

# Introduction to Online Experimentation and A/B Testing

Data Science Dojo

# Agenda

- **Introduction**

- What is A/B testing?
- Some interesting A/B tests

- **Fundamentals**

- Steps in Experimentation
- Hypothesis testing and related ideas
- Metrics for A/B testing
- Focus on intuitive understanding than specific distributions, formulas and tests

- **Common pitfalls**

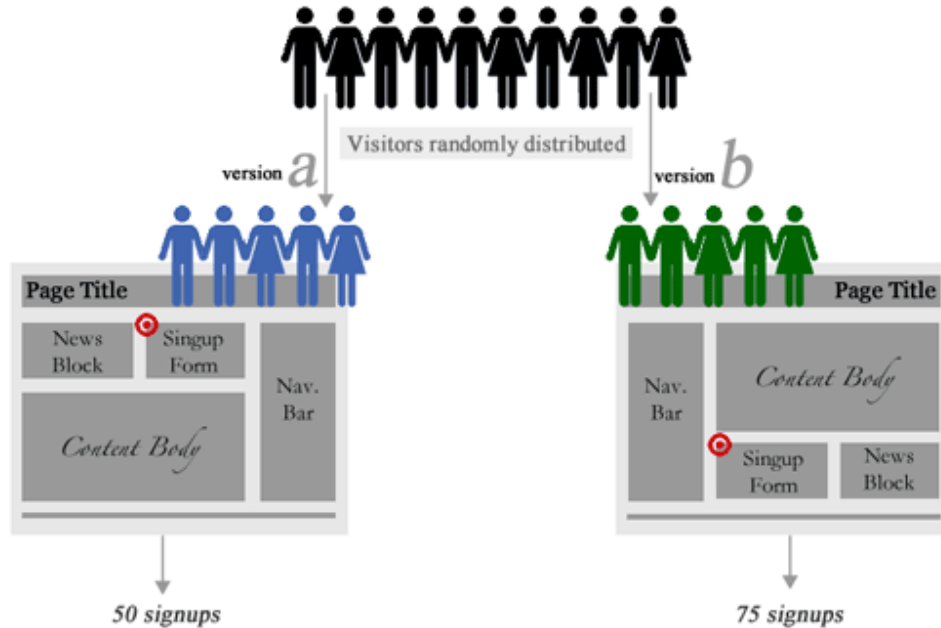
- Depth of discussion will depend upon audience engagement and time

# Introduction

In God we trust. All others bring data.

