

# Physicality and Usability Guidelines to Overcome the Interaction Complexities

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## Abstract

**Objectives:** To develop the physicality and usability guidelines to reduce the interaction complexities and the cognitive burden on the users. **Methods/Statistical Analysis:** The study is conducted on the kitchen appliances. Three case studies were conducted on different kitchen appliances. Forty to fifty participants were selected from different age group, qualification, and cities. The data were collected from the participant on the bases of pretest and posttest questionnaire and direct observation method. The study was divided into two phases i.e. formulation of guidelines and comparative analysis. The study I and study II were used for guideline formulation and study III provided a comparative analysis. The qualitative research paradigms were employed for data analysis. **Findings:** Based on the data analysis, the new guidelines were proposed and evaluated in terms of physicality principles and usability components. Subsequently, t-test was used to validate, evaluate, and compare the results against ISO and IEC. This research has showed that the proposed physicality and usability guidelines are helpful in overcoming interaction complexities, reducing cognitive burden, and saving time. **Application/Improvements:** The data analysis showed that the proposed guidelines will improve the user experience by 94% and 85% in the physicality and usability of the kitchen appliances, respectively. The proposed guidelines can be employed in improving the design of these appliances to overcome interaction complexities.

**Keywords:** Human Computer Interaction, Interaction Complexities, Kitchen Appliances, Physicality Component, Usability Component

## 1. Introduction

The world has become a globe of modern techniques and electronics. In the era of technology, kitchen appliances are taking their place in technical world<sup>1</sup>. Kitchen appliances are consequently contributing as a primarily social purpose<sup>2</sup>. Moreover, they are playing a paramount

role in mundane life. Due to technological enhancement, the look and feel of everything has been changed. Modern kitchen appliances with technological aspects are best example<sup>3</sup>. There are a huge number of domestic appliances that provide convenience in cooking and other kitchen related tasks. These types of kitchen appliances are frequently used in restaurants, hotels as well

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as homes<sup>4</sup>. Recent domestic appliances are incorporated with electronics and provide outstanding features such as reduction in cost, reliability, efficiency with the help of embedded sensors and microcontrollers<sup>5,6</sup>. The design of appliance has a great impact on its usage. Smart kitchen appliances are intelligent and provides touch interface. These appliances make life easier as well as provide convenience to the user<sup>1</sup>. User can give input by touching the surface of appliance. Due to less physical interaction, smart appliances increase cognitive burden on user<sup>6</sup>.

Physical kitchen appliances have turned their face into Tangible User Interface (TUI)<sup>7</sup>. TUI is a platform in which user collaborate with the system through physical controls. It focuses on designing the interaction with itself and exploits the richness of bodily movement<sup>8</sup>. Some of the kitchen appliances uses Embedded System (ES) or implanted appliances. ES is a device in which electrical and mechanical functions can be planted in terms of real time constrictions. ES are precise, specific, and indivisible while their parts are integrated with each other to provide features and concurrent functionalities<sup>9-12</sup>. The first interaction between user and the device takes place through their physical interface i.e. touch system, buttons, or sliders<sup>13</sup>. Physicality, the branch of Human Computer Interaction (HCI), is the next user interface breakthrough in which appliances with electrical and physical buttons have turned into embedded systems<sup>14</sup>. Physicality illustrates the consequences of features related to the physical interfaces and provides explanations regarding embodiment<sup>10-17</sup>. Physicality relates with the commitment and involvement of human and the system interface during interaction<sup>10,18</sup>. It revisited the bodily interaction with the help of mechanical and physical interface and provides intellect communication capabilities<sup>19</sup>. Usability, on the other hand, defines that how much an interactive system is simple, trouble free, effortless, and pleasant in use<sup>3</sup>. Physicality and Usability works side by side but developers mostly focus on usability and neglect physicality. Usability applies to all aspects of a product or a system with which users might interact<sup>9</sup>. The upcoming appliances

acquires fascinating design features not only in terms of their physical appearance like shape, buttons, size but also they provide embedded software digital interface like functions and menus that provides amusement to user<sup>15</sup>. The experimental and observational research paradigms were selected for conducting a comparative analysis of six different kitchen appliances.

Physical things are those which have some material existence and perceived through senses. Physicality is the characteristic of a physical thing which refers to items that that can be gripped. The researcher provides the intangible perceptive of physicality with cooperative design and finally concluded that physicality plays an important role in cooperative design. The researcher discussed two levels of physicality; first defined the type of work and the collective practice of collaborators. He carried out an experiment on student designers and asked them to design a system. The students developed a software interface. They highlighted that physicality is projected as in the ubiquitous strategies in the near future. The researcher concluded that physicality is an important factor that can be neglected in cooperative design. It has many other aspects that cannot be easily extracted through voice or touch<sup>20</sup>.

Some studies showed that it is obvious that embedded systems are playing the paramount role in routine life. During interaction, users are minute, intellectual and immediate responders. According to the research it is clear that embedded system developers are demanding to augment the complications for the users while the software developers are trying to diminish the complexity due to their design. In their research, the physicality principles have been described for each physical control. The researcher investigated the interaction intricacies in implanted system<sup>13</sup>. In another study the researchers recruited 16 users for assessments of two microwave cookers manufactured by the same company; one of them comprises of dial layout while other interface includes buttons. They presented the assumption that comprises of four components. The participants were well-versed about

the representative tasks. The performance of product conducted through a group of people rather than comparison between performances of individual users. The participants were also allowed to stop their task whenever they want and all their measurements would also be removed on their demand. They analyzed that the results were according to their predictions about hypothesis. But there were also some noteworthy differences such as time completion of a task with dial interface and button interface. A variety of errors also occurred in button interface. The reason of error is large number of same type of buttons made the users confused. The users who are young can perform the tasks efficiently due to their learning proficiency. It is also determined that generation gap also matters. Aged users spend more time than youngsters. It is also suggested that the complexity of interface include multiple factors, only buttons is not the cause of complexity<sup>21</sup>.

