

FITTS' LAW

A Course project report submitted in partial
fulfillment of requirement of

FOUNDATIONS OF COGNITIVE SCIENCE

By

S. Amulya	(19K41A04B6)
P. Rithika Reddy	(19K41A05A8)
S. Shiva Keerthi	(19K41A05B1)
K. Srilatha	(19K41A05A2)
T. Vinuthna	(19K41A05B5)

Under the guidance of

Mr. Rajashekhar P.V

Assistant Professor, Department of CCC



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CHAPTER 1

Introduction to Fitts' law

1.1 Definition

Fitts' law states that the amount of time required for a person to move a pointer (e.g., mouse cursor) to a target area is a function of the distance to the target divided by the size of the target. Thus, the longer the distance and the smaller the target's size, the longer it takes. The equation of Fitts' law is as follows, $T (Time) = a + b \log_2 (2 D (Distance) / W (Width))$

1.2 Background and importance

While examining the human psychomotor behavior in 1954, psychologist Paul Fitts showed that the time required to move a target is directly proportional to distance and inversely proportional to the size of the target. He showed that due to the speed-accuracy trade off, the fast movements and small targets results in greater error rates. In simple words, Fitts' Law is about how long it takes to move your hand to an object. For example, a small object 1 feet meter from your hand takes more time to grasp than a large object; that is, size plays a role. But a small object close by can be just as easy to grasp as an object further away, given that that object is larger. Today, Fitts' law is widely used in the user experience and user interface (UI) designing. Understanding the human psychology is essential for all designers when creating a user-centered product for a great user experience. Developing and understanding these cognitive abilities is the key to interactive and effective design. This law gives the user interface guidelines which helps the designers to make user friendly web page designs. This law is particularly important in visual interface design or any interface involving pointing (e.g., mouse, finger, etc.) here we can use the law to assess the spacing, color contrast, size, etc. of the interactive buttons which can minimize the user's travel distance in turn reducing time and increasing productivity.

1.3 Prime pixel and magic pixels

The prime pixel and magic pixels are the applications of Fitts' law which tells us about the positioning of the user's cursor. The prime pixel is the imaginary point from which the user carries out all their actions when they are browsing through a webpage. If we were able to determine the location of prime pixel, we can easily adapt our design such that we could create

the shortest path to the actions we expect the user to take. However, it is difficult to find out the exact location of the prime pixel at all times, but we can determine it's likely position when a user takes an action. For example, if the user wants to login, they click on "User name" option, then the "Password" and "Submit" options should be as close as possible. Similar to the prime pixel, we have the magic pixels, which give us an imaginary boundary of the web page. The 4 magic pixels are arranged such that one pixel lies in each corner of the screen. The magic pixels are the furthest from the prime pixel, these magic pixels are the least valuable spaces on screen and hence, they are considered least useful places to put anything important when we apply Fitts' law.

CHAPTER 2

User Interface and Design Principles

2.1 User Interface

It is the point when the human interacts with a website or an application to perform some tasks. The main aim of UI is to make the website user-friendly and to have less effort from the user to perform his task. User Interface is very important to make the website or an application user-friendly. While developing a UI knowing your target users and designing the interfaces according to their level is very important. In our daily life, we interact with the computer in many ways by using a keyboard, mouse, touch screen, etc...

2.1.1 Types of User Interface

1. Form-based User Interface

- This is used to enter the data into an application by giving a minimum number of choices.

For Example, the Settings menu in android devices is form-based.

2. Graphical User Interface

- A graphical user interface (GUI) is a type of interface through which the user interacts with electronic devices with the help of visual indicator representations.

Ex- Keyboard and Monitor.

3. Menu-based User Interface

- This type of UI uses a list of options to search within a website or an application.

Ex- ATMs use menu-based UI. This can be easily understood by common people.

4. Touch User Interface

- It's a User Interface is based on touch.

Ex- Most of the smartphones operates using the touch screen.

5. Command-line User Interface

- This interface is based on the interaction between the user and computer-based on voice commands.