W. E. Deming

# What is A/B Testing?



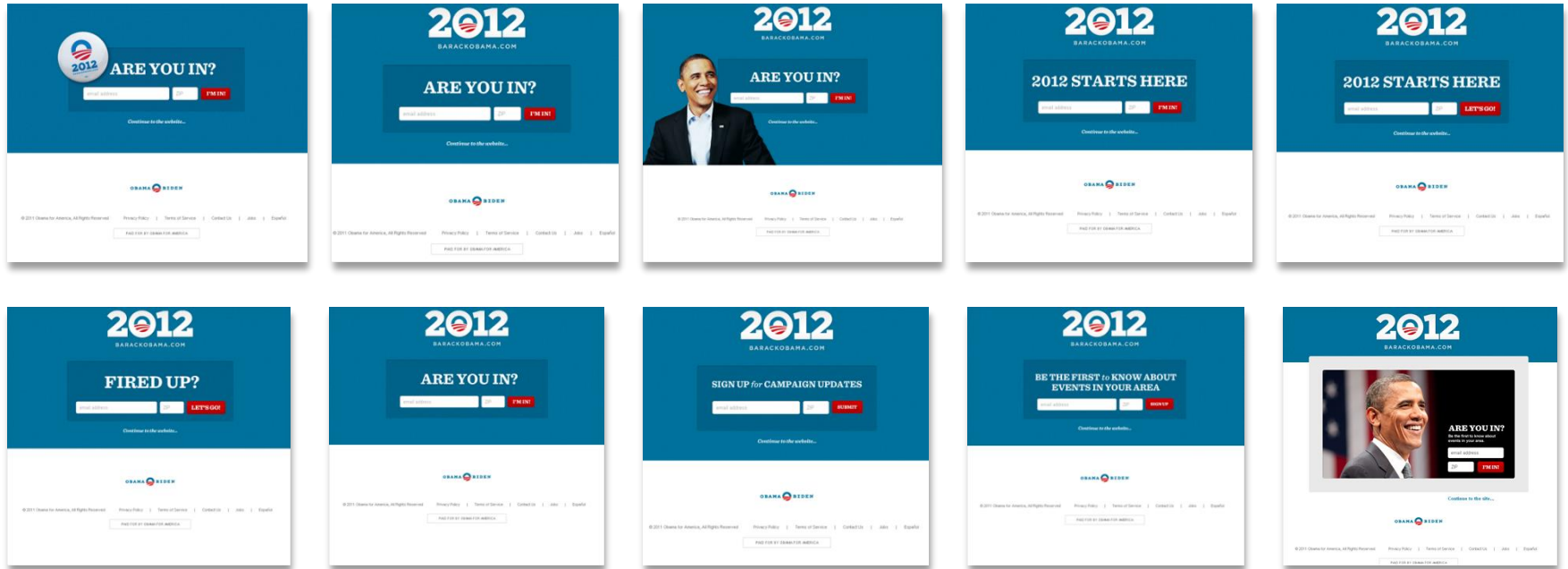
Version B is better than version A

# Obama 2012 Campaign



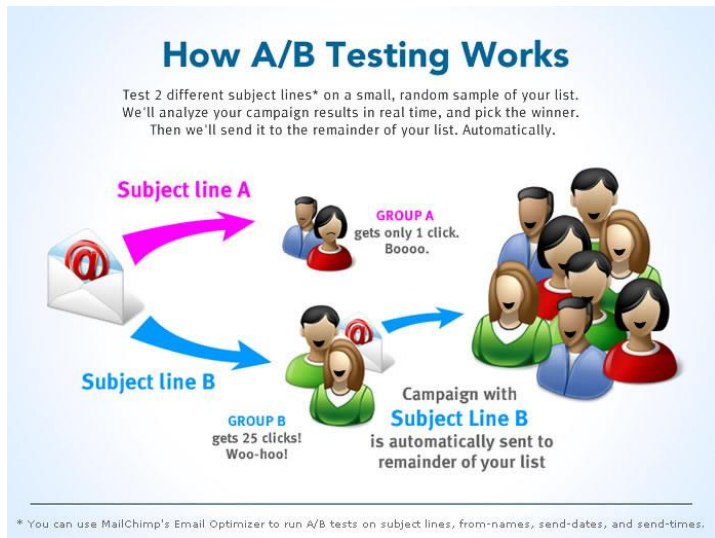
# Obama 2012 Campaign

## Maximize Sign-Ups And Donations



Source: <http://www.nathanielward.net/2011/06/see-ab-testing-in-action-on-barack-obamas-reelection-website/>

