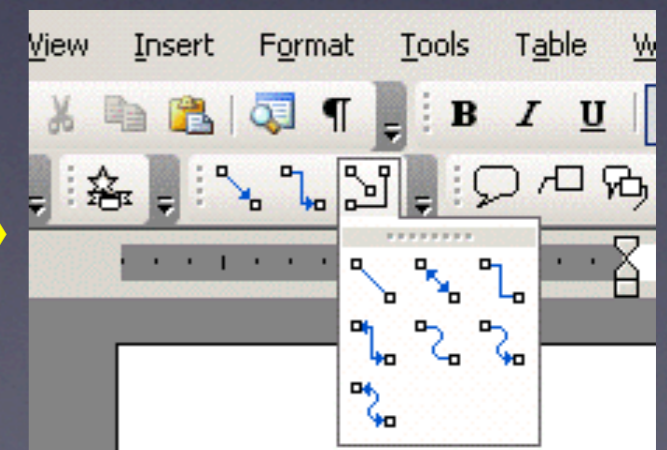
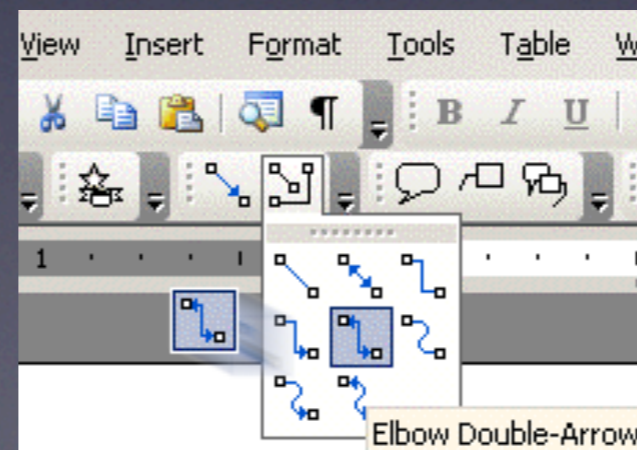
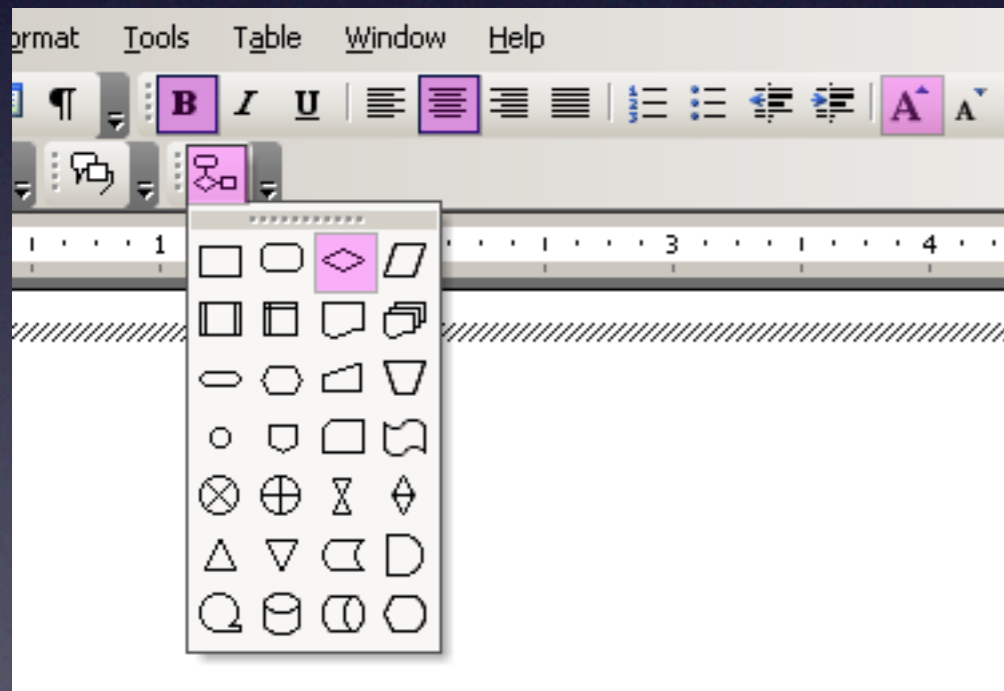
- poor discoverability