Embedded systems are going on increasing day by day. They investigated the complexities found in embedded systems and the main objective of the research was to develop a physicality framework to tame the complexities of embedded systems<sup>6</sup>. The physicality aspects were studied and highlighted that it can be neglected in mundane life devices. The ES developers are increasing complexities and physical interaction due to their small size and Embeddedness and in the result they create cognitive burden on user's mind. There are 23 numbers of participants that perform experiment on the given devices<sup>10</sup>.

The researchers introduce an intellectual cuisine supportive structure that facilitates consumer with collective, interdependent, automatic, and perceptive support for cooking. The structure enhances ordinary and familiar kitchen domestic devices with extensive assortments of perceptions. The interface of appliance was hooked and interdependent inwardly to assume the existing condition in the cuisine procedure and also offer elegant directions. The focus of the research is to provide the method in terms of dispensation and the interpretative abilities

required to direct a chef in the course of procedure<sup>22</sup>. The next sections provide a detailed description of all three user studies conducted in the course of this research.

## 2. User Study I

### 2.1 Introduction

The first experimental and observational study was planned with the objective to evaluate the physicality aspects and usability components of kitchen appliances. The study was conducted to inspect and observe that how much the user feel convenience while operating the appliances. The main focus of the study was to find the hurdles during interaction with the appliance. The study included analysis of the data collected by the user during performing desired tasks and filling of posttest questionnaire. The kitchen appliances selected for the evaluation were oven and toaster.

### 2.2 Design

A pre-test questionnaire included the consent of participants and their demographic details. Pre-test questionnaire includes name, occupation, age and gender of the participants. The tasks were normal to avoid the cognitive burden on user. A post-test questionnaire was designed based on four physicality principles (exposed state, hidden state, tangible transitions, and bounce back)<sup>13</sup>. It also included five usability components learnability, efficiency, memorability, error, and satisfaction<sup>23</sup>.

### 2.3 Participants and Procedure

Forty (40) participants were involved in this user study. All the participants were volunteers. The targeted users were segregated into two equally portions such that 50% male and 50% female. The study was primarily conducted at kitchen and wherever the users were available at their suitable positions. Participants were observed carefully while they are performing representative tasks. When the participants acknowledged about completion of tasks, they were presented with the post-test questionnaire.

## 2.4 Data Analysis

Four questions were based on physicality principles and rest of six includes concepts of usability components.

Likert-scale values evaluated against each physicality principle and usability component discussed in study according to the total number of users. Table 1 shows the

**Table 1.** Result analysis for toaster

S No	Questions	Toaster				
		Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
Physicality principles						
1	The Button is showing its internal function? This feature is helpful to operate the device?	3	3	6	17	11
2	The control offers feeling of bumps. Do you Think it is easy to rotate the dial?	0	1	4	16	19
3	The control returns back to its original state after some time. Do you think it is helpful to know the current status of device?	0	0	11	21	8
4	When dial is moving backward gradually by showing its progress it is easier to know the progress of device than digital display?	1	7	19	9	4
Usability components						
5	It is easy for you to accomplish basic task first time when you use the device?	5	5	6	21	3
6	Do you able to use the control quickly?	3	4	11	16	6
7	It is easy to remember how to use the device second time.	0	1	4	15	20
8	Do you feel the device the device is pleasant to use?	1	2	14	18	5
9	Have you faced any trouble while performing the task?	4	14	14	6	2
10	How easy it is for you to recover from them?	0	2	6	22	10

**Table 2.** Result analysis for oven

S No	Questions	Oven				
		Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
<b>Physicality Components</b>						
1	The button is showing its internal function? This feature is helpful to operate the device?	0	1	4	18	17
2	The control offers feeling of bumps. Do you Think it is easy to rotate the dial?	1	4	1	18	16
3	The control returns back to its original state after some time. Do you think it is helpful to know the current status of device?	0	1	3	25	11
4	When dial is moving backward gradually by showing its progress it is easier to know the progress of device than digital display?	5	5	13	10	7
<b>Usability Components</b>						
5	It is easy for you to accomplish basic task first time when you use the device?	1	3	11	17	8
6	Do you able to use the control quickly?	0	3	7	23	7
7	It is easy to remember how to use the device second time.	2	1	2	12	23
8	Do you feel the device the device is pleasant to use?	0	2	12	23	3
9	Have you faced any trouble while performing the task?	12	13	7	8	0
10	How easy it is for you to recover from them?	0	2	9	16	13

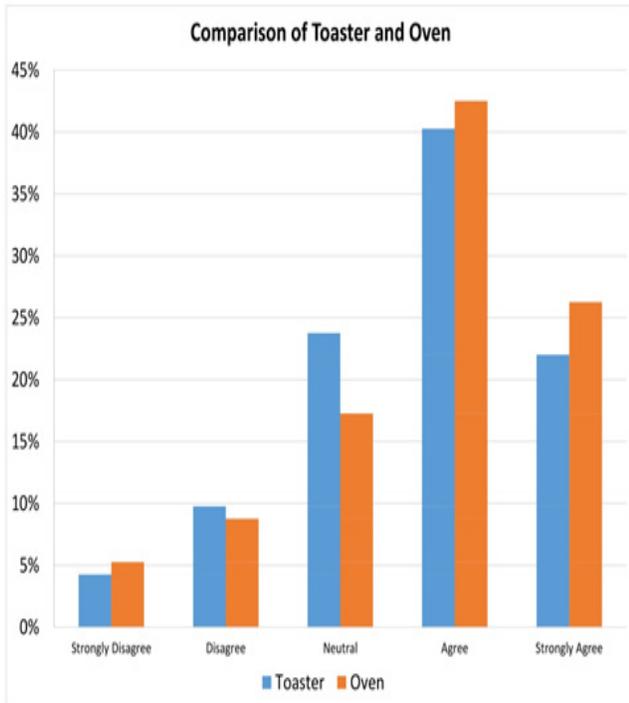


Figure 1. Comparison of toaster and oven.

summary of the questionnaire used in user study I. The study associated with the toaster showed that the participants selected “Agree” (43%) from Likert-scale in most of the cases. On the other hand 15% of the responses were “Neutral”, 28% for “Strongly Agree”, and 7% for “Strongly Disagree” and 7% for “Disagree”. In the analysis of oven, again some tasks assigned to user that was based on physicality principles and usability components. Later on, Likert-scale values analyzed according to each question. On the basis of these questions, average and percentage were calculated. The questions were same as asked for toaster but the representative tasks are different. The summary is shown in Table 2.