Ex-Google Assistant, GPS, etc...

2.2 Design Principles

1. Place users in control of the interface

- It means that the user should always be able to backtrack whatever they are doing. This helps the user to explore the website more freely.
- For example, if the user has entered any incorrect data, he should always be able to go back and change the data.
- Always, try to include a search bar that makes the website's search more usable.

2. Consistency in user interfaces

- If we maintain consistency in our interface, it helps the user to get used to the interface and implement the same knowledge in other parts of the application.
- Using the same colors, fonts, and icons throughout the application is very important.

3. Easy to navigate the interface

- Usually, the users tend to move through screens from top-left to bottom-right.
- Considering this the buttons which help the user to perform an action should be placed on the bottom right-hand side.
- Users should be able to predict what button they need to press to complete the action.
- Not only increasing the size of target buttons and reducing distance but also try to reduce the number of targets the user must interact with to complete a task.
- Don't try to use difficult terminology which is hard for a user to understand. Use the words which the user can understand just by looking at them.

4. Reduce Cognitive Load

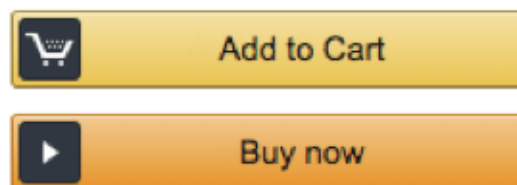
- In 1956, Psychologist George Miller introduced the theory of chunking. He says that human working memory can handle seven-plus or minus two chunks of information while processing information.
- For example, in some of the interfaces, it forces the user to enter a 12-digit account number without any spaces. This creates ambiguity for the user.
- Thus, it can be made user-friendly by automatically giving spaces for every 4 digits he enters.
- Reduce the number of actions required to complete a task. The three-click rule is very important in user interface design.

2.3 Fitts law applications in UI

1. Size

- Target buttons should be larger in size. If they are larger in size the user can easily see those buttons and hit them.
- Low priority buttons can be smaller in size(10 mm), medium priority buttons can be the size of a keyboard key(16mm), high priority buttons must be the size of a coin(18mm)

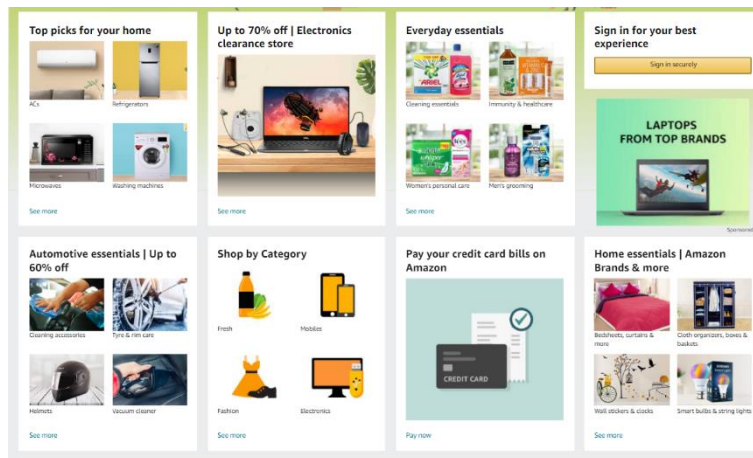
Ex – Login Page, e-shopping websites, etc...