- discoverability

- instability

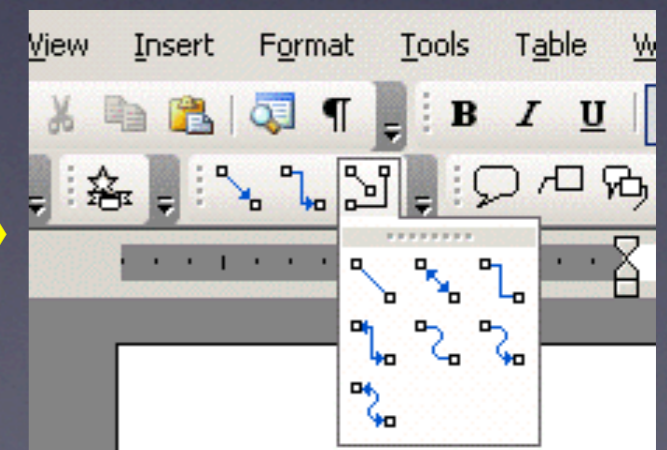
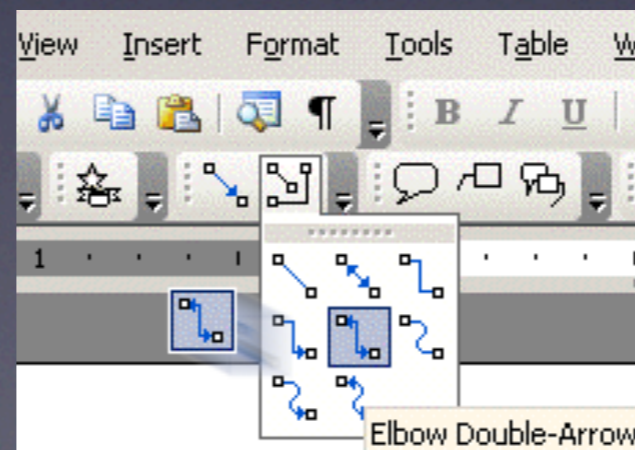
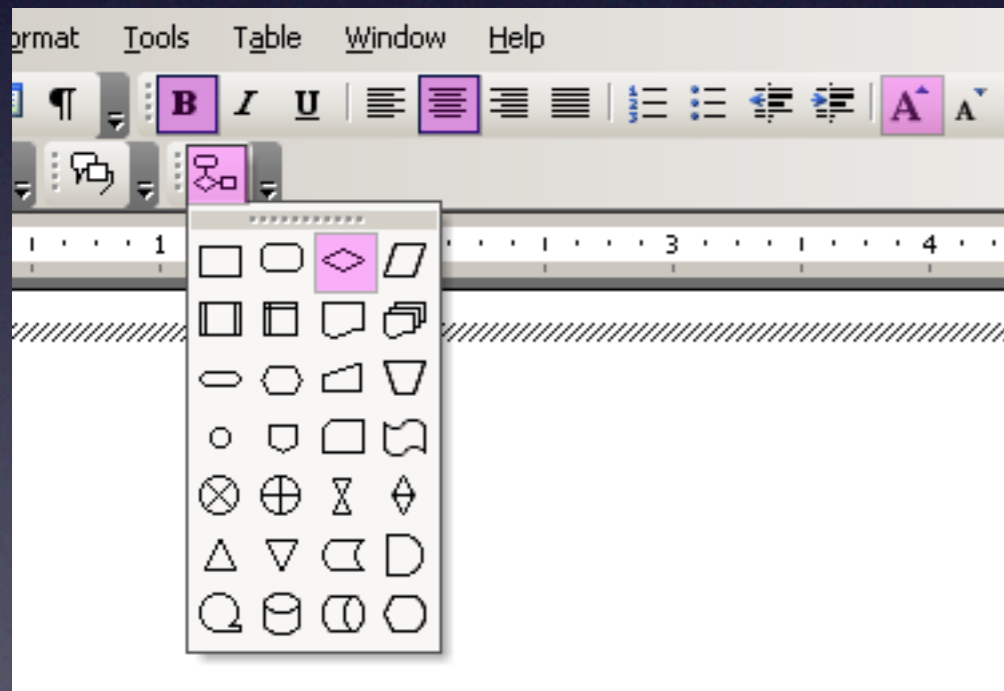