The results of oven showed that the participants selected “Agree” (45%) from Likert-scale in most of the cases. However, 10% of the responses were “Neutral”, 43% for Strongly Agree, 0% for Strongly Disagree and 2% for Disagree. Figure 1 provides the comparison on both appliances.

## 2.5 Comparison and Result

After compiling the results analysis of both appliances, the comparison between them has been made. The aver-

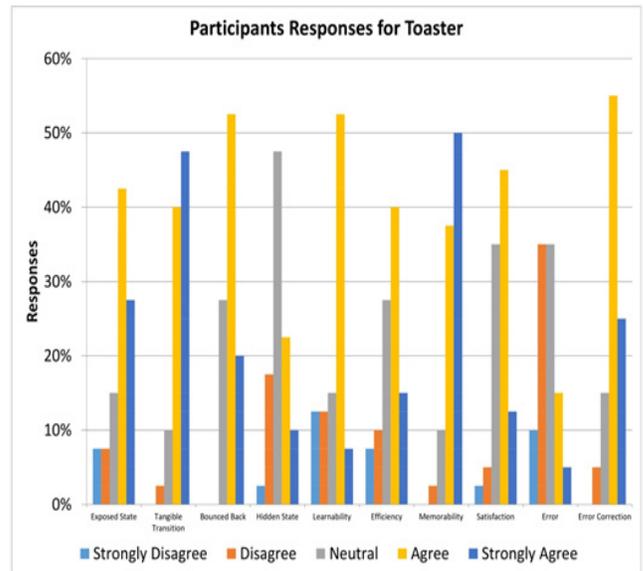


Figure 2. Responses of participants for each physicality principle and usability component for toaster.

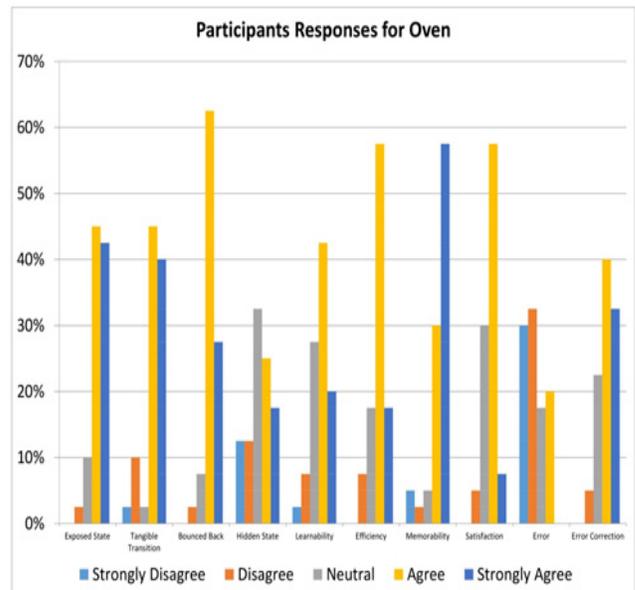


Figure 3. Responses of participants for each physicality principle and usability component for oven.

age results inclined towards “Agree” for oven. The results of toaster are slightly different from oven. Physicality principles and usability components evaluated for both the appliances. The results for toaster after the evaluation of physicality principles and usability tend towards “Agree”. The results are shown in Figure 2. The result for oven after the evaluation of physicality principles and usability also inclined towards “Agree” but it is slightly different from “Strongly Agree”. The results are shown in Figure 3.

## 2.6 Findings

Although the result analysis showed that appliances have been designed according to user’s approach but there is a gap between their satisfaction and usage level. The gap draws the user’s attention towards betterment and improvement in the appliance design.

## 2.7 Interaction Complexities with respect to Physicality Principles and Usability Components

There are some observations that were examined during the trial. These observations describe the feelings of user during interaction with appliance regarding each physicality principal and usability component. The remarks will play a paramount role towards the improvement of the upcoming appliances Table 3.

## 2.8 Proposed Guidelines

After the detailed discussion and result analysis, the new guidelines have been proposed in the light of observations. The guidelines are provided in Table 4.

**Table 3.** Interaction complexities (oven and toaster)

S No	Principle /Component	Interaction complexity
1	Exposed state	Trouble to on and off
2	Hidden state	Lack of user’s perception
3	Compliant Interaction	Time complexity
4	Tangible transition	Trouble in per-heat
5	Learnability	Complex structure
6	Learnability	Cognitive burden due to limited control
7	Efficiency	Easy for familiar while complicated for unfamiliar
8	Memorable	Unlabeled Controls
9	Satisfaction	Confusion during interaction

**Table 4.** Proposed guidelines (oven and toaster)

S No	Principle / Component	Proposed Guideline
1	Exposed state	There should be a proper button for on and off
2	Hidden state	The instruction on the device should be written properly
3	Compliant Interaction	The control must possess the property of exposing its time.
4	Tangible transition	There should be instruction for operating the device must be written around the control
5	Learnability	The structure of appliance should be self-illustrative
6	Learnability	The control on the appliance should be an adequate in order to overcome Cognitive burden.
7	Efficiency	The design of an appliance must be simple
8	Memorable	The control should be labeled
9	Satisfaction	The device should be rich by all means like numbers of labeled control, functionality and their structure

## 3. User Study II

### 3.1 Introduction

A comparative study was planned with the objective to appraise physicality principles and usability components on both appliances. The selected kitchen appliances are most commonly used in mundane life. The study was intended to compare the user's response regarding both appliances. The functionalities of the appliances were same but their structure was different. The main focus of

the study is to analyze that which appliance is better for user regarding their structure. The study includes analysis of data collected by the use during performing representative tasks and filling of post test questionnaires. The kitchen appliances used for evaluation are juicer blender and chopper.