2. Layout

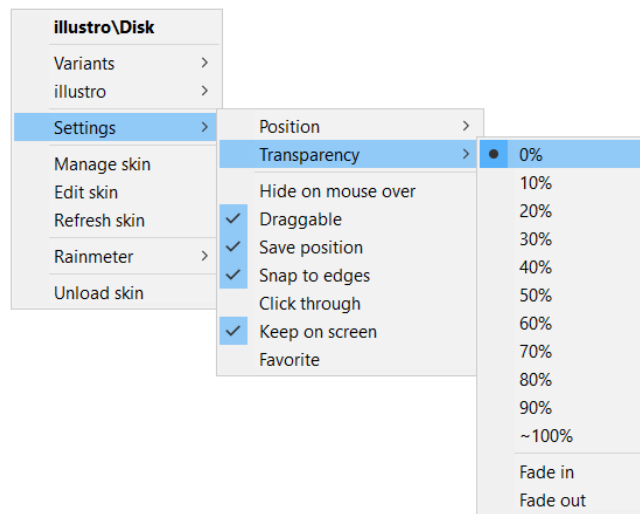
- Providing a good layout to the interface makes it much more attractive. Organize the contents in such a way that it is pleasant to read.
- The layout should make the navigation easier. All the necessary elements in the website must be properly arranged within the user's reach for minimizing their effort.

- The layout should be adjusted to any gadget that the user will use whether it may be pc or a mobile etc.



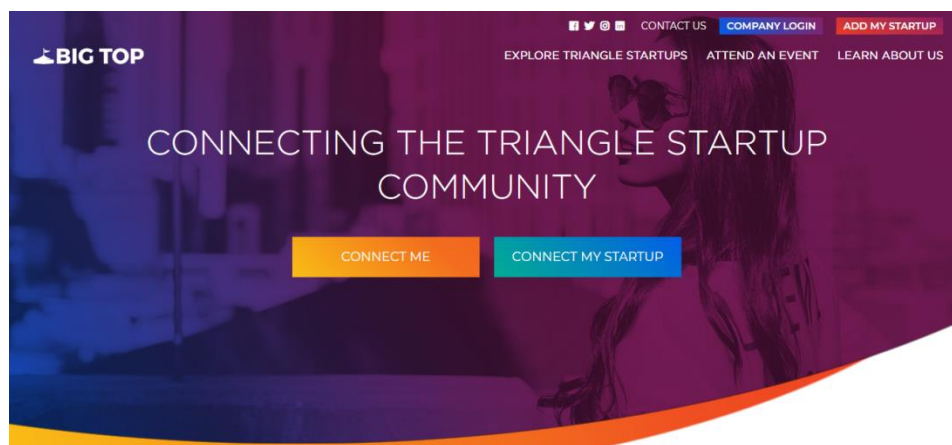
3. Menu

- In a website rather than dumping all the options they should be organized in such a way that the user should be able to quickly reach his required option.
- Pop-up menus can also be able to reduce the travel time because the user doesn't need to move the mouse.
- For Example, on the Amazon website, we see the menu clearly specifying whether it is accessories, electronic appliances, shopping, etc. This makes the website more user-friendly.



4. Color Contrast

- The background should not be the same color as the image. It will be difficult to read the content when both are of the same color.
- The colors we use reflect the personality of the brand, in turn influences the purchasing decision of the user.
- Choose a color which is likable by all the people(Preferably blue)
- Bright and vibrant color palette gives a lively and cheerful look.
- White and black palettes give an elegant look.



5. Spacing

- Buttons to complete an action should be close to the active elements
- The target buttons should be placed just below the elements that the user needs to give to complete the action.
- But, one must also remember that negative space is not wasted space.
- Giving required amount of empty spaces will contribute to the emotional aspect of the user experience and it will add more breathing space in the UI, as a result, the interaction feels more relaxed for the user.
- And also, the negative space gives more emphasis to the particular section.
- Ex – In a login page, the email and password sections are a little close, and then there is a gap after which sign in/log in button is given, this negative space gives more emphasis to the submission button and also they are not too far nor too close, which is optimal.