# Exploring the Design Space for Adaptive Graphical User Interfaces





# Exploring the Design Space for Adaptive Graphical User Interfaces





# Putting It All Together



# Putting It All Together

**Interaction  
Mechanics**

stability

locality



# Putting It All Together

## Interaction Mechanics

stability

locality

## Algorithm Behavior

frequency of adaptation

accuracy

predictability



# Putting It All Together

## Interaction Mechanics

stability

locality

## Algorithm Behavior

frequency of adaptation

accuracy

predictability

## Context

interaction frequency

task complexity



# Stability

Interaction Mechanics
stability
locality

Algorithm Behavior
frequency of adaptation
accuracy
predictability

Context
interaction frequency
task complexity

*User satisfaction*

## Split Interfaces



## Moving Interface



*Low stability*

*High stability*

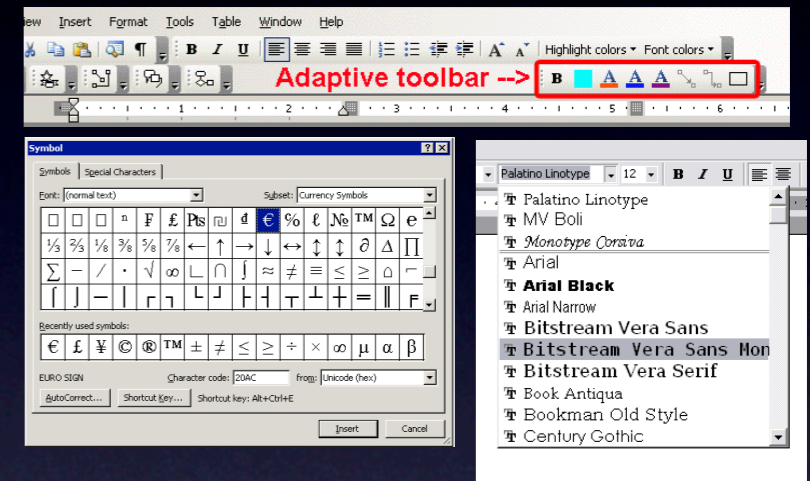


# Stability

Interaction Mechanics	Algorithm Behavior	Context
stability	frequency of adaptation	interaction frequency
locality	accuracy	task complexity
	predictability	

User satisfaction

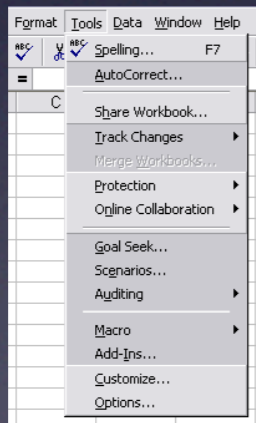
## Split Interfaces



## Moving Interface



## MS Smart Menus



Low stability

High stability



# Stability

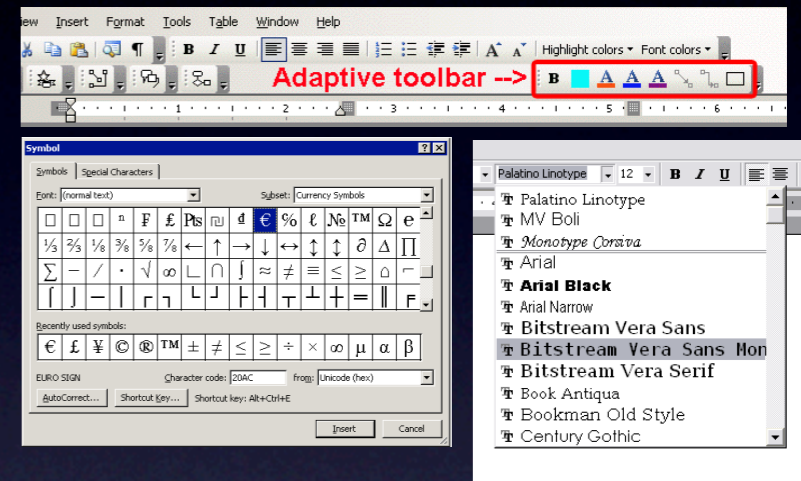
Interaction Mechanics  
stability  
locality

Algorithm Behavior  
frequency of adaptation  
accuracy  
predictability

Context  
interaction frequency  
task complexity

User satisfaction

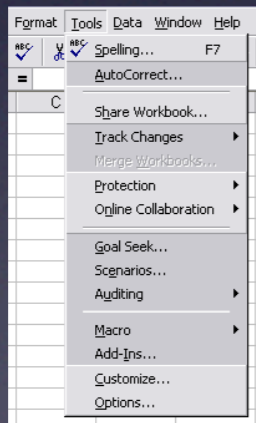
## Split Interfaces



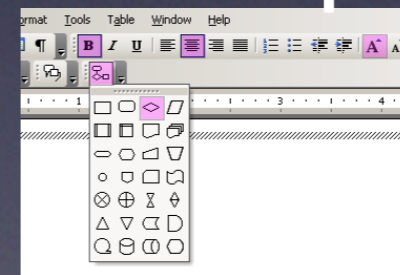
## Moving Interface



## MS Smart Menus



## Visual Popout



Low stability

High stability



# Locality

Interaction Mechanics
stability
locality

Algorithm Behavior
frequency of adaptation
accuracy
predictability

Context
interaction frequency
task complexity

- User comments indicate that, especially for manual tasks, high locality improves discoverability of adaptation.