### 3.2 Design

A pre-test questionnaire (Annex-I) includes the consent of participants and their demographic details. Pre-test questionnaire includes name, occupation, Age

and Gender of the participant. The tasks were normal to avoid the cognitive burden on user. A post-test questionnaire was designed based on four physicality principles (exposed state, hidden state, tangible transitions, bounce back) discussed by author in<sup>13</sup>. It also includes five usability components (learnability, efficiency, memorability, error and satisfaction) developed by Jakob Nielson<sup>29</sup>.

### 3.3 Participants and Procedure

There were forty participants included in this user study. All the participants were volunteers. The targeted users were segregated into two equally portions of male and female. None of the forty participants were familiar with physicality principles and usability components. The

study was mainly conducted in kitchen. However, some users were approached at their convenient locations. Participants observed through their facial expressions during performing tasks. Some participants captured from behind by their approval. When the participants acknowledged about completion of tasks, they were presented with the post-test questionnaire.

### 3.4 Data Analysis

Three questions were based on physicality principles and rest of five includes concepts of usability components. Likert-scale values evaluated against each physicality principle and usability component discussed in study according to the total number of users. Subsequently average and percentage can also be calculated in Table

**Table 5.** Result analysis for juicer blender

S No	Questions	Juicer blender			
		Principle/ component	Yes	Neutral	No
Physicality Principles					
1	Is the button showing its internal state?	Exposed state	10	17	13
2	Is there any control showed feeling of bumps? Is it helpful to operate the device?	Tangible transition	2	9	29
3	Whether the device showed its current sate when you press the button?	Bounced back	34	5	1
Usability Component					
4	Is it easy to use the device first time?	Learnability	13	14	3
5	Do you able to use the device quickly?	Efficiency	8	17	15
6	Is it pleasant to use?	Satisfaction	9	22	9
7	Will you remember how to use the device next time?	Memorable	37	3	0

Table 5 Continued

S No	Questions	Juicer blender			
		Principle/ component	Yes	Neutral	No
8	Have you faced any trouble while performing the tasks? If yes, how much it is easy for you to recover from them?	Error Control	21	12	7
9	Are you satisfied with the device?	Satisfaction	11	20	9

Table 6. Result analysis for chopper

S No	Questions	Chopper			
		Principle/ component	Yes	Neutral	No
Physicality Principles					
1	Is the button showing its internal state?	Exposed state	7	12	21
2	Is there any control showed feeling of bumps? Is it helpful to operate the device?	Tangible transition	20	16	4
3	Whether the device showed its current sate when you press the button?	Bounced back	36	2	2
Usability Component					
4	Is it easy to use the device first time?	Learnability	6	15	19
5	Do you able to use the device quickly?	Efficiency	5	12	23
6	Is it pleasant to use?	Satisfaction	7	20	13
7	Will you remember how to use the device next time?	Memorable	33	6	1
8	Have you faced any trouble while performing the tasks? If yes, how much it is easy for you to recover from them?	Error Control	29	8	3

5. The average results showed that 16.11 (40%) participants were agreed on “Yes” while 13.22 (33%) showed their responses as “Neutral”. There are only 10.67 (27%) of the participants exhibited “No” observations. The average values have also been calculated for further analysis of results.

As the study was comparative, for the analysis of appliance II again some tasks assigned to the user. Some of the tasks for appliance II were different from the appliance I. The tasks were of moderate nature while the questions were based on three physicality principles and five usability components. Later on, Likert-scale values have been analyzed according to each question. On the basis of these questions, average and percentage have been calculated. The responses according to questions are shown in Table 6. The average results showed that 16.44 (41%) participants were agreed on “Yes” while 13.44 (34%) showed their responses as “Neutral”. There are only 10.11 (25%) of the participants exhibited “No” observations.

### 3.5 Comparison and Analysis

After compiling the results analysis of both appliances, the comparison between them has been made. The average results inclined towards “Yes” for both appliances. The

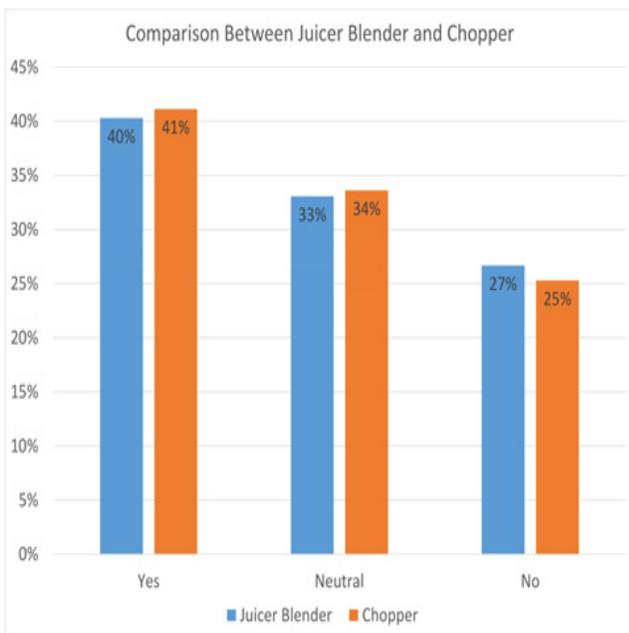


Figure 4. Comparison of juicer blender and chopper.