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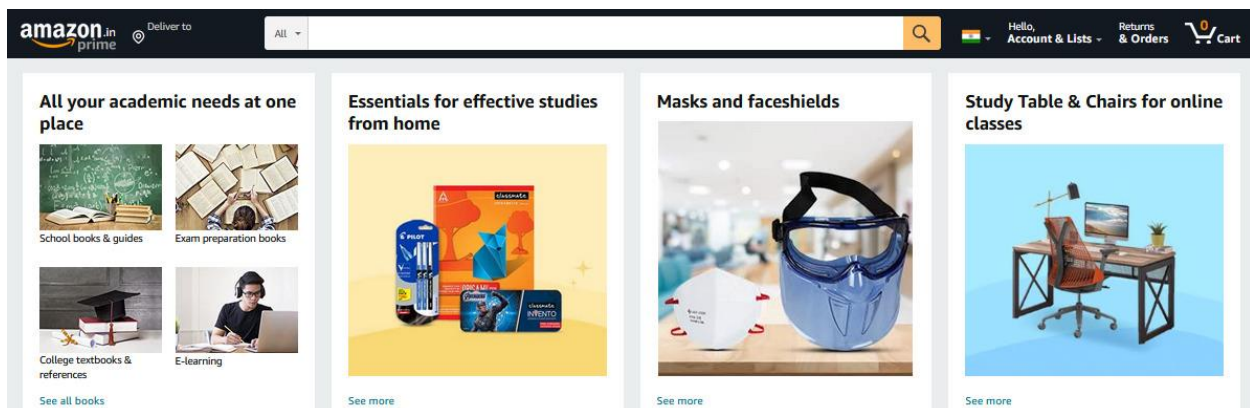
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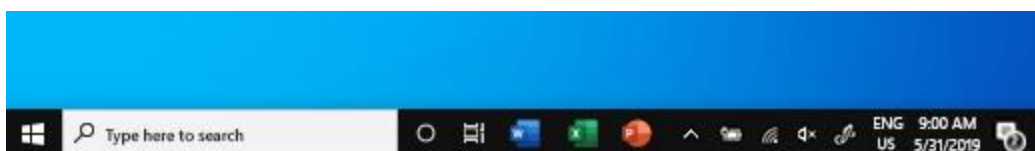
6. Similarity

- Birds of a feather flock together. Organizing similar things in close knit groups gives the user a more comfortable and relaxed experience while navigating a website.



7. Taskbars

- The user can travel to the outer edges and corners much faster in a web page or an interface.
- Taskbars are very much useful as they are placed in the area where the user can easily move.



CHAPTER 3

The Fitts' law experiment

3.1 Aim

The aim of this experiment is to study Fitts' law and to compare the experimental results/data of youngsters and adults.

3.2 Objectives

- This experiment is to study the behavioral reflexes of different age groups of people.
- We try to compare and contrast the attention, perception and quicker reflexes of both groups.
- The results of this experiment can be used to create specialized user interface designs for target customers of different age groups.

3.3 Methodology/Data collection

3.3.1 PsyToolKit Website

Due to the COVID - 19 pandemic, it was not possible for us to conduct the experiment manually. Therefore, we opted for the Fitts' law demo version from a website called PsyToolkit; it is frequently used for academic studies, for student projects, and for teaching cognitive and personality psychology. We shared the link of this web page to different participants (friends and family) and explained them about the rules of this experiment.

3.3.2 Participants

The participants we chose are divided into 2 groups based on their age. The first group consists of youngsters (of age 20-23 years) and the second group comprises adults (of age 40-46 years). Due to the lockdown because of corona virus, we were not able to gather data from a larger group of participants. So, we contacted our friends and family to participate in the experiment, we were able to gather 7 youngsters and 7 adults to perform the experiment. Then,

we shared the PsyToolkit Fitts' law demo version's website link and explained them about the rules and instructions.

3.3.3 Direct instructions and rules given to the participants

- Sit in an isolated place with no distractions to perform the experiment.
- Perform the experiment on a computer or laptop connected with a mouse.
- Open the link, and click to start. You can read the rules of the experiment given on the screen as shown in the Fig.1 below. You can click the spacebar to start the experiment.
- Move the mouse cursor to the small yellow rectangle in the top left of the screen, and click the (left) mouse button once.
- Now a red rectangle of random size will appear, and you need to move the cursor as soon as you can into the red rectangle area (you do not need to click it).
- There are 20 trials.
- It is better to consider the first attempt as practice, collect the data from second attempt so that you will get a detailed understanding regarding the experiment.
- At the end of the experiment, after pressing space bar, you will see a graph (scatter plot), take a screenshot of it.
- If we press the space bar again, the detailed data of experiment is given in tabular form, please document these values and send them to us.
- Thank you for your participation.