# A/B Testing On Newsletters And Email

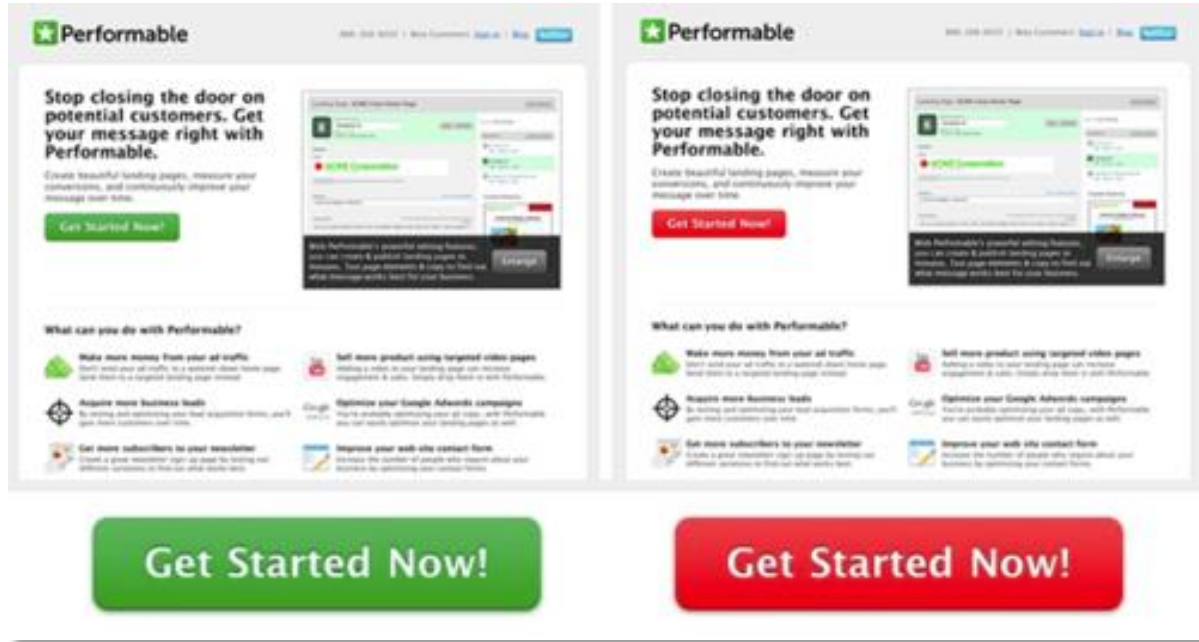


## Run tests on many things:

- Subject lines
- **From** names
- **Send** dates
- **Send** time

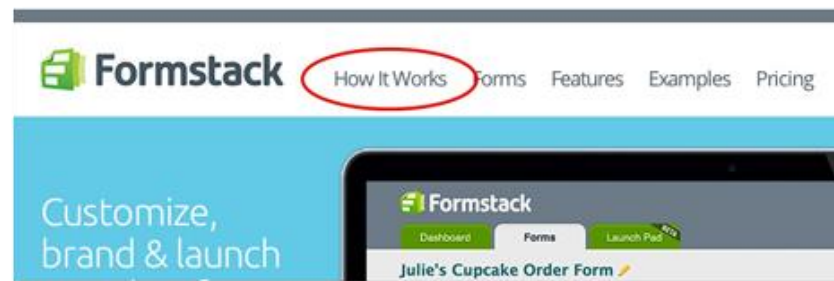
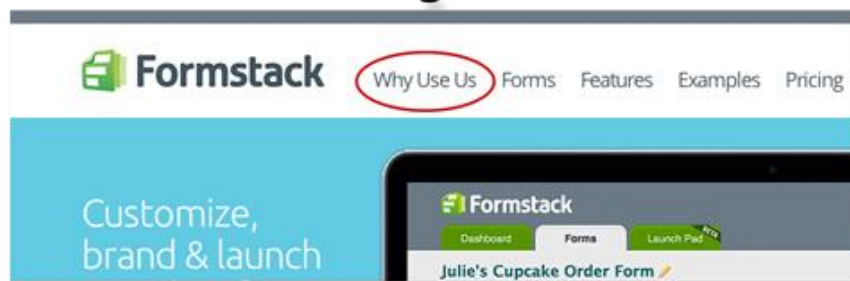


# Testing Call-to-Action Button



**Red button** increased clicks by **21%**

# Testing Navigation Bar



**'How It Works'** increased clicks by 47.7%

# Jocelyn or Michael?



JOCELYN



MICHAEL

**Michael** increased conversions by **21%**

# AwayFind - Mobile notifications for priority messages

Version A of the AwayFind website. The header includes the logo and navigation links: PRODUCT TOUR, WHO USES AWAYFIND?, FOR GOOGLE APPS, SUPPORT, PLANS & PRICING, and LOGIN. The main headline is "Check email every 5 mins? Stop! Let us find your urgent messages." The subtext reads: "When you receive an urgent message, AwayFind will notify you via your mobile device, a voice call, IM or even delegate the message to someone you specify." A green button says "Try it Free" with the note "no credit card required, setup in 2 minutes". To the right is a smartphone displaying an "URGENT EMAIL ALERT" from Geoff Rodgers: "I know it's last minute, but I can't make our downtown meeting today. Let me know when..." with "Reply" and "View" buttons. Below the main content, it states "AwayFind users have escaped from 250,240,213 unimportant emails... Meet a few below!" followed by three headshots of customers and logos for Apple, Google, ESPN, and Dell.

Version A

Version B of the AwayFind website. The header is identical to Version A. The main headline is "Checking email every 5 minutes? Stop! Get AWAY from your inbox — let urgent emails cut through the clutter and FIND you...instantly." The subtext reads: "When you receive a timely message, AwayFind will notify you on your mobile device with an SMS, Voice call or even our iPhone & Android apps." A green button says "Try it Free" with the note "no credit card required, setup in 2 minutes". To the right is a smartphone displaying the same "URGENT EMAIL ALERT" as in Version A. Below the main content, it states "AwayFind users have escaped from 37,019,993 unimportant emails... Meet a few below!" followed by the same three customer headshots and company logos as in Version A.

Version B

Which version increased sign-ups by **38%**?

# AwayFind - Mobile notifications for priority messages

↑  
← **AWAYfind** →  
↓

PRODUCT TOUR WHO USES AWAYFIND? FOR GOOGLE APPS SUPPORT PLANS & PRICING LOGIN

Check email every 5 mins? Stop!  
Let us find your urgent messages.

When you receive an urgent message, AwayFind will notify you via your mobile device, a voice call, IM or even delegate the message to someone you specify.

**Try it Free**  
no credit card required, setup in 2 minutes

URGENT EMAIL ALERT  
From: Geoff Rodgers  
I know it's last minute, but I can't make our downtown meeting today. Let me know when...

Reply View

AwayFind users have escaped from **250,240,213** unimportant emails... Meet a few below!

Our customers are at some cool companies

Apple Google ESPN DELL

Version A

↑  
← **AWAYfind** →  
↓

PRODUCT TOUR WHO USES AWAYFIND? FOR GOOGLE APPS SUPPORT PLANS & PRICING LOGIN

Checking email every 5 minutes? Stop!  
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URGENT EMAIL ALERT  
From: Geoff Rodgers  
I know it's last minute, but I can't make our downtown meeting today. Let me know when...

Reply View

AwayFind users have escaped from **37,019,993** unimportant emails... Meet a few below!