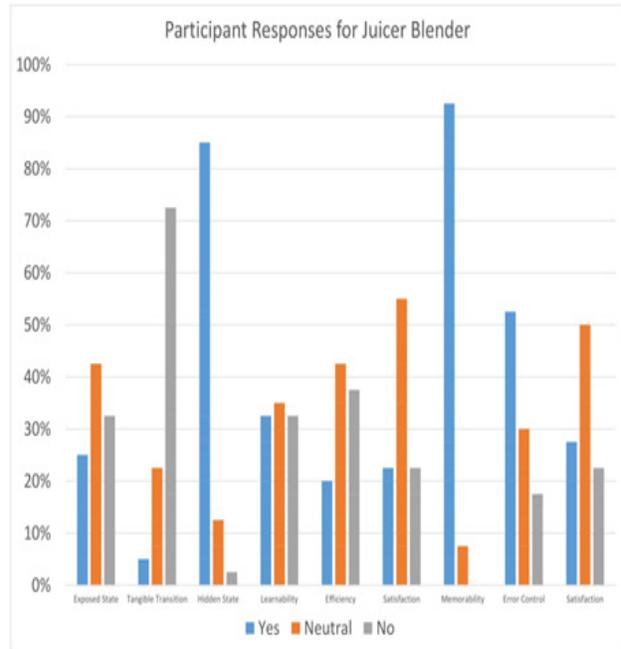


Figure 5. Responses of participants for each physicality principle and usability component for juicer blender.

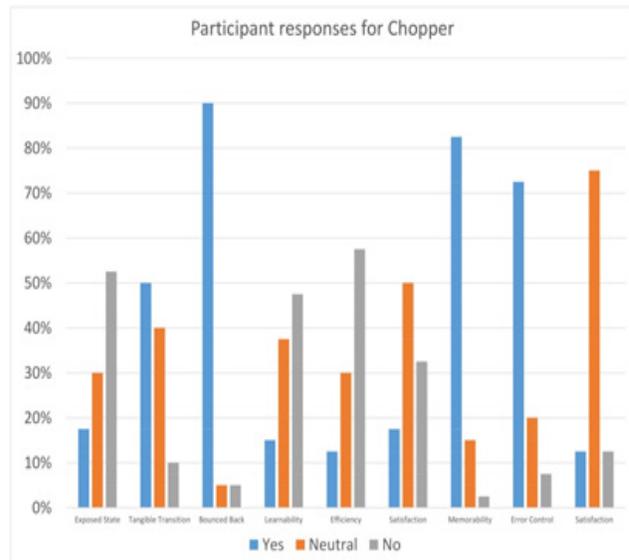


Figure 6. Responses of participants for each physicality principle and usability component for chopper

results of appliance II are slightly greater than appliance II. The combine results are depicted in Figure 4.

Physicality principles and usability components are evaluated for both appliances. There were Nine (09) questions in which four (04) were based on physicality

principles while rest of five (05) were based on usability components. The results showed that appliance I, after the evaluation of physicality principles and usability tends towards “Yes” as well as “Neutral”. The results are shown in Figure 5. The participant are either satisfied with the appliances or neutral with its overall functionalities. While there is small number of participant with negative impact of the physicality principles i.e., Tangible transition.

The results for appliance II after the evaluation of physicality principles and usability also inclined towards “Yes”. The results are shown in Figure 6.

### 3.6 Findings

The result analysis showed that both the appliances have been designed according to user’s approach but there is a

gap between their satisfaction and usage level. The appliance I consist of only one control while appliance II is rich in physicality principle than appliance I. Although appliance I is simple but there were some flaws in it while appliance II is complex but it still gather more positive results than appliance I. The gap draws the user’s attention towards betterment and improvement in the appliance design.

### 3.7 Interaction Complexities w.r.t Physicality Principle and Usability Components

The focus of the study is to evaluate the overall design and functionality of the appliances according to physicality principles and usability components. The study is experimental as well as observational. The issues regard-

**Table 7.** Interaction complexities for juicer blender and chopper

S No	Principle component	Proposed guidelines
1	Exposed State	There must have physicality aspects for on and off button.
2	Hidden Transition	There should be no hidden functionalities and controls in the appliance.
3	Tangible Transition	The surface of the dimmer should not be smooth.
4	Bounced Back	There should be a proper indication about the current status of the control on the appliance.
5	Learnability	The functionalities should be properly fabricated.
6	Learnability	The interface of the device should be comprehensible and accessible.
7	Efficiency	The design of the appliance must be simple.
8	Memorability	The controls should be labeled.
9	Satisfaction	The appliance should be straightforward.

ing appliances encountered during experiment have been analyzed. In the light of these issues the guidelines have been made. The improvements are required for designing appliance to reduce interaction complexities. The users get confused in a variety of ways. They felt cognitive burden, confusion, depression and trouble while performing initial tasks. The reason is lack of desired and unlabeled controls and limited instructions written on the device in some cases. However, there are some observations that examined during the trial Table 7.

### 3.8 Proposed Guidelines

After the detailed discussion and result analysis, some guidelines have been made. Some of the guidelines were similar while some of them were different according to observation. The proposed guideline is highlighted in Table 8 based on these findings.

