An Affordance-Based Design Model for Interactive Screens to Trigger User Driven Actions in Self-Service Restaurants

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This thesis, An Affordance-Based Design Model for Interactive Screens to Trigger User Driven Actions in Self-Service Restaurants, presents an affordance-based design model for interactive screens in public self service restaurants (SSRs). As interactive displays become increasingly prevalent in public settings, designers and engineers face significant challenges in creating interfaces that effectively capture attention, communicate information, and influence user-driven actions in environments characterized by diverse user populations, cognitive overload, and varying contextual factors.

Drawing on affordance theory, human-computer interaction principles, and persuasive technology research, this study develops an introductory model that systematically addresses these challenges through the integration of visual, perceived, contextual, and interaction affordances. The model is then validated through three progressive experiments conducted at Flavoria, a university self-service restaurant in Turku, Finland. Each experiment explores different levels of communication for user engagement: passive communication through a rush meter display, active input via an animated polling interface, and two-way communication through an interactive food waste pledge system. Data collected from these experiments, including interaction metrics demonstrated the model's effectiveness in achieving engagement rates of 5-10% among diners, which represents a notable success rate for public interactive displays.

The primary contribution of this research is an introductory quantifiable model for measuring and optimizing affordances in interactive screen design. It provides designers and engineers with a systematic approach to creating more effective interactive displays. The model bridges theoretical concepts with practical design guidelines, offering both a mathematical model for affordance measurement and a structured application process for implementation. In addition, this research explores how to utilize this model for designing different levels of communication on interactive screens to support user-driven actions.

This research advances our understanding of how affordance-based design can be utilized for user engagement and trigger actions in public interactive screens, contributing to both the theoretical discourse on affordances and the practical side of human-computer interaction.

Keywords: affordance theory, human-computer interaction, interactive displays, public dining spaces, food sustainability, user engagement, design model, self service restaurants, mathematical model

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Abbreviations

SSR: Self-service restaurant

HCI: Human-Computer Interaction

ELM: Elaboration Likelihood Model

SDT: Self-Determination Theory

ABDMIS : Affordance-Based Design Model for Interactive Screens

1 Introduction

1.1 Background

In today's increasingly digitized world, interactive screens have become common fixtures in public spaces, serving as critical interfaces between digital information and human users. From shopping malls to transportation hubs, educational institutions to dining facilities, these screens represent a significant opportunity to communicate information, influence actions, and enhance user experiences in shared environments. However, despite their prevalence, many public interactive displays fail to achieve this intended purpose due to challenges in capturing attention of end users, communicating effectively, and encouraging interaction in complex, often distracting environments.

To solve for these challenges with interactive screens in public spaces, we utilize the concept of affordance. Affordance, originally introduced by ecological psychologist James Gibson [1] and later adapted to design contexts by Donald Norman [2], refer to the perceived and actual properties of objects that determine how they can be used, essentially communicating possibilities for action to potential users. In the context of interactive screens, affordances play a crucial role in signaling interactivity, guiding user behavior, and facilitating meaningful engagement.

1.2 Motivation

The motivation for this research stems from the recognition that existing approaches to interactive screen design often cut short of systematically accounting for the multifaceted nature of affordances in public contexts. While considerable research has explored affordances in controlled environments [3] or personal devices [4], public spaces present unique challenges due to their diverse user populations [5] [6], competing distractions [7], and varying contextual factors [8] [9]. These challenges are particularly evident in self-service restaurants (SSRs), where users' have limited time and the primary focus is often on food selection and consumption rather than screen engagement. For instance, our previous study conducted in the Flavoria SSR (where this thesis experiments are also conducted) investigated the use of an LED light system, employing familiar traffic-light color cues (green for correct, red for incorrect) to guide diners in using digital weighing scales accurately. However, contrary to expectations, this intervention did not consistently improve user compliance. This suggests that familiar, simple visual cues alone may be insufficient to capture attention and guide behavior effectively when users are multitasking or potentially unaware of the system's importance in such a complex environment [10]. This study highlighted the need for approaches that go beyond simple visual signifiers, considering factors like interaction design, context, and user engagement more deeply.

Realizing this need requires a nuanced understanding of how to design screens that effectively: 1) capture attention, 2) take user input, 3) communicate messages, and 4) influence actions in the specific context of dining environments.

This research addresses these challenges mentioned above by developing an introductory quantifiable model for affordance-based design of interactive screens in public spaces, with a specific focus on self-service restaurant environments. By integrating insights from affordance theory, human-computer interaction, and persuasive technology research, the model provides a systematic approach to designing screens that effectively engage users and influence behavior in complex public contexts.

1.3 Problem Statement

Despite the growing prevalence of interactive screens in public spaces [11], designers and engineers face challenges in creating interfaces that effectively engage users and achieve their intended purposes [12]. These challenges are particularly notable in environments like self-service restaurants (SSRs), where users' attention is primarily directed toward food consumption rather than screen engagement [13]. Four interconnected problems identified for the purpose of this research include 1) Attention Capture Challenge 2) User Input Facilitation Challenge 3) Communication Effectiveness Challenge and 4) Action Influence Challenge

1.3.1 Attention Capture Challenge

The challenge of attention capture presents a significant hurdle in busy public environments with numerous competing distractions [14]. Interactive screens often struggle to stand out amidst the visual and auditory noise, resulting in low engagement rates and limited impact [13] [14]. This problem is particularly pronounced in dining environments where social interactions and food-related activities naturally command users' attention, leaving little cognitive bandwidth for screen engagement. Research by Huang [14] demonstrated that even well-designed public displays frequently fail to attract initial attention in environments with competing stimuli, with many passersby not noticing or engaging with the displays.

1.3.2 User Input Facilitation Challenge

Once attention is captured, interactive displays face challenges in facilitating effective user input. Many public touchscreens suffer from usability issues including lack of tactile feedback, ambiguous input recognition, and accessibility barriers [15] [16]. Additionally, many public displays suffer from affordance communication issues, failing to effectively convey their interactive capabilities to potential users. This phenomenon, termed "display blindness" by Müller [17], occurs when users perceive screens as merely decorative or informational rather than interactive. Without clear signals that invite interaction, even well-designed screens may go unused, their potential for engagement unrealized.

1.3.3 Communication Effectiveness Challenge

Interactive displays in public spaces face challenges in effectively[1] communicating their intended messages to potential users [18]. This challenge extends beyond mere visibility to the comprehension of complex information, which often requires more than momentary attention to effectively convey meaning [19]. Research by Hinrichs [18] demonstrates that message complexity significantly impacts comprehension rates in public displays, with understanding decreasing as information density increases. Observational studies reveal that most passersby glance at public displays for less than a second, and only a small fraction engage for more than a few seconds, highlighting the critical challenge of communicating complex messages in such brief interactions [14]

[1] Communication effectiveness is how well a public display gets its message across to people, especially when they only look at it for a short time. It means the message is not just seen, but also quickly understood.

1.3.4 Action Influence Challenge

The primary objective of many interactive displays in public spaces is to influence user actions and behaviors; however, achieving actual behavior change remains a complex challenge. Research indicates significant gaps between the provision of information, user comprehension, and the translation into behavioral change. For instance, a meta-analysis of choice architecture interventions across behavioral domains found that while such interventions can promote behavior change, their effectiveness varies significantly depending on the technique and domain, with food choices being particularly responsive [20].

In dining environments, triggering user-driven actions with interactive screens encounters additional barriers, including competing priorities such as taste, cost, and convenience, as well as habitual behaviors and social norms. A systematic review highlighted that information alone is unlikely to change behavior due to structural factors like low mobility, time pressures, social dynamics, and economic restrictions [21].

Studies have demonstrated that even when diners understand and appreciate information, this does not necessarily lead to changed behavior. For example, interventions using menu-based 'nudges' have shown mixed results in encouraging sustainable food choices, indicating that additional motivational elements may be necessary to effect significant change [22].

1.4 Research Questions and Objectives

To address the four core challenges (Attention Capture, User Input Facilitation, Communication Effectiveness and Action Influence) identified in the problem statement for designing interactive screens to trigger user driven actions in public self-service restaurants, this research aims to develop an introductory quantifiable model to answer the following key questions:

RQ1: How insights from affordance theory, human-computer interaction, and persuasive technology are integrated to build an introductory quantifiable model for designing interactive screens to trigger user driven actions in public Self-Service dining environments?

RQ2: How this introductory model for designing interactive screens based on its affordances is utilized when designing different levels of communications (passive [2], active [3], and two-way [4]) on interactive public screens to support user-driven actions?