Our customers are at some cool companies

Apple Google ESPN DELL

Version B

**Version B!**  
**A longer yet clearer message is more effective.**

# Online Form

**Get Data Center Pricing**

With eight data centers, Expedient provides superior colocation, network and managed services to enterprises, commercial, education and government entities. We are committed to providing our clients with reliable, secure and redundant managed data center services. As a managed data services provider, we can offer your company high quality, cost effective solutions to meet your needs.

Fill out the form below and get data center pricing today.

Company Name :

Name :

Phone :  -  -  Ext.

Contact Email :

Services : ☐ Colocation ☐ Cloud Computing ☐ Virtual Colocation ☐ Virtual On Demand ☐ Virtual Instance ☐ Managed Backup ☐ Managed SAN ☐ Managed Server ☐ Managed Exchange ☐ Internet Connectivity ☐ Other

Desired Data Center :



Comments :

Security Question : How many months are there in a year?

Answer :

Expedient respects your right to privacy and we will never sell or share your data.

If you have immediate questions, please call 877-570-7827, Monday through Friday 8am - 5pm EST.



Version A

**Cloud Computing Quote Request**

Request service pricing on cloud computing through any of Expedient's 8 nationwide data centers.

Company Name :

Name :

Contact Type :

Title :

Comments :

Contact Phone :

Contact Email :

Data Center Location :

Total Required RAM in GB :

Total Required Processor in GHz :

Total Required Storage in GB :

Internet Connectivity :

Additional Managed Services

Firewall : ☐

Remote Backups : ☐

SAN Storage : ☐

Load Balancing : ☐

Priority :

Security Question : How many months are there in a year?

Answer :

Version B

Which Radically Redesigned Form Increased B2B Leads By **368.5%**?

# Online Form

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Version A

**Version A!**  
**Better be to the point**

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Comments :

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Contact Email :

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Total Required RAM in GB :

Total Required Processor in GHz :

Total Required Storage in GB :

Internet Connectivity :

Additional Managed Services

Firewall : ☐

Remote Backups : ☐

SAN Storage : ☐

Load Balancing : ☐

Priority :

Security Question : How many months are there in a year?

Answer :

Version B



# WIKIJOB

WIKIJOB

Perform Better at Reasoning Tests with WikiJob

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2 weeks access - £12.99

Every day hundreds of people use WikiJob to practise for their numerical and verbal assessment tests.

10 Numerical Reasoning Practice Tests  
Help you practice your basic math skills under pressure.

8 Verbal Reasoning Tests  
Over 200 questions to help you practice your comprehension skills.

Fully Worked Solutions  
All questions come complete with online marking and complete answers to help you learn.

Why WikiJob?

WikiJob's tests are written in such a way as to simulate the kind of question you will receive during online assessments. Although these do not contain any questions from the real tests, they are based upon them, and designed to provide practice to help you through.

Each test is automatically marked and you are given your percentile, which shows how you did in relation to everybody else who took the test.

Verbal Reasoning Practice Test 1

View Take

FULLY WORKED SOLUTIONS

Version A

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Testimonials

"Good training for the work environment in Europe."

"Very useful for practice!"

"Almost a carbon copy of the real aptitude test."

Verbal Reasoning Practice Test 1

View Take

FULLY WORKED SOLUTIONS

Version B

Version B has **testimonials**, does it work?



# WIKIJOB

WIKIJOB

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Verbal Reasoning Practice Test 1

View Take

FULLY WORKED SOLUTIONS

Version A

WIKIJOB

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Each test is automatically marked and you are given your percentile, which shows how you did in relation to everybody else who took the test.

Verbal Reasoning Practice Test 1

View Take

FULLY WORKED SOLUTIONS

**Testimonials**

"Good training for the work environment in Europe."

"Very useful for practice!"

"Almost a carbon copy of the real aptitude test."


Version B

**Yes, testimonials increased sales by 34%**

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**Closet Organization**

**Room Organization**

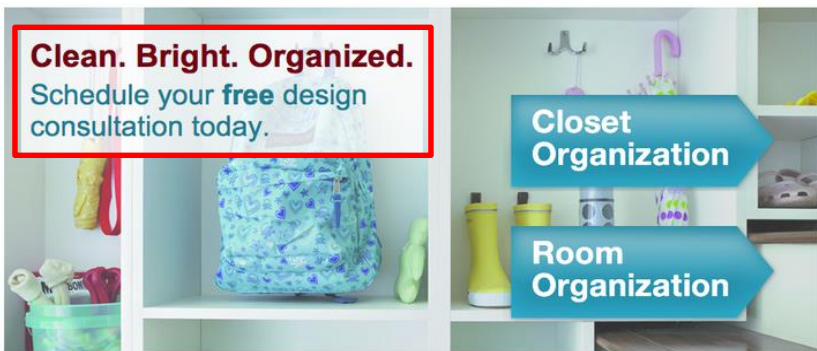


“ It's not just clothes and it's not just shoes. It's space to live in and enjoy.”  
— Tracy Lee, Mill Valley, CA