Fig 1: Fitts' law experiment rules from PsyToolKit

3.4 Analyzing the data

3.4.1 About the data

The results from the Fitts' experiment are tabulated with 6 columns, consisting of parameters named as: x-position, y-position, size of the stimulus, distance of the stimulus, Fitts' law calculated time and experimental time. For each participant, there are 20 rows. To compare the data, we have mainly considered two parameters: size and distance. We picked out the smallest as well as largest stimulus in size and distance to make 2 separate tables which helps us to analyze the results. In each table, we compare the participant's Fitts' expected time with experimentally obtained time to calculate the error percentage from the data. From these tables, we can compare and analyze the time deviation of youngsters and adults.

3.4.2 Based on size of the stimulus

S.no	Age	Smallest size	Fitts' time	Exp. time	Error %	Largest size	Fitts' time	Exp. time	Error %
Youngsters(20-23 years)									
1	20	9	707	963	36.2%	100	249	90	-63.8%
2	23	6	761	1035	36.02%	100	314	470	49.6%
3	20	6	698	864	23.7%	99	227	52	-77%
4	20	12	655	900	37.4%	99	104	153	47.1%
5	20	9	517	506	-2.12%	99	519	745	43.5%
6	21	8	474	579	22.1%	91	424	411	-3.06%
7	20	27	415	602	45.06%	97	615	974	58.37%
Total			4227	5449	28.9%		2452	2895	18.06%
Adults(40-46 years)									
8	45	5	804	1203	49.6%	90	316	419	32.5%
9	42	19	570	1300	128%	97	379	513	35.35%
10	40	17	650	915	40.7%	92	197	498	152%
11	42	5	802	2000	149.3%	94	267	436	63.2%
12	46	5	584	2000	242.4%	94	206	602	192.2%
13	43	8	741	1226	65.4%	96	396	717	81.06%
14	46	22	498	2000	301.6%	97	394	1018	158.3%
Total			4649	10644	128.9%		2155	4203	95.03%

Table 1: Resultant table based on the size of stimulus with error percentage

In the above table, we have considered the smallest and largest size of stimulus for each participant and noted down the respective Fitts' time and experimental time. The error percentage is calculated using the formula:

$$\delta = \left| \frac{v_A - v_E}{v_E} \right| \cdot 100\%$$

δ = percent error
 v_A = actual value observed
 v_E = expected value

Here, actual value observed is the experimental time and expected value is the Fitts' time. After the calculation of error percentage for both teenagers and adults, we can see a huge contrast between the two groups; the youngsters are more accurate and faster when compared to the adults.

3.4.3 Based on distance of the stimulus

S.no	Age	Smallest Distance	Fitts time	Exp. time	Error %	Largest Distance	Fitts time	Exp. time	Error %
Youngsters (20-23 years)									
1	20	189	206	140	-32.03%	899	617	759	23%
2	23	196	391	788	101.5%	755	458	817	78.3%
3	20	238	227	52	-77.09%	887	615	974	58.3%
4	20	88	114	215	88.5%	732	502	539	73%
5	20	311	611	1050	71.8%	862	431	645	49.6%
6	21	327	383	653	70.4%	879	432	982	127%
7	20	158	278	451	62.2%	875	677	1142	68.6%
Total			2210	3349	51.5%		3732	5858	56.9%
Adults (40-46 years)									
8	45	191	319	834	161.4%	829	453	1300	186.9%
9	42	346	346	574	65.89%	726	404	931	130.4%
10	40	180	197	331	68.02%	682	524	823	57%
11	42	266	315	528	67.6%	723	580	937	61.5%
12	46	143	584	600	2.73%	662	393	913	132.3%
13	43	102	115	593	415%	842	581	1000	72.1%
14	46	347	498	600	20.4%	894	495	788	59.1%
Total			2374	4060	71.01%		3430	6692	95.1%

Table 2: Resultant table based on the distance of stimulus with error percentage

Similar to Table 1, in the above Table 2, we have considered the smallest and largest distance of stimulus, for each participant we have noted down the respective Fitts' time and experimental time. The error percentage is calculated using the same formula as mentioned in section 3.3.2. In this table too, we can see that the youngsters are much closer to the expected Fitts' time as compared to the adults.