To address these questions, the research has the following objectives:

The primary objective of this research (RQ1) is to develop an introductory model for affordance-based design of interactive screens in public spaces, with specific application to self-service restaurant environments. This model aims to integrate theoretical insights with practical design guidelines, providing a structured approach that designers and engineers can apply to create more effective public displays. By systematically addressing the challenges identified in the problem statement, the model seeks to bridge the gap between affordance theory and practical implementation in real-world contexts.

The second objective (RQ2) is to validate the model through a series of experiments exploring different levels of communication and engagement in a real-world dining environment. These experiments will test the model's effectiveness across a range of communication modalities, from passive information displays to active input mechanisms to two-way communication systems. This validation process will provide empirical evidence for the model's utility and identify areas for refinement

[2]Passive communication refers to one-way information display that does not require user interaction (e.g., a static screen showing current wait times).

[3]Active communication includes system-initiated prompts designed to encourage interaction (e.g., a screen asking, "Are you planning to dine here today?" with touchable options).

[4]Two-way communication involves reciprocal interaction, where the system responds dynamically to user input (e.g., a screen that tailors follow-up content based on the interaction, and provides personalized feedback).

and extension.

1.5 Significance of the Research

This research makes several contributions to both theory and practice in the Human-Computer Interaction field:

From a theoretical perspective, this research applies affordance theory to the specific context of public interactive displays in SSRs, accounting for the challenges of shared, attention-competitive environments. While affordance theory has been widely applied to personal devices [4] and controlled environments [3], its use in public self-service restaurant screens addresses the unique challenges of this setting. By adapting and applying affordance concepts for public interactive screens, the research contributes to the theoretical understanding of affordances in human-computer interaction field.

The research also integrates insights from human-computer interaction and persuasive technology. This interdisciplinary approach provides a more holistic understanding of user engagement in public spaces than would be possible through a single theoretical lens. By synthesizing diverse perspectives, the research guides a richer theoretical foundation for understanding the complex dynamics of public interaction.

A particularly notable theoretical contribution is the development of an introductory quantifiable model for measuring affordances in interactive screen design. This advances our understanding of affordances towards a more systematic, measurable approach to affordance evaluation. By providing mathematical formulations for affordance strength and effectiveness, the research operationalizes theoretical propositions and facilitates the empirical validation of design principles.

From a practical perspective, the research provides designers and engineers with an introductory model for creating effective interactive screens for different levels of communication in public spaces, particularly in self-service restaurant environments. This model offers a systematic approach to address the challenges of public display design, guiding designers through the process of analyzing context, developing appropriate affordances, and evaluating outcomes. By providing this structured model, the research helps bridge the gap between theoretical understanding and practical application.

Beyond its immediate application in dining environments, the model has broader implications for the design of interactive systems in various public context. The principles and approaches developed in this research can be adapted to address the specific challenges of different public spaces, though it is beyond the scope of this research.

1.6 Thesis Structure Overview

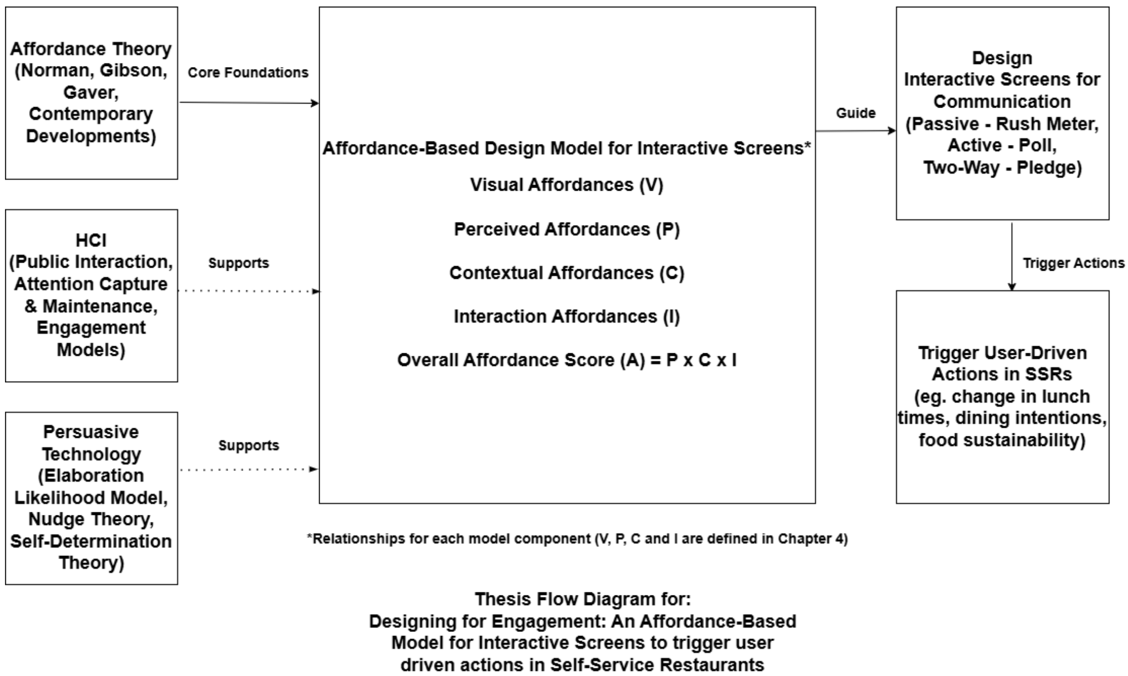

Figure 1.1: Thesis Flow Diagram

This thesis is organized into eight chapters:

This introductory chapter has provided background information, defined the research problem, outlined research questions and objectives, and established the significance of the research. It has set the stage for the detailed exploration of affordance-based design model for interactive screens in self-service restaurant environments that follows.

Chapter 2: Theoretical Background examines relevant literature on affordance theory, human-computer interaction in public spaces and persuasive technology. This review identifies gaps and opportunities in current understanding, providing the theoretical foundation for the development of the affordance-based design model. By synthesizing insights from multiple disciplines, the literature review establishes the conceptual foundations that guides the research. Key Learnings for each subsection in this Chapter (Chapter 2) are explicitly mentioned which are linked and later used in Chapter 4 for building the Affordance-Based Design Model.

Chapter 3: Methodology describes the research approach: methodology for model development, experimental design, data collection methods, and analysis approach used in the study. This chapter provides a detailed account of how the research was conducted, ensuring transparency and reproducibility. It explains the methods employed and justifies the methodological choices made throughout the research process.

Chapter 4: Affordance-Based Design Model presents the developed model, including its conceptual foundation, core components, mathematical formulation, application process, and validation approach. This chapter is the heart of the thesis, detailing the innovative model that represents the primary contribution of the research. It provides a comprehensive explanation of how the model works and how it can be applied in practice.

Chapter 5: Case Studies: Flavoria Experiments details the three experiments conducted at Flavoria, a SSR university restaurant, including their design rationale, implementation details, data collection, and findings. These case studies demonstrate the application of the model in a real-world setting and provide empirical evidence for its effectiveness. By exploring different levels of interaction, passive, active, and two-way, the experiments test the model's versatility and identify its strengths and limitations.

Chapter 6: Results and Analysis presents the results of the model application, including engagement metrics, affordance effectiveness analysis, and comparative analysis of different interaction modalities. This chapter provides a detailed examination of the empirical findings, using both quantitative and qualitative data to assess the model's performance. It identifies patterns and insights that emerge from the experimental implementations.

Chapter 7: Discussion interprets the results, evaluates the model's effectiveness, discusses design implications, theoretical contributions, practical applications, limitations, and generalizability. This chapter places the research findings in the broader context of affordance theory and interactive display design, exploring their significance and implications. It acknowledges the limitations of the research and suggests how these might be addressed in future work.

Chapter 8: Conclusion and Future Work summarizes the research contributions, answers the research questions and discusses implications. This final chapter brings the thesis to a close, reflecting on what has been accomplished.

The thesis also includes a comprehensive bibliography and appendix containing link to development code. These supplementary materials provide additional information for readers interested in the technical details of the research or seeking to replicate aspects of the study.

The thesis flow diagram Figure 1.1 represents a visual knowledge flow diagram of this thesis.

1.7 Declaration on Use of Generative AI

This work is the result of the author's own independent effort. Generative AI tools, namely, **ChatGPT,** was used to enhance the clarity, tone and coherence of the text. Additionally, **bolt.new** was used to assist with code generation. These tools were employed solely for language and code optimization; all research, development, programming, analysis, and content was developed and written by the author.