Version A

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Version B

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Organization



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Version A

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Organization

Room  
Organization



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Version B

Version A increased leads by **115%.**  
**This is why you should test...!**

**data science dojo**  
unleash the data scientist in you

# Fundamentals

# Why We Use A/B Testing

## Problem

- Users are complex and our intuition is often wrong
- Rolling out a feature to all the users at the same time is risky



## A/B testing purpose


- Know what the users want subconsciously or otherwise.
- Helps to fail fast and move on

Impact is always expected to be positive, but outcome is often humbling

# A/B Testing vs. Multivariate Testing



# A/B Testing vs Multivariate Testing

	A/B Testing	Multivariate Testing
Common use	Compare two very different designs with each other	Several minor variations are up for debate: <ul style="list-style-type: none"><li>➤ Two colors of button with three different headlines</li></ul> <p> Also called full factorial testing</p>
Advantages	<ul style="list-style-type: none"><li>➤ Simple in design</li><li>➤ Small sample size may be ok</li></ul>	A lot of different combinations tried at once.
Limitations	Trying only one alternative	<ul style="list-style-type: none"><li>➤ Bigger sample size</li><li>➤ Complex</li><li>➤ Need better understanding of interactions</li></ul>

# Terminology



# Control and Treatment

## Control

Default experience, the way things are now.

**Example:** Current look and feel of your 'Buy Now' button

A green rectangular button with rounded corners and a slight 3D effect, containing the text "Buy Now" in white.

## Treatment

The change we want to make.

**Example:** Change the button from green to blue

A blue rectangular button with rounded corners and a slight 3D effect, containing the text "Buy Now" in white.

## Illustration



# Factor and Level

## Factor

- The item we want change

## Level

- The variations of factor



# Metrics Used For A/B Testing

- **Search engines**

Queries/UU, Session length, Sessions/UU, Page views, Bounce rate

- **Online Retailers**

Conversion rate, revenue/UU, Avg Cart Value and so on

- **Other websites**

CTR, signup for newsletter

**Each business is different**

# Brainstorming

# Null vs Alternate Hypothesis

- Null Hypothesis ( $H_0$ ):
  - Control and treatment are similar (in terms of the parameter we are estimating)
- Alternate Hypothesis ( $H_a$ ):
  - Treatment is different from control

# Null vs Alternate Hypothesis



Control



Treatment

- **Null Hypothesis ( $H_0$ ):** Green and blue buttons have the same CTR
- **Alternate Hypothesis ( $H_a$ ):** CTRs for both buttons are different

# Type I and Type II Error

## Type I Error

The probability of **falsely rejecting** null hypothesis

## Type II Error

The probability of **falsely accepting** null hypothesis

Ground Truth			
		Ho is true.	Ho is false.
Experiment Outcome	Reject Ho.	Type I error	Correct decision.
	Do not reject Ho.	Correct decision.	Type II error

Can you tell me in simple words...



# The Cook and Smoke Detector

- Null Hypothesis ( $H_0$ ): There is no fire
- Alternate Hypothesis ( $H_a$ ): There is fire



# The Cook and Smoke Detector

- Type I Error: There is no fire but smoke detector goes off.
- The cook removes the alarm to prevent type I error.
- This increases the chance of Type II Error i.e. a fire without an alarm.



# The Boy Who Cried Wolf

- Null Hypothesis ( $H_0$ ): There is no wolf
- Alternate Hypothesis ( $H_a$ ): There is a wolf



# The Boy Who Cried Wolf

- **Type I Error:** Villagers believe the boy when there is no wolf
- **Type II Error:** Villagers do not believe the boy when the wolf is really there



# Confidence Intervals

**Problem:** On a 5-point scale, a product has an average review of 4.32 and a standard deviation of 0.845 based on 62 participants in the study. What is the 95% confidence interval?

$$\bar{X} \pm 1.96 \sigma / \sqrt{n}$$

# Confidence Intervals

Mean  $\bar{X} = 4.32$

Standard deviation  $\sigma = 0.845$

Standard error  $SE = \frac{0.845}{\sqrt{n}} = \frac{0.845}{\sqrt{62}} = 0.11$

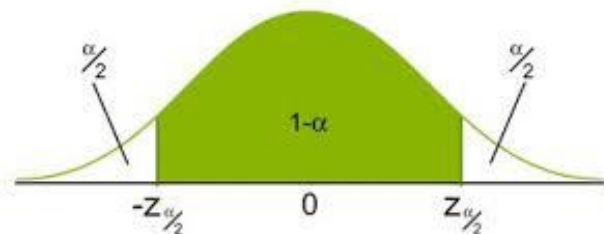
Margin or error is  $2 \times 0.11 = 0.22$