## 4. User Study III

### 4.1 Introduction

A relative study was planned with the aim to evaluate the guidelines proposed in User Study I and User Study II. For this purpose two kitchen appliances have been selected. Design guidelines according to physicality principles and usability components have been applied on these appliances. The selected kitchen appliances are most commonly used in everyday life. The study was intended to compare the user's response regarding both appliances. The functionalities of the appliances were same but their structure was different. The main focus of the study is to analyze that which appliance is better for user regarding their structure. The study includes analysis of data collected by the user during performing representative tasks

**Table 8.** Proposed guidelines for juicer blender and chopper

S No	Principle component	Proposed guidelines
1	Exposed State	Complication while switching on/off.
2	Hidden Transition	Status of the appliance was unrecognizable.
3	Tangible Transition	Difficulty while rotating the dial.
4	Bounced Back	Improper indication while pressing the control.
5	Learnability	Complicated functionalities.
6	Learnability	Cognitive burden due to limited control.
7	Efficiency	Lack of user's performance.
8	Memorability	Unlabeled controls.
9	Satisfaction	Confusion during interaction.

and filling of post test questionnaires. The kitchen appliances used for evaluation are fryers.

## 4.2 Design

A pre-test questionnaire (Annex-I) includes the consent of participants and their demographic details. Pre-test questionnaire includes name, occupation, age and gender of the participant. The tasks were normal to avoid the cognitive burden on user. A post-test questionnaire was designed based on four physicality principles exposed state, compliant interaction, hidden state and tangible transition discussed by author in<sup>13</sup>. It also includes five usability components (learnability, efficiency, memorability, error and satisfaction) developed by Jakob Nielson<sup>29</sup>.

The questionnaire was designed on the basis of design guidelines that were proposed in previous studies.

## 4.3 Participants and Procedure

There were fifty participants included in this user study. All the participants were volunteers. The targeted users were segregated into two equally proportions of male and female. Two of the fifty participants were familiar with physicality principles and usability components.

## 4.4 Data Analysis

Four questions were based on physicality principles and rest of five includes concepts of usability components.

**Table 9.** Result analysis for appliance I (fryer)

S No	Questions	Appliance 1 (Fryer)		
		Principle / component	Yes	No
Physicality Principles				
1	Is there a button for on and off?	Exposed state	8	42
2	Is the dimmer showed its time while coming back to its original state?	Compliant interaction	29	21
3	Are the controls showed its functionality?	Hidden state	34	16
4	Is the dimmer easy to rotate?	Tangible transition	38	12
Usability Components				
5	Is the structure of appliance self-illustrative?	Learnability	11	39
6	Are the controls on appliance overcome cognitive burden while performing the tasks	Learnability	14	36

Table 9 Continued

S No	Questions	Appliance 1 (Fryer)		
		Principle / component	Yes	No
7	Is the design simple?	Efficiency	40	10
8	Is the appliance easy to use>	Efficiency	30	20
9	Are the controls labeled in order to remember next time?	Memorability	19	31
10	Are you satisfied with this device?	Satisfaction	7	43
11	Is it easy to recover from error if error occurs?	Error Control	29	21

Table 10. Result analysis for appliance II (fryer)

S No	Questions	Appliance II (Fryer)		
		Principle/ component	Yes	No
	Physicality Principles			
1	Is there a button for on and off?	Exposed state	8	42
2	Is the dimmer showed its time while coming back to its original state?	Compliant interaction	29	21
3	Are the controls showed its functionality?	Hidden state	34	16
4	Is the dimmer easy to rotate?	Tangible transition	38	12
	Usability Components			
5	Is the structure of appliance self-illustrative?	Learnability	11	39

Table 10 Continued

6	Are the controls on appliance overcome cognitive burden while performing the tasks	Learnability	14	36
7	Is the design simple?	Efficiency	40	10
8	Is the appliance easy to use>	Efficiency	30	20
9	Are the controls labeled in order to remember next time?	Memorability	19	31
10	Are you satisfied with this device?	Satisfaction	7	43
11	Is it easy to recover from error if error occurs?	Error Control	29	21

Likert-scale values evaluated against each physicality principle and usability component discussed in study according to the total number of users. Subsequently average and percentages are also calculated in Table 9. The average results showed that 23.55 (47%) of the participants were agreed on “Yes” while 26.45 (53%) showed their responses against “No”. This showed that the percentage of “No” responses against appliance I is greater than responses against “Yes”. As the study was comparative, for the analysis of appliance II again some tasks assigned to the user. Some of the tasks for appliance II were different from the appliance I. The tasks were of moderate nature while the questions were based on four physicality principles and five usability components. Later on, Likert-scale values have been analyzed according to each question. On the basis of these questions, average and percentage have been calculated in Table 10. A large number of populations showed their interest in this appliance. The average results showed that 44.45 (89%) of the participants were agreed on “Yes” while 5.55 only (11%) of the participants showed their responses against “No”.

#### 4.5 Comparison and Analysis

This study is based on the evaluation of physicality prin-

ciples and usability guidelines evaluation to overcome interaction complexities in kitchen appliances. However, the comparison has been made on the basis of guidelines. After compiling the results analysis of both appliances, finally the comparison between them has been made in

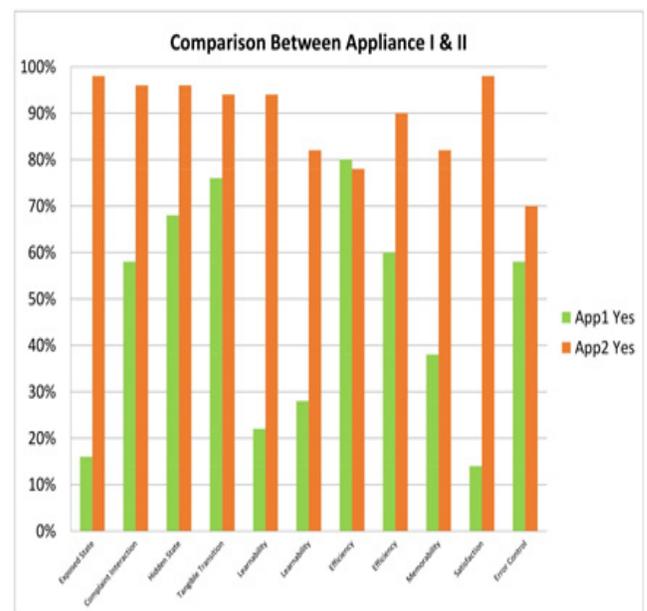


Figure 7. Comparison of appliance I (fryer) and appliance II (fryer).