2 Theoretical Background

This chapter presents the theoretical foundations that underpin the development of our affordance-based design model for interactive screens in self-service restaurant environments. The chapter is structured around three complementary theoretical domains: affordance theory, human-computer interaction research, and persuasive technology theories. Each domain contributes essential insights that address aspects of the problems identified in Section 1.3. Key learnings are summarized at the end of each section, which are later linked to the model development in Chapter 4.

2.1 Affordance Theory and Its Evolution

The concept of affordance provides a powerful framework for understanding how users perceive and interact with objects in their environment. This section traces the evolution of affordance theory from its ecological psychology origins to its contemporary applications in digital interface design. We selected affordance theory as our primary theoretical foundation because it directly addresses the fundamental challenge of communicating action possibilities to users, a critical requirement for interactive screens that must engage users in attention-competitive environments. The evolution of this theory from Gibson [1] to Norman [2] to contemporary researchers (specifically, Gaver [23]) mirrors the progression from physical to digital interfaces, making it particularly relevant for understanding how users perceive and interact with screens in public spaces.

2.1.1 Gibson's Ecological Approach

The concept of affordance was first introduced by ecological psychologist James J. Gibson in his seminal work "The Ecological Approach to Visual Perception" [1]. Gibson defined affordances as action possibilities that exist in the environment in relation to an actor's capabilities. In his ecological framework, affordances are inherent properties of the environment that exist independently of perception but are relative to the actor. As Gibson [1] stated, "The affordances of the environment are what it offers the animal, what it provides or furnishes, either for good or ill."

Gibson's conceptualization of affordances was revolutionary in that it rejected the traditional dualism between the physical and mental worlds, instead proposing a direct relationship between perception and action [24] [25]. In this view, organisms directly perceive the functional significance of environmental features without requiring intermediate cognitive processing [1] [26]. This direct perception approach suggests that affordances are not constructed through mental representations but are directly available in the optical array as invariant combinations of properties.

For Gibson, affordances are binary, they either exist or they don't, and are determined by the relationship between environmental properties and the actor's physical capabilities [27]. For example, a surface affords walking if it is relatively flat, extended, rigid, and horizontal relative to the actor's ability to walk. Importantly, these affordances exist regardless of whether they are perceived or utilized.

Key Learnings for Model Development (KL-2.1.1)

KL-2.1.1.A - Relational Nature of Affordances: Gibson's fundamental insight that affordances emerge from the relationship between environmental properties and user capabilities reveals the need for our model to consider both the physical characteristics of interactive screens and the capabilities of diverse users. This relational perspective directly shapes our Form Effectiveness parameter (Table 4.1), which evaluates how well physical forms suggest their function to users with varying capabilities. Similarly, this insight drives our Adaptability parameter (Table 4.7), which assesses whether required physical actions align with users' capabilities in restaurant environments where attention and physical engagement may be limited.

KL-2.1.1.B - Direct Perception: Gibson's assertion that affordances can be directly perceived without cognitive mediation highlights the importance of creating visual elements that communicate their function immediately and intuitively. In self-service restaurant environments where users have limited time and attention, this insight guides our Form Effectiveness parameter (Table 4.1) by emphasizing that interactive elements must visually communicate their function through their shape, contour, and dimensionality without requiring conscious interpretation or prior learning. This parameter evaluates how effectively a design element's form directly suggests its interactive possibilities.

KL-2.1.1.C - Environmental Influence: Gibson's ecological approach emphasizes that affordances are fundamentally shaped by environmental characteristics, suggesting that our model must explicitly account for the physical environment in which interactions occur. This insight directly leads to our Physical Environment parameter (Table 4.5), which evaluates how environmental factors such as lighting conditions, viewing distance, ambient noise, and spatial layout influence affordance effectiveness in self-service restaurant settings. This parameter acknowledges that the same interactive screen may afford different actions depending on its physical placement and surrounding environmental conditions.

2.1.2 Norman's Perceived Affordances

Donald Norman [2] adapted Gibson's concept of affordances for design contexts in his influential book "The Design of Everyday Things." Norman shifted the focus from actual to perceived affordances, emphasizing the importance of how users interpret the possibilities for action based on their perception of objects. As Norman [2] explained, "When affordances are taken advantage of, the user knows what to do just by looking: no picture, label, or instruction needed."

Norman's adaptation introduced several important distinctions. First, he differentiated between perceived and actual affordances, highlighting that design should focus on what users perceive as possible, which may differ from what is actually possible. This distinction is particularly relevant for interactive screens, where many action possibilities are not inherently visible and must be communicated through design elements [28].

Second, Norman recognized that perception of affordances is influenced by cultural conventions, past experiences, and learned associations, not just physical capabilities. This acknowledgment of socio-cultural factors expanded the concept beyond Gibson's more ecological focus, making it more applicable to designed environments where cultural conventions play a significant role in shaping user expectations and behaviors [29].

In later work, Norman [30] introduced the concept of "signifiers", perceivable indicators that communicate appropriate behavior to users, to clarify his earlier discussion of perceived affordances. This refinement acknowledged that in many design contexts, particularly digital interfaces, designers must explicitly create signals that indicate possible actions rather than relying on inherent physical affordances.

Norman's work has been particularly influential in human-computer interaction (HCI) and interface design, where the concept of perceived affordances helps explain why some interfaces are intuitive while others require learning. For digital interfaces, where many physical constraints are absent, Norman's emphasis on perceived affordances and signifiers provides valuable guidance for communicating interaction possibilities to users [29].

Key Learnings for Model Development (KL-2.1.2)

KL-2.1.2.A - Perceived vs. Actual Affordances: Norman's crucial distinction between what is technically possible and what users perceive as possible reveals the need for our model to separate visual properties from how they are interpreted by users. This insight directly shapes our Recognizability parameter (Table 4.3), which evaluates how readily users can identify an element's function based on its appearance. In self-service restaurant environments where users may have limited technological literacy or attention, this parameter becomes essential for assessing whether interactive elements are not just visible but also comprehensible in terms of their function.

KL-2.1.2.B - Cultural and Experiential Influence: Norman's recognition that affordance perception is shaped by cultural conventions and past experiences highlights the need for our model to account for diverse user backgrounds and expectations. This insight directly informs our Consistency parameter (Table 4.3), which evaluates how well interactive elements align with established patterns and conventions that users may have encountered previously. In multicultural environments like university restaurants, this parameter becomes particularly important for assessing whether designs accommodate users with different cultural backgrounds, technological experiences, and mental models. This insight also influences our approach to Color Appropriateness (Table 4.1), recognizing that color interpretations vary across cultures.

KL-2.1.2.C - Signifiers as Communication: Norman's concept of signifiers as explicit indicators of appropriate behavior reveals the need for our model to evaluate how well interactive elements communicate their function through visual cues. This insight directly shapes our Iconography Effectiveness parameter (Table 4.1), which assesses how effectively symbols and icons communicate function across diverse user populations. Similarly, it informs our Feedback

Effectiveness parameter (Table 4.3), which evaluates how clearly the system communicates that an action is possible or has occurred. In self-service restaurant environments where interactions may be brief and attention limited, these parameters become essential for ensuring that users can quickly understand interaction possibilities and receive clear confirmation of their actions.

KL-2.1.2.D - Learnability: Norman's emphasis on how users learn to interpret affordances over time reveals the need for our model to address the learning curve associated with interactive elements. This insight directly shapes our Learnability parameter (Table 4.3), which evaluates how easily users can learn and remember how to interact with elements after initial exposure. In self-service restaurant environments where users may be repeat visitors, this parameter becomes essential for assessing whether designs support progressive learning and increasing interaction efficiency over time. This parameter acknowledges that perceived affordances are not static but evolve through user experience and learning, potentially becoming stronger and more intuitive with repeated exposure.

2.1.3 Gaver's Technology Affordances

William Gaver [23] further developed the concept of affordances specifically for technology design. Gaver introduced a framework that distinguishes between perceptible affordances (where the affordance is directly perceivable), hidden affordances (where the affordance exists but is not perceived), false affordances (where users perceive non-existent action possibilities), and correct rejection (where no affordance exists and none is perceived).

This categorization provides a useful framework for understanding interaction failures in public displays. For example, many touchscreens suffer from hidden affordances, they are touchable, but users don't perceive this possibility, leading to low engagement rates [31]. Conversely, some displays create false affordances through design elements that appear interactive but aren't, leading to user frustration and disengagement [31].

Gaver emphasized the sequential and nested nature of affordances in technological systems, where one affordance may lead to another in a sequence of actions. For example, a touchscreen button affords touching, which then affords the activation of a function. This sequential perspective is particularly relevant for interactive systems where users engage in multi-step interactions, as is often the case with public displays that guide users through information exploration or task completion.