The confidence interval is

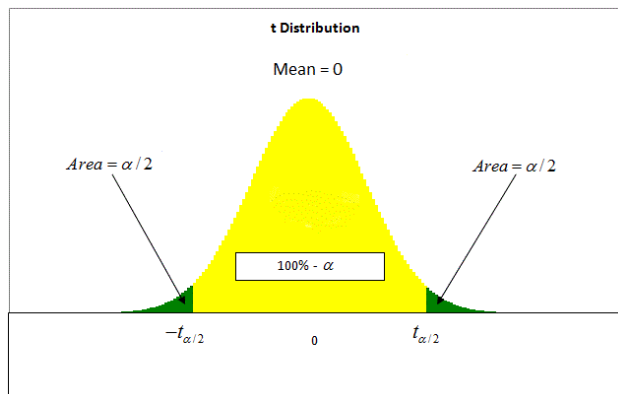
$4.32 + 0.22 = 4.54$

$4.32 - 0.22 = 4.10$

# Calculating Confidence Interval



At the level of significance  $\alpha$ ,  
the critical values are  
 $-Z_{\alpha/2}$  and  $Z_{\alpha/2}$



Confidence level	Z score
90%	1.645
95%	1.960
98%	2.326
99%	2.576

Critical Values ( $t^*$ )			
n - 1	Confidence Level		
	0.900	0.950	0.990
10	1.812	2.228	3.169
20	1.725	2.086	2.845
30	1.697	2.042	2.750
40	1.684	2.021	2.704
50	1.676	2.009	2.678
60	1.671	2.000	2.660
70	1.667	1.994	2.648
80	1.664	1.990	2.639
90	1.662	1.987	2.632
100	1.660	1.984	2.626

# Type I and Type II Error

## Type I Error

The probability of **falsely rejecting** null hypothesis

## Type II Error

The probability of **falsely accepting** null hypothesis

Experiment Outcome

Ground Truth		
	Ho is true.	Ho is false.
Reject Ho.	<b>Type I error</b>	<b>Correct decision.</b>
Do not reject Ho.	<b>Correct decision.</b>	<b>Type II error</b>



# Confidence Interval

- Range of plausible values of parameter being estimated given the sample data



# A/A Test

- Comparing the identical experience on different random sets of users
- Used for validation of setup