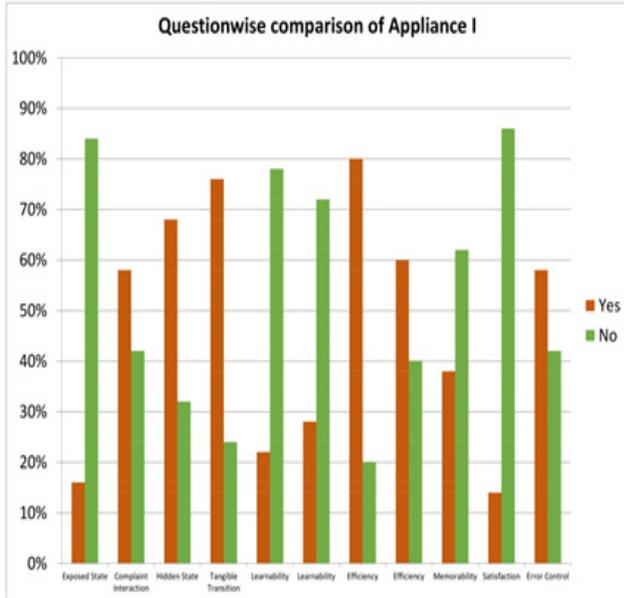


Figure 8. Responses of participants for each physicality principle and usability component for appliance I (fryer).

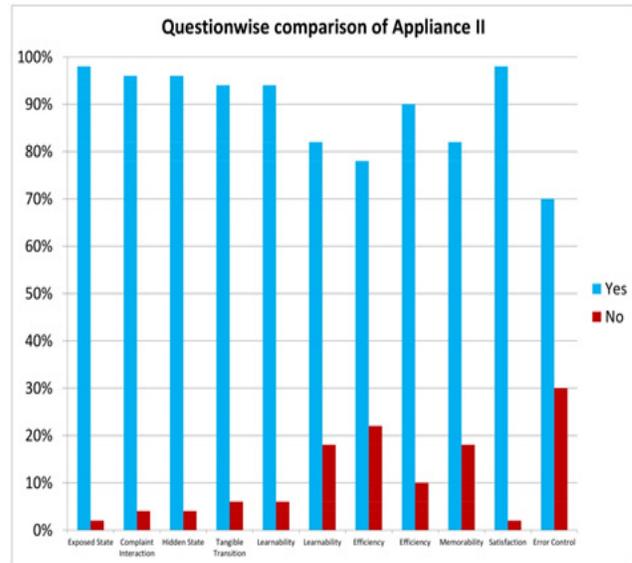


Figure 9. Responses of participants for each physicality Principle and usability component for appliance II (fryer).

Table 11. Result comparison for appliance I (fryer) and appliance II (fryer)

S No	Principle/Component	Appliance I (Fryer)		Appliance I (Fryer)	
		Yes	No	Yes	No
1	Exposed state	16%	84%	98%	2%
2	Compliant interaction	58%	42%	96%	4%
3	Hidden state	68%	32%	96%	4%
4	Tangible transition	76%	24%	94%	6%
5	Learnability	22%	78%	94%	6%
6	Learnability	28%	72%	82%	18%
7	Efficiency	80%	20%	78%	22%
8	Efficiency	60%	40%	90%	10%
9	Memorability	38%	62%	82%	18%
10	Satisfaction	14%	86%	98%	2%
11	Error Control	58%	42%	70%	30%

Figure 7. Results can be analyzed in detail which showed that the user's reactions were tending towards "Yes". There were eleven (11) questions in which four (04) of them was based on physicality principles while rest of seven (07) based on usability components. The evaluated results also compared, presented in Table 11. The results for appliance I according to physicality principle and usability components tend towards "No". Participant's Responses for Physicality Principles and Usability Components for Appliance I are shown in Figure 8. The results for appliance II after the evaluation of physicality principles and usability also inclined towards "Yes". The results are shown in Figure 9.

#### 4.6 Findings

Although the result analysis showed that both the appliances have been designed according to user's approach

but there is a gap between their satisfaction and usage level. The appliance I consist of only one control while appliance II is rich in physicality principle than appliance I. Although appliance I is simple but there were some flaws in it while appliance II is complex but it still gather more positive results than appliance I. The gap draws the user's attention towards betterment and improvement in the appliance design.

#### 4.7 Guidelines Evaluation

However, there are some observations that were examined during the trial. These observations describe the feelings of user during interaction with appliance regarding each physicality principle and usability component. The remarks will play a paramount role towards the improvement of the upcoming appliances. The average of "agreed" results also presented in Table xi. The observations were

**Table 12.** Proposed guidelines for fryer

S No	Principle/Component	Proposed Guideline	Agreed %
1	Exposed state	There must have physicality aspect for on and off button.	98%
2	Compliant interaction	The control must possess the property of exposing its time.	96%
3	Hidden state	The control must Showed their Functionality.	96%
4	Tangible transition	The surface of the dimmer should not be smooth.	94%
5	Learnability	The structure of appliance should be self-illustrative.	94%
6	Learnability	The control on the appliance should be adequate in order to overcome cognitive burden.	82%
7	Efficiency	The appliance should be simple to handle.	78%

Table 12 Continued

8	Efficiency	The appliance should be easy to use.	90%
9	Memorability	The control should be labeled.	82%
10	Satisfaction	The device should be rich by all means like labeled controls, exposed functionality and simple structure.	98%
11	Error Control	The appliance should be easy to use to handle in case of error.	70%

based on guidelines to evaluate that whether the proposed guidelines used for betterment or not Table 12.