Additionally, Gaver highlighted the social aspects of affordances, noting that technology can afford collaborative activities and that affordances can be socially constructed and shared. This social dimension is especially relevant for public interactive displays, where user behavior is influenced by social norms and the presence of others [7]. The visibility of interactions in public spaces creates both opportunities (such as the "honeypot effect" [32] where observing others interact encourages engagement) and challenges (such as social embarrassment that may inhibit interaction) [32] [7].

Key Learnings for Model Development (KL-2.1.3)

KL-2.1.3.A - Affordance Perceptibility Categories: Gaver's categorization of affordance types (perceptible, hidden, false) reveals the need for our model to explicitly evaluate how discoverable interactive elements are to users. This insight directly shapes our Discoverability parameter (Table 4.3), which assesses how easily users can identify which elements are interactive and which are not. In self-service restaurant environments where users may not be actively seeking interaction opportunities, this parameter becomes crucial for evaluating whether affordances are perceptible enough to overcome attention barriers. The parameter also addresses the need to avoid false affordances that could lead to user frustration when elements appear interactive but aren't, a common problem in public displays that our model must specifically address.

KL-2.1.3.B - Sequential and Nested Affordances: Gaver's concept of sequential and nested affordances, where one interaction leads to another in a chain, reveals the need for our model to consider how interactions unfold over time. This insight directly shapes our Layout Optimization parameter (Table 4.1), which evaluates how the spatial arrangement of elements guides users through intended interaction sequences.

KL-2.1.3.C - Social Dimension of Affordances: Gaver's recognition of the social aspects of affordances highlights the need for our model to account for how social context influences interaction. This insight directly shapes our Social Context parameter (Table 4.5), which evaluates how social presence affects affordance effectiveness. In self-service restaurant environments where users are typically surrounded by others, this parameter becomes crucial for assessing whether designs appropriately address social barriers (such as embarrassment) and leverage social facilitators (such as the honeypot effect). This parameter acknowledges that affordances in public spaces are not just individual perceptions but are socially constructed and influenced by the presence and behavior of others.

2.1.4 Contemporary Developments in Affordance Theory

Recent developments in affordance theory have expanded the concept in several important directions that are particularly relevant for interactive screen design in public spaces. Researchers like Kaptelinin and Nardi [29] have explored how digital technologies create new types of affordances that extend beyond physical action possibilities to include informational and social affordances. These expanded categories acknowledge that digital systems offer possibilities not just for physical manipulation but also for information access, communication, and social connection.

Scholars such as Costall [33] and Heft [27] have emphasized the socio-cultural dimensions of affordances, arguing that affordances are not just relationships between individuals and environments but are embedded in existing understanding, social practices and cultural contexts.

More recent work has explored how affordances change over time through learning, adaptation, and technological evolution [34]. This dynamic perspective acknowledges that affordances are not static properties but evolve as users become more familiar with systems and as technologies themselves change. For public displays that may be encountered repeatedly by the same users, this temporal dimension is important for understanding how engagement patterns may shift over time.

Researchers have also begun developing methods for measuring and modeling affordances, moving beyond qualitative descriptions to more systematic approaches [35] [28]. These quantitative approaches provide a foundation for the mathematical model developed in this research, offering methods for operationalizing affordance concepts in ways that can be empirically tested and systematically applied in design processes.

These developments have enriched affordance theory and expanded its applicability to complex technological environments, including public interactive displays. The evolution from Gibson's ecological affordances to contemporary socio-technical perspectives provides a robust theoretical foundation for understanding how users perceive and interact with screens in public spaces, particularly in attention-competitive environments like self-service restaurants.

Key Learnings for Model Development (KL-2.1.4)

KL-2.1.4.A - Expanded Affordance Types: Contemporary research expanding affordance types beyond physical to include informational and social dimensions reveals the need for our model to address multiple affordance categories. This insight directly shapes the overall structure of our model, which includes not just physical and visual affordances but also perceived, contextual, and interaction affordances. In self-service restaurant environments where information communication and social dynamics play crucial roles, this multi-dimensional approach becomes essential for evaluating the full range of affordances that influence user engagement. This expanded view informs our decision to create a comprehensive model that addresses visual, perceptual, contextual, and interaction dimensions rather than focusing solely on physical affordances.

KL-2.1.4.B - Socio-Cultural Embeddedness: Contemporary emphasis on the socio-cultural embeddedness of affordances reveals the need for our model to address cultural and social dimensions. This insight directly shapes our Consistency parameter (Table 4.3), which evaluates how well interactive elements align with cultural conventions and established patterns. It also influences our Social Context parameter (Table 4.5), which assesses how social context affects affordance effectiveness. This insight also directly shapes our Cultural Factors parameter (Table 4.5), which evaluates how cultural norms and expectations influence affordance effectiveness. In diverse university restaurant environments, these parameters become crucial for evaluating whether designs appropriately account for the cultural and social contexts in which interactions occur. This socio-cultural perspective acknowledges that affordances are not just physical or perceptual properties but are embedded in and shaped by social practices and cultural norms.

KL-2.1.4.C - Temporal Evolution: Contemporary research on how affordances evolve over time reveals the need for our model to address temporal dimensions of interaction. This insight directly shapes our Temporal Context parameter (Table 4.5), which evaluates how timing and repeated exposure influence affordance effectiveness. In restaurant environments where users may encounter displays repeatedly over time, this parameter becomes important for assessing whether designs remain effective beyond initial encounters and potentially leverage familiarity to deepen engagement over time. This temporal perspective acknowledges that affordances are not static properties but evolve through learning, adaptation, and changing contexts.

KL-2.1.4.D - Quantitative Measurement: Contemporary efforts to develop quantitative methods for measuring affordances reveal the need for our model to include systematic measurement approaches. This insight directly shapes our mathematical framework for affordance measurement (Section 4.3), which provides formulas for quantifying the strength of each affordance component and combining them into an overall measure of affordance effectiveness. This quantitative approach enables systematic evaluation and comparison of different design options, addressing a significant gap in existing research. By operationalizing theoretical concepts in measurable ways, our model supports evidence-based design decisions and systematic improvement of affordance effectiveness in self-service restaurant environments.

KL-2.1.4.E - Mental Model Alignment: Contemporary research on how affordances relate to users' mental models reveals the need for our model to address cognitive compatibility between design and user expectations. This insight directly shapes our Mental Model Alignment parameter (Table 4.3), which evaluates how well interactive elements match users' existing understanding of how similar systems work. In self-service restaurant environments where users bring diverse mental models from previous technological experiences, this parameter becomes crucial for assessing whether designs leverage familiar concepts and metaphors that align with users' existing cognitive frameworks. This parameter acknowledges that affordances are most effective when they build upon users' existing knowledge structures rather than requiring entirely new mental models.

2.2 Human-Computer Interaction in Public Spaces

Research on human-computer interaction in public spaces provides essential insights into the specific challenges and opportunities of designing interactive systems for public spaces. This section examines key findings from studies of public displays and installations, focusing on the unique barriers to engagement in public contexts and strategies for overcoming them. We selected this research domain because it directly addresses the contextual challenges identified in our problem statement, particularly the difficulties of capturing attention, facilitating user input, and communicating messages in public environments. Research on HCI in public spaces complements affordance theory by providing context-specific insights into how theoretical affordance principles manifest in real-world public settings, particularly those with competing distractions and diverse user populations.

We have organized our research for this section into three subsections: 1) Public Interaction, 2) Attention Capture and Maintenance, and 3) Engagement Models

2.2.1 Public Interaction

Human-computer interaction in public spaces presents unique challenges that distinguish it from interaction in private or controlled environments. Müller [13] identified five key challenges, display blindness, honeypot effect, competing distractions, diversity of users and transient interactions, that affect the design and effectiveness of public displays, many of which are particularly relevant in dining environments.

Display blindness represents a significant barrier to engagement with public screens. Users often ignore public displays, perceiving them as irrelevant or assuming they contain advertising content. This phenomenon, termed "display blindness" by Müller [17], is particularly pronounced in environments like restaurants where numerous visuals compete for attention and where users' primary focus is on food consumption rather than screen engagement.

Even when users notice interactive displays, they may exhibit interaction reluctance due to social embarrassment, fear of making mistakes in public, or uncertainty about the interaction process [7]. This reluctance is amplified in dining environments where social norms may discourage technology use during meals and where users may be concerned about disrupting their peers' experience. Overcoming this reluctance requires clear affordances that minimize the perceived risk of engagement and design approaches that make interaction socially acceptable. Users may avoid interaction due to evaluation apprehension, concerns about being negatively evaluated by onlookers, particularly when the interaction involves unfamiliar gestures or actions [7].