**Buy Now**

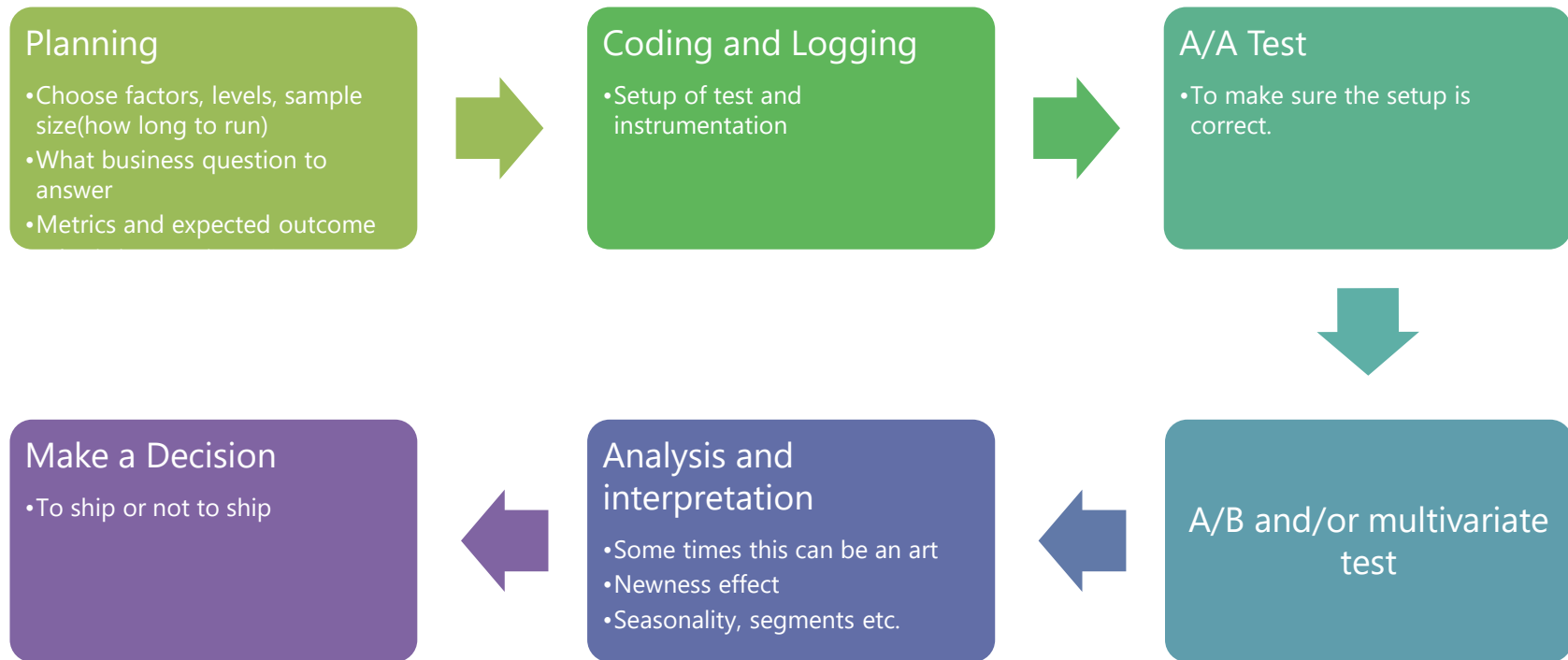
**Control**



**Buy Now**

**Treatment**

# Steps in Experimentation



# Categories of Metrics

	Short-term	Medium-term	Long-term
Examples	<ul style="list-style-type: none"><li>➤ CTR</li><li>➤ PVs</li><li>➤ Bounce Rate</li></ul>	<ul style="list-style-type: none"><li>➤ PVs/user/day</li><li>➤ CTR/user /day</li><li>➤ Avg session length</li></ul>	<b>Days with at least one visit:</b> <ul style="list-style-type: none"><li>➤ Total time on site</li><li>➤ Repeat visits/user</li></ul>
What is measured?	Immediate or almost immediate impact	Engagement over hours up to a day	Loyalty

# Common Pitfalls

# Pitfalls in Online Experimentation

1. Picking an OEC for which it is easy to beat the control
2. Incorrectly computing the confidence intervals
3. Using standard statistical formulas for computation of variance and power
4. Combining metrics over periods where proportions assigned to Control and Treatment vary or over subpopulations sampled at different rates
5. Neglecting to filter bots
6. Failing to validate each step of the analysis pipeline and the OEC components
7. Forgetting to control for all differences, and assuming that humans can keep the variants in sync

# Pitfall 1: Picking an Easy-to-Beat Overall Evaluation Criteria (OEC)

- Before running an experiment an OEC is selected
- OEC should be tied to a long term goals as opposed to short term goals. Click-through Rate (CTR) vs. long term revenue
- Loyal/repeat users get more weight?
- Sometimes getting the true metric is hard. High CTR does not necessarily mean high conversion rate

# Pitfall 1: Picking an Easy-to-Beat Overall Evaluation Criteria (OEC)

- Measuring click through on a small area of the page, ignoring the impact on other areas
  - What if the small area on the page was bold/flashing/high contrast?
  - What happens to the whole page CTR?
- Is 'time on site' a good OEC?
  - What if the treatment has a reduced user's effectiveness?

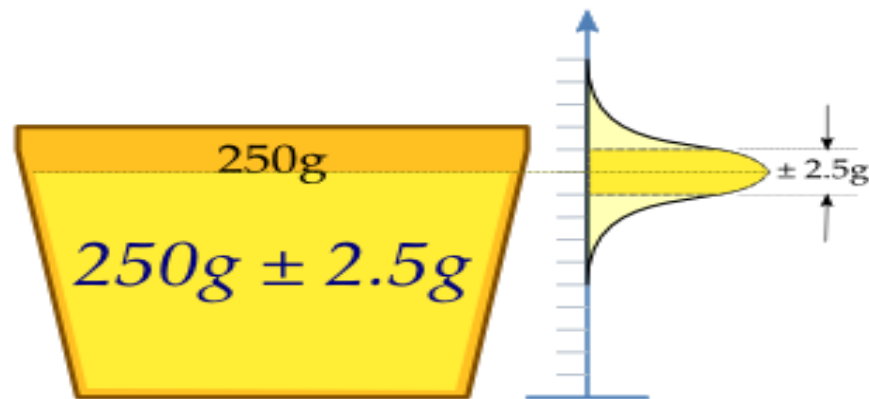


## Pitfall 2: Incorrect Computation of Confidence Intervals

- Hypothesis Test: determines whether there is a statistically significant difference in the means of the control and the treatment
- Confidence Interval: provides a plausible range of the size of the effect (difference in C and T means)

# Pitfall 2: Incorrect Computation of Confidence Intervals

$$\begin{aligned}0.95 &= 1 - \alpha = P(-z \leq Z \leq z) = P\left(-1.96 \leq \frac{\bar{X} - \mu}{\sigma/\sqrt{n}} \leq 1.96\right) \\&= P\left(\bar{X} - 1.96 \frac{\sigma}{\sqrt{n}} \leq \mu \leq \bar{X} + 1.96 \frac{\sigma}{\sqrt{n}}\right) \\&= P(\bar{X} - 1.96 \times 0.5 \leq \mu \leq \bar{X} + 1.96 \times 0.5)\end{aligned}$$



$$(\bar{x} - 0.98; \bar{x} + 0.98) = (250.2 - 0.98; 250.2 + 0.98) = (249.22; 251.18).$$

**Confidence interval implies:** If we randomly fill a cup from this vending machine, there is a 95% chance that our cup will have this much coffee

# Pitfall 2: Incorrect Computation of Confidence Intervals

- Confidence interval should be formed out of absolute difference
- Do not form a confidence interval around percent change. Percentage change involves dividing by a random variable.
- Some techniques to compute CI are mentioned when the OEC is a linear/non-linear combination of metrics that have the same/different basis/experimental unit.