# Adaptation Frequency

Interaction Mechanics
stability
locality

Algorithm Behavior
frequency of adaptation
accuracy
predictability

Context
interaction frequency
task complexity

Two studies of Split Menus:

↑ Sears and Shneiderman [1994]

↓ Findlater and McGrenere [2004]



# Adaptation Frequency

Interaction Mechanics
stability
locality

Algorithm Behavior
frequency of adaptation
accuracy
predictability

Context
interaction frequency
task complexity

Two studies of Split Menus:

↑ Sears and Shneiderman [1994]  
adaptation once per user/session

↓ Findlater and McGrenere [2004]  
adaptation once per interaction



# Accuracy

Interaction Mechanics
stability
locality

Algorithm Behavior
frequency of adaptation
accuracy
predictability

Context
interaction frequency
task complexity



# Accuracy

Interaction Mechanics
stability
locality

Algorithm Behavior
frequency of adaptation
accuracy
predictability

Context
interaction frequency
task complexity

- Participants performed faster at higher accuracy levels  
(also in [Tsandilas and schraefel CHI'05])



# Accuracy

Interaction Mechanics
stability
locality

Algorithm Behavior
frequency of adaptation
accuracy
predictability

Context
interaction frequency
task complexity

- Participants performed faster at higher accuracy levels  
(also in [Tsandilas and schraefel CHI'05])
- Participants were more likely to take advantage of adaptation at higher accuracy levels



# Accuracy

Interaction Mechanics	Algorithm Behavior	Context
stability	frequency of adaptation	interaction frequency
locality	accuracy	task complexity
	predictability	

- Participants performed faster at higher accuracy levels  
(also in [Tsandilas and schraefel CHI'05])
- Participants were more likely to take advantage of adaptation at higher accuracy levels
- More disorienting interfaces affected more by reduced accuracy

[Tsandilas and schraefel CHI'05]



# Predictability

Interaction Mechanics
stability
locality

Algorithm Behavior
frequency of adaptation
accuracy
<b>predictability</b>

Context
interaction frequency
task complexity

A study in progress!



# Interaction Frequency

Interaction Mechanics	Algorithm Behavior	Context
stability	frequency of adaptation	interaction frequency
locality	accuracy	task complexity
	predictability	

Two studies of adaptive deep hierarchical menus:

↑ Greenberg and Witten [1985]

↕ Trevellyan and Browne [1987]



# Interaction Frequency

Interaction Mechanics
stability
locality

Algorithm Behavior
frequency of adaptation
accuracy
predictability

Context
interaction frequency
task complexity

Two studies of adaptive deep hierarchical menus:

↑ Greenberg and Witten [1985]  
30 interactions per trial

↕ Trevellyan and Browne [1987]  
100 interactions per trial:  
-- first 30 positive  
-- last 30 neutral or negative



# Task Complexity

Interaction Mechanics
stability
locality

Algorithm Behavior
frequency of adaptation
accuracy
predictability

Context
interaction frequency
task complexity

## Experiment 1

Split Interface	Moving Interface
<ul style="list-style-type: none"><li>- stability</li><li>- semantic grouping</li></ul>	<ul style="list-style-type: none"><li>- discoverability</li></ul>
<ul style="list-style-type: none"><li>- poor discoverability</li></ul>	<ul style="list-style-type: none"><li>- instability</li></ul>

## Experiment 2

Split Interface	Moving Interface
	<ul style="list-style-type: none"><li>- discoverability</li></ul>
<ul style="list-style-type: none"><li>- poor discoverability</li></ul>	<ul style="list-style-type: none"><li>- instability</li></ul>