Public spaces typically contain numerous competing distractions that divert attention away from displays, making it difficult to capture and maintain user focus [14]. These competing distractions can include (but not limited to) info papers, screens, other users, ambient music, and architectural features. Effective display design must account for this attention competition, using visual strategies that help the display stand out without being disruptive or intrusive.

Public displays must accommodate diverse users with varying technological literacy, physical capabilities, and cultural backgrounds, making it challenging to design universally effective interfaces [32]. This diversity may range from tech-savvy to less technologically oriented users, and may include international users with different cultural expectations and language proficiencies. Designing for this diversity requires interfaces that are intuitive across different user groups and that minimize reliance on specific cultural knowledge or technical expertise.

Unlike personal devices, public displays typically involve brief, transient interactions rather than sustained engagement, limiting the complexity of possible interactions [36]. This transience is amplified where users' primary activity is on natural instincts, with display interaction being secondary and often limited to brief moments between other activities. Effective design must account for this transience, creating interfaces that can deliver value through brief interactions and that don't require extended attention or complex interaction sequences.

These challenges highlight the need for specialized design approaches that account for the unique characteristics of public interaction contexts, particularly in dining environments. Traditional HCI principles developed for desktop or mobile interfaces may not adequately address these challenges, necessitating a model specifically tailored to public display environments.

Key Learnings for Model Development (KL-2.2.1)

KL-2.2.1.A - Display Blindness: The phenomenon of display blindness, where users fail to notice public displays, reveals the need for our model to address visual salience and attention capture. This insight directly shapes our Contrast Ratio parameter (Table 4.1), which evaluates how effectively the display stands out from its surroundings. It also influences our Animation Effectiveness parameter (Table 4.1), which assesses how movement and change are used to attract attention. In restaurant environments where numerous visual elements compete for attention, these parameters become essential for evaluating whether displays can overcome display blindness and capture initial awareness, the necessary first step for any interaction.

KL-2.2.1.B - Interaction Reluctance: The phenomenon of interaction reluctance due to social factors and uncertainty reveals the need for our model to address both the clarity of interaction possibilities and the social acceptability of required actions. This insight directly shapes our Discoverability parameter (Table 4.3), which evaluates how clearly interactive elements are identified as such, reducing uncertainty about what can be interacted with. It also informs our Adaptability parameter (Table 4.7), which assesses whether required physical actions are socially acceptable and comfortable to perform in public settings. In restaurant environments where social norms may discourage certain behaviors, these parameters become essential for evaluating whether designs minimize the social barriers that often prevent users from acting on perceived affordances.

KL-2.2.1.C: Social Dynamics: The dual role of social presence as both barrier and facilitator reveals the need for our model to explicitly account for how social context influences interaction. This insight directly shapes our Social Context parameter (Table 4.5), which evaluates how social factors affect affordance effectiveness. This parameter assesses whether designs appropriately address social barriers (such as embarrassment and evaluation apprehension) while leveraging social facilitators (such as the honeypot effect). In restaurant environments where users are typically surrounded by others, this parameter becomes crucial for evaluating whether designs create socially acceptable interaction opportunities and potentially transform social presence from a barrier to an engagement catalyst.

KL-2.2.1.D - Competing Distractions: The challenge of competing distractions in public environments reveals the need for our model to address how displays compete for attention and align with users' primary activities. This insight directly shapes our Task Context parameter (Table 4.5), which evaluates how well the display function relates to users' primary tasks and goals. This insight also directly shapes our User State parameter (Table 4.5), which evaluates how factors such as time pressure, cognitive load, and emotional state influence affordance effectiveness In restaurant environments where users' primary focus is on dining and socializing, this parameter becomes essential for assessing whether the display complements rather than competes with these activities. This parameter acknowledges that affordances are more effective when they align with users' existing goals and activities rather than requiring users to shift their attention entirely.

KL-2.2.1.E - User Diversity - The need to accommodate diverse users with varying capabilities and backgrounds reveals the requirement for our model to address universal design principles. This insight directly shapes our Size Optimization parameter (Table 4.1), which evaluates whether elements are appropriately sized for users with different visual capabilities and viewing distances. It also informs our Iconography Clarity parameter (Table 4.1), which assesses whether visual symbols are comprehensible across different cultural backgrounds and literacy levels. In diverse university restaurant environments, these parameters become crucial for evaluating whether designs are accessible and meaningful to the full range of potential users.

KL-2.2.1.F - Transient Interaction: The brief, transient nature of public interactions reveals the need for our model to address immediate comprehension and cognitive efficiency. This insight directly shapes our Response Time parameter (Table 4.7), which evaluates how mentally demanding interactions are. In restaurant environments where attention may be limited to brief moments, this parameter becomes essential for assessing whether designs minimize unnecessary cognitive load and enable quick, intuitive interactions. This parameter acknowledges that affordances in public spaces must be immediately effective without requiring extended learning or complex mental processing.

2.2.2 Attention Capture and Maintenance

Capturing and maintaining attention is a critical challenge for public interactive displays, particularly in attention-competitive environments like self-service restaurants. Research in this area has identified six key factors, visual saliance, novel elements, relevance, revealing information gradually, user proximity zones and peripheral awareness, that influence attention in public contexts, providing valuable guidance for display design.

Visual Salience: Visual salience plays a crucial role in capturing initial attention. Features such as movement, contrast, size, and color can increase the visual salience of displays, helping them stand out in visually complex environments [11]. In contexts where numerous visual elements compete for attention, strategic use of these salience features can help displays overcome display blindness and capture users' peripheral awareness. However, this must be balanced with environmental fit, as displays that are too visually dominant may be perceived as disruptive or inappropriate.

Novel Elements: Novel elements can capture attention by violating expectations and triggering orienting responses [13] [37]. This novelty effect can be particularly effective in environments where users may visit repeatedly and become habituated to standard elements. Periodically changing display content or introducing novel interactive elements can leverage this effect, though the effectiveness of novelty typically diminishes over time as users become familiar with the display.

Relevance: Displays showing content relevant to users' current goals, interests, or context are more likely to capture and maintain attention [14]. Content that connects to users' immediate concerns or interests is more likely to overcome attention competition from other environmental stimuli [38].

Revealing information gradually: Revealing information gradually can maintain interest and encourage continued engagement [36]. This progressive disclosure approach aligns well with the transient nature of public interaction, allowing users to gain value from brief attention while incentivizing longer engagement through the promise of additional information or functionality. As an example, this might involve displays that show high-level information at a glance but reveal more detailed content as users approach or interact.

User proximity zones: Designing for different levels of engagement based on user proximity (e.g., ambient, implicit, subtle, and explicit interaction zones) can help transition users from awareness to engagement [39]. This zoned approach acknowledges that user engagement exists on a continuum rather than as a binary state, allowing displays to provide value even to users who don't directly interact. As an example, this might involve displays that function as ambient information sources from a distance but offer interactive capabilities to users who approach more closely.

Peripheral Awareness: Displays that support peripheral awareness allow users to monitor information without requiring direct attention, potentially leading to more sustained engagement over time [40]. Displays designed for peripheral awareness can provide value without demanding attention, allowing users to absorb information while primarily engaged in other activities. Further research by Huang [14] found that the average attention time for public displays is extremely brief, often just a few seconds, highlighting the importance of designing for immediate comprehension and rapid engagement. This finding underscores the need for clear affordances that quickly communicate both content relevance and interaction possibilities, particularly in dining environments where attention may be even more limited than in other public contexts.

Key Learnings for Model Development (KL-2.2.2)

KL-2.2.2.A - Visual Salience Factors: Research identifying specific visual factors that capture attention (movement, contrast, size, color) reveals the need for our model to explicitly address these elements. This insight directly shapes multiple parameters in our Visual Affordances component: Color Appropriateness (Table 4.1) evaluates how effectively color is used to attract attention and indicate interactivity; Size Optimization (Table 4.1) assesses whether elements are appropriately sized to capture attention while remaining usable; Contrast Ratio (Table 4.1) measures visual distinction from surroundings; and Animation Effectiveness (Table 4.1) evaluates how movement is used to draw attention and suggest interaction. In restaurant environments where numerous visual elements compete for attention, these parameters become essential for evaluating whether displays can effectively capture initial awareness, the necessary first step for any interaction.