# Pitfall 3: Standard Statistical Formulas for Computation of Variance and Power

- Variance of the metric is needed to compute the statistical significance
- Variance estimates using standard statistical formula for some families of metrics are inaccurate
- This happens when the experimental unit used in random assignment is different from the experiment unit used in the calculation of the metric.

# Pitfall 3: Standard Statistical Formulas for Computation of Variance and Power

- Variance, Power and Sample size estimates may be wrong if care is not taken
- How to correct this?
  - Bootstrap method: Estimate variance using bootstrap samples and compare with the variance from standard formula
- This should be done for all metrics and especially for the one with different experiment and randomization units

# Pitfall 4: Simpson's Paradox

- Unintuitive but not uncommon
- Simpson's paradox: 'A correlation or trend present in different groups is reversed when the groups are combined'.

	Treatment A	Treatment B
Small Stones	Group 1	Group 2
	93% (81/87)	87% (234/270)
Large Stones	Group 3	Group 4
	73% (192/263)	69% (55/80)
Both	78% (273/350)	83% (289/350)

# Pitfall 4: Simpson's Paradox

- 1 million visitors/day
- On Friday the treatment ran with 1% traffic
- On Saturday, the allocation was raised to 50%.
- If we consider Friday and Saturday separately T has a better CTR
- T's CTR is worse when aggregated over days

**Table 1: Conversion Rate for two days.**  
Each day has 1M customers, and the Treatment (T) is better than Control (C) on each day, yet worse overall

	Friday C/T split: 99%/1%	Saturday C/T split: 50%/50%	Total
C	$\frac{20,000}{990,000} = 2.02\%$	$\frac{5,000}{500,000} = 1.00\%$	$\frac{25,000}{1,490,000} = 1.68\%$
T	$\frac{230}{10,000} = 2.30\%$	$\frac{6,000}{500,000} = 1.20\%$	$\frac{6,230}{510,000} = 1.20\%$

It is possible to have  $\frac{a}{b} < \frac{A}{B}$  and  $\frac{c}{d} < \frac{C}{D}$  while  $\frac{a+c}{b+d} > \frac{A+C}{B+D}$

# Pitfall 4: Simpson's Paradox – A Scenario in Controlled Experiments

- Sampling of users with non uniform sampling to make sure all browsers have a representative sample
- Overall results show treatment is better than control but when segmented by browser, control looks better than treatment for each browser



# Pitfall 5: Ignoring Bot Traffic

- For experimentation, we are interested in removing bots/fraud clicks that are not uniformly distributed across the control and treatment
- Uniformly distributed bots will only reduce the power of the experiment

## Pitfall 5: Ignoring Bot Traffic

Failing to exclude bot traffic and fraud clicks may **invalidate the results** of an experiment

# Pitfall 6: Failing to Validate Each Step of Analysis

It is important to keep a check on the health of the pipeline

- Assignment of users to experiment variants
- Calculation of metrics
- Any abnormal shift in metrics
- Movement of metrics that are not expected to move
- Broken instrumentation

# Pitfall 6: Failing to Validate Each Step of Analysis

## Logging Tests:

- Compare with **real historical data**
- Compare with **generated data**
- Look for **unexpected patterns**
  - **Volume** of data over time
  - New and repeat **users** over time
  - **Abnormal shift** in any of the metrics
- A/A Tests
- Rich Instrumentation

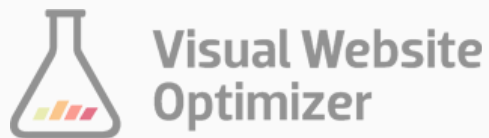
# Pitfall 7: Failing to 'Control' the Control

- **Don't allow any difference** between the Control and the Treatment besides what is actually being tested
- If the **Treatment** has some **updates**, **Control** should have them too and vice versa

# Pitfall 7: Failing to 'Control' the Control

- If the site is receiving **frequent updates**, these updates should be **applied equally** to the control and the treatment
- Forgetting to **control for all differences**, and assuming that humans can keep the variants in sync.

# A/B Testing Tools



# Humor



Have you heard the latest statistics joke?

Probably....

Did you hear about the statistician who  
was thrown in jail?

He now has zero degrees of freedom.

A statistician's wife has twins. He was delighted, and he called to tell his minister the good news.

"Excellent!", said the minister. "Bring them to church on Sunday and we'll baptize them."

"No," replied the statistician. "Let's just baptize one. We'll keep the other as control."

*Three statisticians go out hunting together. After a while they spot a solitary rabbit.*

*The first statistician takes aim and overshoots. The second aims and undershoots.*

*The third shouts out "We got him!"*

How many statisticians does it take to change a light bulb?

1 – 3.      $\alpha=0.05$

# Questions?



# Appendix