3.5 Results and inferences

- From Table 1 and Table 2, avg. error percentages of youngsters and adults are as follows:
 - For smallest size of stimulus,
 - Youngsters = 28.9%
 - Adults = 128.9%
 - Youngsters are 100% more accurate than adults.
 - For largest size of stimulus,
 - Youngsters = 18.06%
 - Adults = 95.03%
 - Youngsters are 76.97% more accurate than adults.
 - For smallest distance stimulus
 - Youngsters = 51.5%
 - Adults = 71.01%
 - Youngsters are 19.51% more accurate than adults.
 - For largest distance stimulus
 - Youngsters = 56.9%
 - Adults = 95.1%
 - Youngsters are 38.2% more accurate than adults.
- Thus, from our experimental results, we can conclude that the youngsters' experimental time is more accurate to Fitts' law time as compared to the adults.
- This may be due to quicker reflexes of the teenagers.

- Another reason might be that many of the adults might not be regularly using computers but, the youngsters generally use computers on a daily basis.
- This activity requires attention and perception.
 - Attention: It is the ability to choose and concentrate on relevant stimuli. Attention is the cognitive process that makes it possible to position ourselves towards relevant stimuli and consequently respond to it. This cognitive ability is very important and is an essential function in our daily lives.
 - Perception: It is the ability to capture, process, and actively make sense of the information that our senses receive. This cognitive process allows people to take in information through their senses (sensation) and then utilize this information to respond and interact with the world.
- From this experiment, we can say that to take the best advantage of Fitts' law for both youngsters and adults, the user interface should be designed in such a way that the interactive buttons must be closer and the size must adjusted such that it is neither too small or too large.
- For any web page or website, finding out the exact target audience may give a clear picture about the user interface design.
- From our experiment, we can say that for the webpages designed for the adults, it is better to have bigger and more closely spaced buttons with clear indications for better user experience.
- In contrast to this, as youngsters have faster reflexes; we can have medium sized buttons, and convenient spacing. And, we must focus more on the color contrast and design of the page to attract them.

CHAPTER 4

Conclusion

- Fitts' Law is commonly used in human computer interaction to make designs for websites and applications, this helps to provide a user-friendly experience for the consumers.
- Knowingly or unknowingly, Fitts' Law is used by all of us in our daily life in the usage of Android devices, PCs, ATMs, and many more.
- We have tested the Fitts' law experiment against 2 age groups of people, that is, the youngsters and adults. And we can summarize our inferences as follows:
 - The youngsters have faster reflexes as compared to the adults.
 - The adults tend to respond more quickly for the closely spaced stimuli and larger stimuli.
- This experiment can be used to improve the user interface based on the following points:
 - Target audience plays a key role in the design of a website. So, it is important to point out who we are trying to attract so that we can provide a better user experience.
 - From our experiment, as we have concluded that adults tend to respond better when the stimuli is larger and closely spaced. We can incorporate this in the website by providing clear instructions with larger and closely spaced buttons for their comfort. Adults usually prefer a more elegant and minimalistic design look with a simple color palette.
 - The youngsters, on the other hand, are faster. Hence, the website can be with good spacing and medium sized buttons, based on their importance. However, they are usually attracted to brighter colors and beautiful website design, so we can focus more on color contrast to attract the youngsters.
- Finally, we can say that an ideal web page consists of properly spaced buttons, closely knit design, good sizing of the buttons, a comfortable color contrast which also keeps their target audience in mind.

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