KL-2.2.2.B - Novelty Effect: The attention-capturing effect of novel or unexpected elements reveals the need for our model to address temporal aspects of attention. This insight directly shapes our Animation Effectiveness parameter (Table 4.1), which evaluates how movement and change are used to attract attention. It also influences our Temporal Factors parameter (Table 4.5), which considers how repeated exposure affects attention and engagement over time. In restaurant environments where users may visit repeatedly, these parameters become important for assessing whether designs can maintain effectiveness beyond initial encounters, potentially through elements that change or introduce novelty over time.

KL-2.2.2.C - Content Relevance: The importance of content relevance to users' goals and interests reveals the need for our model to address contextual alignment. This insight directly shapes our Task Context parameter (Table 4.5), which evaluates how well display function relates to users' primary tasks and interests. It also influences our Recognizability parameter (Table 4.3), which assesses how quickly users can identify content as relevant to their needs. In restaurant environments where users have specific goals and interests related to dining, these parameters become crucial for evaluating whether displays offer content that users perceive as worth their limited attention.

KL-2.2.2.D - Proximity Zones: The concept of different engagement zones based on user proximity reveals the need for our model to address spatial relationships between users and displays. This insight directly shapes our Physical Environment parameter (Table 4.5), which evaluates how environmental factors including viewing distance affect affordance effectiveness. In restaurant environments where users may encounter displays from varying distances as they move through the space, this parameter becomes important for assessing whether designs appropriately adapt to different proximity zones and create a coherent engagement journey as users approach or pass by.

KL-2.2.2.E - Brief Attention Span: The finding that attention to public displays is typically very brief reveals the need for our model to prioritize immediate comprehension. This insight directly shapes our Recognizability parameter (Table 4.3), which evaluates how quickly users can understand an element's function based on its appearance. It also influences our Discoverability parameter (Table 4.3), which assesses how readily users can identify interactive elements. In restaurant environments where attention may be limited to just a few seconds, these parameters become crucial for evaluating whether designs can effectively communicate their purpose and interaction possibilities within extremely brief attention windows.

2.2.3 Engagement Models

Several models have been developed to conceptualize engagement with public interactive displays, providing frameworks for understanding how users transition from awareness to interaction. The four models we will discuss (audience funnel, four phases of interaction, engagement bridge and social learning model) were chosen based on their relevance to our context of engagement in public spaces and offer valuable insights for designing displays that effectively guide users through the engagement process.

Audience funnel: The "audience funnel" model proposed by Michelis and Müller

[13] describes engagement as a series of phases: passing by, viewing and reacting, subtle interaction, direct interaction, multiple interactions, and follow-up actions. This model highlights how users transition from awareness to engagement and identifies potential drop-off points where users may disengage. This model suggests the importance of designing for each phase of the funnel, with particular attention to the critical transition from viewing to initial interaction, which often represents the most significant engagement barrier.

Four phases of interaction: Vogel and Balakrishnan [36] described "four phases of interaction" with public displays: ambient display [1], implicit interaction [2], subtle interaction [3], and personal interaction [4]. Each phase corresponds to different user distances from the display and involves different types of content and interaction techniques. This proximity-based model is particularly relevant in environments where users may encounter displays from varying distances as they move through the space. Designing for these different proximity zones can create a more fluid engagement experience that accommodates the movement patterns typical in dining environments.

Engagement Bridge: Brignull and Rogers [7] introduced the concept of the "engagement bridge," which describes how users move from peripheral awareness to focal awareness to direct interaction. They identified the transition from awareness to interaction as a critical threshold that many users fail to cross, often due to social barriers or unclear affordances. In addition, error experiences significantly impact users' willingness to continue engagement with public displays, making error toler-

[1] Ambient Displays: Displays that provide information in the periphery of a user's attention, which can be easily ignored but remain available for glancing.

[2] Implicit Interactions: Interactions where the user is not explicitly directing input at the system, but the system responds to user presence or behavior.

[3] Subtle Interaction: The system begins to visibly react to the user's presence in a way that suggests interactivity, without demanding it.

[4] Personal Interaction: A direct and intentional interaction with the system, usually requiring explicit input like touch.

ance a critical factor in maintaining interaction momentum. Effective design must create clear crossing points that help users overcome this threshold, such as explicit calls to action or interaction opportunities that align with natural pauses in the dining experience.

Social learning model: Brignull & Rogers [7] expanded on the honeypot effect, developing a model that explains how observing others interact with a display influences potential users' willingness to engage, creating a cascading effect of increasing engagement. This "social learning model" is particularly relevant in environments where users are in close proximity and can readily observe others' interactions. Display placement that maximizes the visibility of interactions can leverage this effect, potentially transforming social presence from a barrier to a facilitator of engagement.

These models provide valuable understanding on how users engage with public displays and identify critical points where design interventions can increase engagement. They highlight the importance of designing not just for the interaction itself but for the entire engagement journey, from initial awareness to sustained interaction.

Key Learnings for Model Development (KL-2.2.3)

KL-2.2.3.A - Proximity-Based Phases: The concept of different interaction phases based on user proximity reveals the need for our model to address spatial relationships between users and displays. This insight directly shapes our Physical Environment parameter (Table 4.5), which evaluates how environmental factors including viewing distance affect affordance effectiveness. In restaurant environments where users may encounter displays from varying distances as they move through the space, this parameter becomes important for assessing whether designs appropriately adapt to different proximity zones and create a coherent engagement journey as users approach or pass by. This parameter acknowledges that affordances should change based on user proximity, with different design strategies for distant, mid-range, and close interactions.

KL-2.2.3.B - Engagement Threshold: The identification of a critical threshold between awareness and interaction (from the "Engagement Bridge" model) reveals the need for our model to address transition barriers. This insight directly shapes our Discoverability parameter (Table 4.3), which evaluates how clearly interactive elements are identified as such, reducing uncertainty about what can be interacted with. It also influences our Adaptability parameter (Table 4.7), which assesses whether required physical actions are socially acceptable and comfortable to perform in public settings. Furthermore, research on engagement thresholds reveals the need for our model to address the appropriate level of interaction complexity for different contexts. This insight directly shapes our Interaction Complexity parameter (Table 4.7), which evaluates how well the system balances simplicity with functionality. In restaurant environments where social and cognitive barriers may prevent users from crossing the engagement threshold, these parameters become crucial for evaluating whether designs create clear "crossing points" that help users transition from awareness to interaction.

KL-2.2.3.C - Honeypot Effect: The model of how observing others interact influences engagement reveals the need for our model to address social learning and influence. This insight directly shapes our Social Context parameter (Table 4.5), which evaluates how social factors affect affordance effectiveness, including the potential for positive social influence. In restaurant environments where users are in close proximity and can readily observe others' interactions, this parameter becomes important for assessing whether designs effectively leverage the honeypot effect to encourage engagement. This parameter acknowledges that affordances in public spaces are not just individual perceptions but are socially influenced and can benefit from designs that make interactions visible to others.

KL-2.2.3.D - Error Tolerance: Research on interaction barriers in public displays reveals the need for our model to address error prevention and recovery. This insight directly shapes our Error Tolerance parameter (Table 4.7), which evaluates how well the system prevents, detects, and helps users recover from errors. In restaurant environments where interactions may be hurried or distracted, this parameter becomes essential for assessing whether designs minimize error potential and provide clear paths to recovery when errors occur.

2.3 Persuasive Technology Theories to Influence Engagement

Persuasive technology[5] research provides valuable insights into how interactive systems can influence user behavior and decision-making. This section examines key theories from this field, specifically, Elaboration Likelihood Model (ELM), Nudge Theory and Self-Determination Theory (SDT), focusing on their applications to communication in public contexts. We selected persuasive technology as our third theoretical domain because it directly addresses the "Action Influence" challenge identified in our problem statement in Section 1.3. While affordance theory helps us understand how to communicate action possibilities and public interaction research helps us overcome contextual barriers, persuasive technology research provides specific strategies for translating awareness and understanding into actual behavior change.

[5] Persuasive technology: any interactive computing system designed to change people's attitudes or behaviors. [41]

2.3.1 Elaboration Likelihood Model (ELM)

The Elaboration Likelihood Model (ELM), developed by Petty and Cacioppo [42], is a dual-process theory of persuasion that explains how people process persuasive messages through two routes: the central route and the peripheral route. The central route involves careful, thoughtful consideration of message arguments and is engaged when motivation and ability to process information are high. Persuasion through this route leads to stronger, more enduring attitude change but requires significant cognitive effort. The peripheral route, in contrast, relies on peripheral cues such as source credibility, message presentation, or emotional appeals rather than carefully evaluating arguments. This route leads to more temporary attitude change but requires less cognitive effort.