# Task Complexity

Interaction Mechanics
stability
locality

Algorithm Behavior
frequency of adaptation
accuracy
predictability

Context
interaction frequency
task complexity

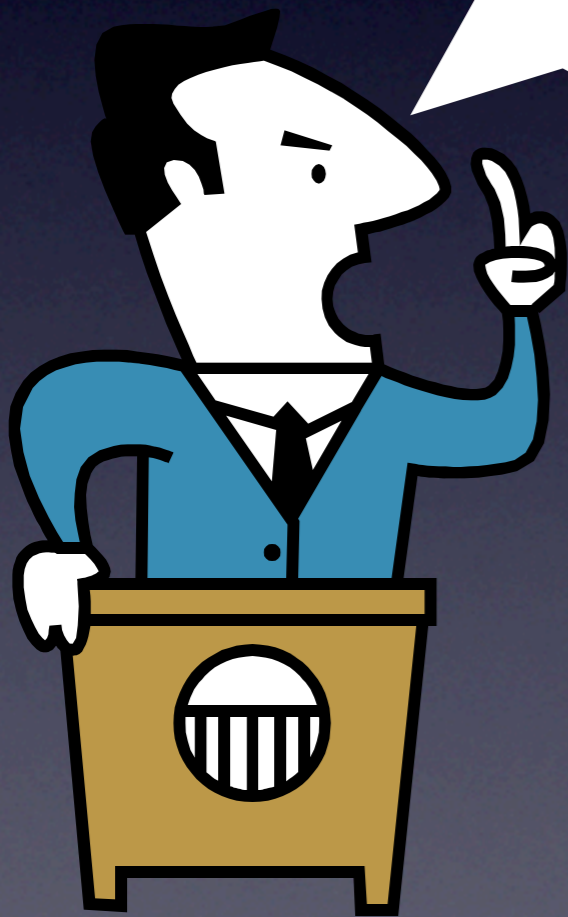
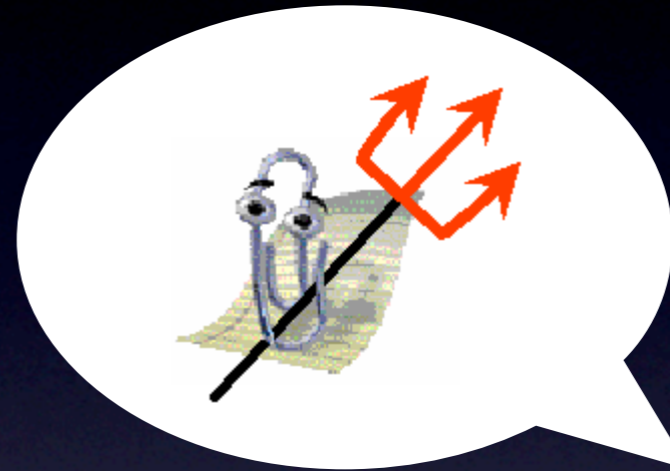
## Experiment 1

Split Interface	Moving Interface
<ul style="list-style-type: none"><li>- stability</li><li>- semantic grouping</li></ul>	<ul style="list-style-type: none"><li>- discoverability</li></ul>
<ul style="list-style-type: none"><li>- poor discoverability</li></ul>	<ul style="list-style-type: none"><li>- instability</li></ul>

## Experiment 2

Split Interface	Moving Interface
	<ul style="list-style-type: none"><li>- discoverability</li></ul>
<ul style="list-style-type: none"><li>- poor discoverability</li></ul>	<ul style="list-style-type: none"><li>- instability</li></ul>

# Conclusions






# Conclusions

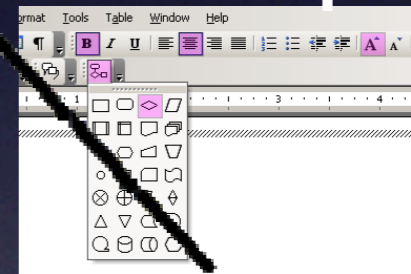
  
Split Interface



Moving Interface



  
Visual Popout






# Conclusions

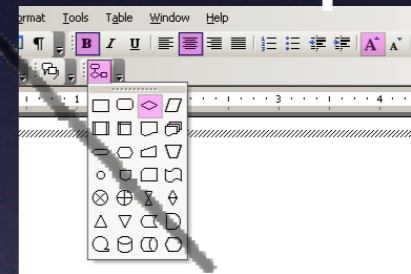
  
Split Interface



Moving Interface



  
Visual Popout



← Preferred

[Experiment I]

Disliked →



# Conclusions

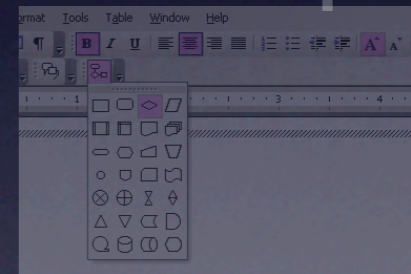
  
Split Interface



Moving Interface



Visual Popout



← Preferred

Faster

[Experiment 2]

→ Disliked



# Conclusions

## Interaction Mechanics

stability

locality

## Algorithm Behavior

frequency of adaptation

accuracy

predictability

## Context

interaction frequency

task complexity



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