#### 4.8 t-Test Analysis

The user responses have been statistically analyzed subsequently. Paired sample t-test was applied to the data using SPSS. Appliance II data has been assigned  $\mu_1$  and appliance I has been assigned  $\mu_2$ . The standard deviation has been calculated. The value of standard deviation was 14.3000 and value of t was derived as  $t = 4.849$ . The significance value was 0.001. According to value of t and significance value we reject null hypothesis and hence conclude that the appliance based on proposed guidelines is better than other appliance.

### 5. Proposed Design Rules

Based on the above analysis, this research proposed the following design principle that reduces the limitations of the appliances under the study.

- Appliance should have a proper “On” and “Off” button.
- The instructions on the appliance should be written properly.
- The controls and structure of appliance should be self-illustrative.
- The controls on the appliance should be adequate in order to overcome cognitive burden.
- The design of appliance must be simple so that every user can interact with it effortlessly.
- For the best use of appliance, all the controls should be labeled properly so that user can easily use it next time.
- The controls must possess the property of exposing its time properly.
- The instruction for operating the appliance must be written around the control.
- There should be a proper indication about the current status of the control on the appliance.
- The surface of the dimmer should not be smooth and easy to rotate.
- There should be no hidden functionalities and controls in the appliance.
- The interface of appliance should be straightforward.
- The functionalities should be properly fabricated.
- The interface of the appliance should be comprehensible and accessible.
- The control must possess the property of exposing its time.
- The controls must demonstrate their functionality.
- The appliance should be easy to use.

- The appliance should be rich by all means like labeled controls, exposed functionality and simple structure.
- The appliance should be easy to handle in case of error.

The design guidelines have been compared with the existing guidelines. The ISO standard for user interface is “ISO 14915 and IEC 61997, ISO 9241 (parts 12-17) and ISO/IEC 9126 (parts 2 and 3)” were focused for comparison. The “ISO 97.040.01 (ISO 3055.1985)” discussed kitchen equipments in general. They conferred the sizes of kitchen equipment and certain appliances. Other standards were also checked but they are beyond of scope. The following four proposed design guidelines have already been addressed in the above stated guidelines:

- The functionalities should be properly fabricated.
- The instructions on the appliance should be written properly.
- The appliance should be rich by all means like labeled controls, exposed functionality and simple structure.
- The interface of the appliance should be comprehensible and accessible.

## 6. Conclusion

The study was embarked to investigate the concept of physicality principles and usability components in designing kitchen appliances in order to overcome interaction complexities. Kitchen appliances are the most common appliances that everyone can use in their mundane life. The need of kitchen appliances is growing day by day. The increasing number of embedded kitchen appliances suggests that kitchen appliances are a gateway towards efficient, simple and easy work. These appliances can play a significant role in performing multiple tasks. The focus of the research is on the subject that how to overcome the interaction complexities in kitchen appliances. Kitchen appliances used in everyday life were evaluated to highlight the interaction complexities. Three user studies were conducted with different intentions mainly to understand

the user’s interaction with appliances and issues regarding these appliances. Kitchen is a place that can be organized in such a way that every task can be done effectively. This study is set out to investigate the complexities that user encountered during study.

In 1<sup>st</sup> user study, ordinary kitchen appliances were focused. Two kitchen appliances were evaluated according to physicality principles and usability components. The main focus of the study is to find the interaction complexities encountered during operating the appliance. In this study, four physicality principles and five usability components were evaluated. The study was observational as well as experimental. Both the appliances were independently evaluated according to physicality principles and usability components. The users had “neutral” remarks about efficiency, “strongly agree” for memorability and “disagree” for error component. The rest of the principles and components for both of the appliances have “agreed” responses. The overall average result results was “agree” as well as it was concluded that the appliance II “oven” has more positive responses against appliance I. The observations have been recorded and interaction complexities have been found during experiment. Finally, guidelines have been formulated to overcome the interaction complexities of kitchen appliances. Adaptation of these guidelines while designing kitchen appliances can significantly overcome interaction complexities as well as cognitive burden.

In 2<sup>nd</sup> user study, again two kitchen appliances were used for evaluation. The study was comparative, experimental as well as observational. Both of the kitchen appliances have some common features but different in terms of manifestation. Four physicality principles and five usability components have been evaluated. Responses were neutral in most of the cases while for some principles and components, responses were yes. Physicality and usability plays a vital role regarding user’s satisfaction. The overall result analysis showed that physicality and usability of appliance II is greater than appliance I. In this study, complexities have been uncovered and some guidelines have been in order to get rid of interaction intricacies. User study 3 has been conducted on

the behalf of user study 1 and two. This study was also comparative, experimental and observational. The guidelines formulated in user study 1 and 2 have been applied on user study 3. In this study, these guidelines have been evaluated. Two appliances have been used for assessment. Appliance II was according to physicality principles and usability components that were conceived from previous studies. Four physicality principles and five usability components have been addressed. In all of the cases the user responses for appliance II were highly ranked than appliance I. It has been concluded that users feel more satisfaction and convenience during interacting with appliance II that was based on formulated principles. Finally, guidelines have been modified and proposed. The user's responses have been statistically analyzed. Paired sample t-test was applied using SPSS tool. The standard deviation was calculated and significance value has been assessed. It was concluded in t-test that the appliance that was based on guidelines is highly motivated and useful than other appliance. However, the aim of this study was to propose the guidelines that will overcome complexities and cognitive burden from the user. Moreover, it will help in the design of kitchen appliances to provide convenience to the user. Further the proposed design guidelines were also compared with existing guidelines formed by ISO and IEC. It has been observed that four of the proposed guidelines have already been offered in existing guidelines. As the kitchen appliances are the most frequently used appliances in mundane life, therefore the proposed design guidelines will play a paramount role for designing kitchen appliances. The satisfaction level of the user can be elevated which can improve the physicality and usability of kitchen appliances in addition to get rid of cognitive burden.

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