The ELM has important implications for designing persuasive interactive displays. Displays intended for brief interactions may be more effective using peripheral route strategies [41], given the limited attention and cognitive resources typically available during dining experiences. This might involve visually appealing designs, credible sources, or emotional appeals rather than detailed arguments. However, for users who have more time and interest, perhaps while waiting for food or companions, central route processing might be supported through more detailed information and substantive content [42].

Context plays a crucial role in determining which processing route dominates [43]. Understanding users' motivation and ability to process information in specific contexts is crucial for determining the appropriate persuasive approach [42]. In busy contexts (for example, dining halls), users may have limited motivation and ability to process complex information, suggesting a focus on simple, visually compelling messages with clear cues for action. In contrast, in waiting areas or during off-peak times, users may have greater capacity for central route processing, allowing for more detailed information or more complex interaction opportunities.

Combining strong arguments (for central processing) with attractive design elements (for peripheral processing) can address different processing styles and contexts. This multimodal approach acknowledges that the same display may be encountered by different users in different states of receptivity, or by the same user under different conditions. By providing both substantive content and peripheral cues, displays can engage users regardless of their current processing mode, maximizing the potential for persuasive impact across diverse contexts and user states.

Key Learnings for Model Development (KL-2.3.1)

KL-2.3.1.A - Dual Processing Routes: The distinction between central and peripheral processing routes reveals the need for our model to address different levels of cognitive engagement. This insight directly shapes our Response Time parameter (Table 4.7), which evaluates how mentally demanding interactions are. In restaurant environments where users typically have limited cognitive resources available, these parameters become essential for evaluating whether designs effectively support both quick, low-effort interactions (peripheral route) and more deliberate, information-rich interactions (central route) when appropriate.

KL-2.3.1.B - Context-Dependent Processing: The recognition that processing route depends on contextual factors reveals the need for our model to address how context influences message processing. This insight directly shapes our Task Context parameter (Table 4.5), which evaluates how well display function relates to users' primary tasks and goals. It also influences our Temporal Factors parameter (Table 4.5), which considers how timing affects affordance effectiveness. In restaurant environments where context significantly influences users' available cognitive resources and processing motivation, these parameters become crucial for assessing whether designs appropriately adapt to different contextual conditions, potentially offering simpler interactions during busy periods and more detailed engagement during quieter moments.

KL-2.3.1.C - Peripheral Cue Importance: The importance of peripheral cues in low-involvement contexts reveals the need for our model to address visual and social influence elements. This insight directly shapes multiple parameters in our Visual Affordances component, particularly Color Appropriateness (Table 4.1) and Iconography Clarity (Table 4.1), which evaluate how effectively visual elements communicate at a glance. It also influences our Social Context parameter (Table 4.5), which assesses how social factors affect affordance effectiveness. In restaurant environments where peripheral processing is often the norm, these parameters become essential for evaluating whether designs include effective peripheral cues that can influence users even during brief, low-involvement interactions.

2.3.2 Nudge Theory

Nudge Theory, popularized by Thaler and Sunstein [44], focuses on how subtle changes to choice architecture can influence behavior while preserving freedom of choice. Nudges are interventions that alter people's behavior in predictable ways without forbidding options or restricting freedom, for example, defaults and option ordering. This approach is particularly relevant for public displays where direct control over user behavior is neither possible nor desirable, but where subtle influences may effectively promote sustainability behaviors.

Among the many strategies mentioned in the Nudge Theory, this thesis focuses on three nudge techniques particularly applicable to interactive displays in public spaces: default options, feedback mechanisms and social proof:

Default options can significantly influence choices, as people tend to stick with pre-selected options rather than actively choosing alternatives. In interactive displays, this might involve pre-selecting sustainable options in choice interfaces or setting default views that highlight sustainability information. Feedback mechanisms that provide immediate information about the consequences of actions can help users understand the impact of their choices.

Feedback mechanisms play a crucial role in nudging behavior by connecting actions to their consequences [45]. Immediate, clear feedback helps users understand the impact of their choices and can reinforce desired behaviors.

Social proof, the tendency to look to others' behavior for guidance in uncertain situations, is a powerful influence on decision-making [46]. Communicating that others are engaging in sustainable behaviors can significantly increase the likelihood that users will adopt similar behaviors. Displays can leverage social proof by highlighting collective sustainability efforts or showing how many others have made sustainable choices.

Therefore, nudge approaches are particularly appropriate for public displays because they work with rather than against users' natural decision-making processes, requiring minimal cognitive effort while preserving autonomy. This alignment with cognitive and motivational realities makes nudges well-suited to attention-competitive environments like restaurants, where users have limited capacity and motivation for effortful decision-making but may be receptive to subtle influences that align with their existing values and goals.

Key Learnings for Model Development (KL-2.3.2)

KL-2.3.2.A - Choice Architecture: The concept of choice architecture and how presentation influences decisions reveals the need for our model to address how interactive elements are arranged and presented. This insight directly shapes our Layout Optimization parameter (Table 4.1), which evaluates how spatial arrangement guides attention and interaction flow. In restaurant environments where users make quick decisions with limited cognitive resources, this parameter becomes essential for assessing whether designs strategically arrange options to guide users toward desired behaviors while maintaining freedom of choice. This parameter acknowledges that the arrangement of interactive elements is not neutral but significantly influences user decisions and behaviors.

KL-2.3.2.B: Nudging Strategies: The concept of nudging through subtle interventions reveals the need for our model to address how designs can influence behavior without restricting freedom. This insight directly shapes multiple parameters across our model, including Color Appropriateness (Table 4.1), which evaluates how color is used to attract attention to specific elements and Discoverability (Table 4.3), which assesses how easily users can identify interactive elements. In restaurant environments where subtle influence may be more effective than direct persuasion, these parameters become important for assessing whether designs effectively implement nudging strategies that guide behavior while respecting user autonomy.

KL-2.3.2.C - Feedback Mechanisms: The importance of immediate feedback about action consequences reveals the need for our model to address how systems communicate results. This insight directly shapes our Feedback Effectiveness parameter (Table 4.3), which evaluates how clearly the system communicates that an action is possible or has occurred. In restaurant environments where interactions may be brief and users may not have time to figure out whether their actions had the intended effect, this parameter becomes crucial for assessing whether designs provide clear, immediate feedback that confirms actions and communicates their consequences.

KL-2.3.2.D - Social Proof: The influence of social proof in determining appropriate behavior reveals the need for our model to address social influence mechanisms. This insight directly shapes our Social Context parameter (Table 4.5), which evaluates how social factors affect affordance effectiveness, including the potential for positive social influence. In restaurant environments where users are influenced by the behavior of others, this parameter becomes important for assessing whether designs effectively leverage social proof to encourage engagement and potentially normalize desired behaviors.

2.3.3 Self-Determination Theory (SDT)

Self-Determination Theory, developed by Deci and Ryan [47], is a macro-theory of human motivation that identifies three universal psychological needs essential for well-being and intrinsic motivation, namely, autonomy, competence and relatedness. Autonomy involves the need to feel that one's actions are self-determined rather than controlled by external forces. Competence refers to the need to feel effective and capable in one's actions and interactions. Displays that provide appropriate challenges[6], clear guidance, and positive feedback can enhance users' sense of competence [48]. Relatedness encompasses the need to feel connected to others and part of a community. Interactive displays that highlight collective efforts, facilitate social sharing, or create a sense of community can address this need for social connection.

Self-Determination Theory (SDT) provides valuable guidance for designing interactive displays by emphasizing the support of autonomy, competence, and relatedness. Autonomy can be fostered by offering users meaningful choices and clear rationales, encouraging actions aligned with personal values rather than externally imposed directives. Competence is supported through optimal challenges, step-by-step guidance, and feedback that helps users feel capable of engaging in sustainable behaviors. Relatedness is addressed by highlighting collective efforts and enabling social sharing, reinforcing a sense of community around sustainability. By con-

[6] Appropriate Challenges: Appropriate challenges refer to tasks that are neither too easy nor too difficult, allowing individuals to effectively apply their skills while promoting a sense of growth and mastery. In the context of SDT, they support the psychological need for competence by enabling users to feel capable and successful in meeting achievable goals

necting actions to users' values and identity, interactive displays can help promote long-term engagement [49].

Furthermore, SDT distinguishes between different types of motivation, specifically, intrinsic and extrinsic motivations [47]. Intrinsic motivation involves engaging in an activity because it is inherently interesting or enjoyable. Extrinsic motivation involves engaging in an activity for instrumental reasons, which can vary in the degree of autonomy from external regulation (controlled) to integrated regulation (autonomous). Amotivation represents a lack of intention to act, often resulting from not valuing the activity, not feeling competent, or not believing it will yield desired outcomes.

Key Learnings for Model Development (KL-2.3.3)

KL-2.3.3.A - Basic Psychological Needs: SDT's identification of three basic psychological needs (autonomy, competence, relatedness) reveals the need for our model to address emotional and psychological aspects of interaction. This insight directly shapes our Input Modality Appropriateness parameter (Table 4.7), which evaluates how interactions satisfy these fundamental needs. In environments where engagement is voluntary and must compete with other activities, this parameter becomes essential for assessing whether designs create intrinsically rewarding experiences that satisfy users' psychological needs. This parameter acknowledges that effective affordances must address not just functional aspects of interaction but also emotional and psychological dimensions.

KL-2.3.3.B - Motivation Types: SDT's distinction between intrinsic and extrinsic motivation reveals the need for our model to address different motivational drivers. This insight directly shapes our Input Modality Appropriateness parameter (Table 4.7), which evaluates how interactions provide both intrinsic and extrinsic benefits to cater to intrinsic and extrinsic motivations. It also influences our Task Context parameter (Table 4.5), which assesses how well display function aligns with users' existing motivations and goals. In restaurant environments where users may have varying motivations for engagement, these parameters become important for evaluating whether designs can effectively engage users with different motivational orientations and potentially help shift motivation from extrinsic to more intrinsic forms.

KL-2.3.3.C: Engagement Level Appropriateness: SDT's emphasis on appropriate challenge reveals the need for our model to address the appropriate depth of engagement for different users and contexts. This insight directly shapes our Engagement Level Appropriateness parameter (Table 4.7), which evaluates how well the system matches engagement opportunities to users' motivation and available resources. In environments where engagement opportunities range from glancing at information to extended interaction, this parameter becomes important for assessing whether designs offer appropriate engagement pathways that respect users' current motivation and capacity for involvement. This parameter acknowledges that effective affordances must not only enable interaction but must invite the right level of engagement for specific users in specific contexts.

3 Methodology

This research adopts a design science research (DSR) methodology, which is particularly appropriate for developing innovative artifacts that address real-world problems while contributing to theoretical knowledge. Following Hevner's Three Cycle View of Design Science Research [50], this study integrates three interconnected cycles of research activities: the Relevance Cycle, the Rigor Cycle, and the Design Cycle:

The Relevance Cycle connects the research with its application environment, identifying real-world problems and opportunities in self-service restaurant environments and defining requirements and evaluation criteria.

The Rigor Cycle links the research to the scientific knowledge base, drawing from established theories and methods while ensuring that the research contributes new knowledge to the field.

The Design Cycle iterates between building and evaluating the design artifacts, in this case, the affordance-based model and its experimental implementations.

This three-cycle approach ensures that the research is both practically relevant and theoretically grounded, addressing the dual objectives of solving real-world problems and advancing scientific knowledge.

Fig 3.1 represents a visual representation of the Three Cycles in the context of this research.

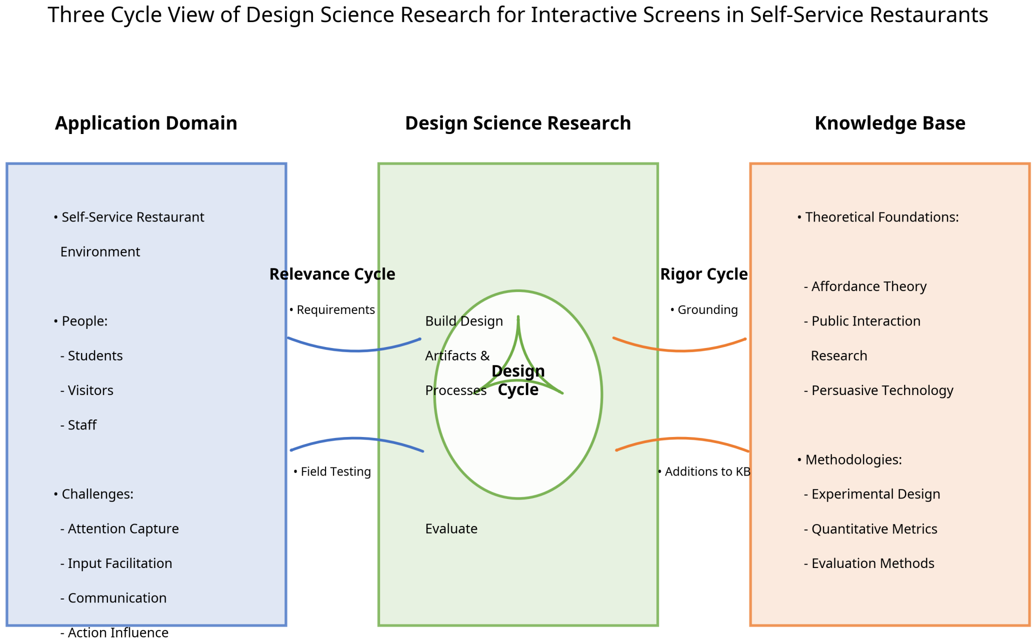

Figure 3.1: Three Cycle View Applied to this Thesis

3.1 The Relevance Cycle: Application Domain and Requirements

3.1.1 Application Domain

The relevance cycle of this research is anchored in the specific context of self-service restaurant (SSR) environments. These environments present unique challenges for interactive displays due to their distinctive characteristics and usage patterns. Public self-service restaurants typically experience traffic with variable density throughout the day, creating periods of intense crowding alternating with relative quiet. This temporal variability affects both the visibility of displays and users' available attention and time for interaction. The user population in these environments is notably diverse, encompassing different cultural backgrounds, technological literacy levels, and familiarity with the space, necessitating inclusive design approaches that accommodate this heterogeneity.

A critical contextual factor is that users' primary focus in these environments is on dining activities rather than technology interaction. Interactive displays must therefore compete with the core activities of food selection, social dining, and related tasks for users' limited attention. This competition is intensified by users' constrained time and attention resources, as many visitors have limited meal breaks and specific time pressures. The social dynamics of dining environments further complicate interaction patterns, as social norms, privacy concerns, and group behaviors significantly influence willingness to engage with public displays. Additionally, these spaces typically feature competing visual and auditory stimuli, from menu displays to conversation noise, creating a challenging perceptual environment for any interactive system.

Setting: Flavoria University Restaurant

The primary application environment for this research was Flavoria, a university self-service buffet restaurant that serves approximately 500 to 1000 diners daily on working days. Flavoria was selected as the experimental setting for several reasons that made it particularly suitable for testing the affordance-based design model.

Flavoria offers a relatively controlled environment with consistent traffic patterns, regular user population, and stable operational procedures, while still being a real-world dining facility. This balance of control and authenticity made it ideal for testing the model in a realistic context. The restaurant's established routines and predictable usage patterns provided a stable baseline against which to measure the impact of the experimental interventions.

The restaurant serves a diverse population of students, faculty, and staff, providing access to users with varying demographics, technological literacy, and dining habits. This diversity allowed for testing the model's effectiveness across diverse user groups, an important consideration given the public nature of the displays being designed. The university population included both regular diners who visited multiple times per week and occasional visitors, enabling assessment of both initial reactions and evolving engagement patterns over time.

Flavoria has an existing commitment to sustainability initiatives, making it an appropriate context for testing interventions related to food sustainability. This alignment between the restaurant's goals and the research focus facilitated institutional support for the experiments and increased the relevance of the findings for the restaurant's ongoing operations. The sustainability focus also provided a meaningful context for the design interventions, addressing real challenges rather than artificial test scenarios.

3.1.2 Problem Identification and Requirements

Through preliminary observations, four key challenges (Attention Capture, Input Facilitation, Communication Effectiveness and Action Influence) were identified (as referred to in Section 1.3: Problem Statement) that define the requirements for the affordance-based model.

The Attention Capture Challenge recognizes that interactive displays in SSRs must compete with numerous distractions and overcome "display blindness" to capture user attention. This challenge is particularly acute in dining environments where users' attention is primarily directed toward food, companions, and personal devices rather than ambient displays. The model must therefore address how design elements can effectively attract notice without becoming disruptive or intrusive.

The Input Facilitation Challenge acknowledges that once attention is captured, displays must clearly communicate interaction possibilities and provide intuitive input mechanisms. Many public displays fail at this critical juncture, either by not clearly signaling their interactive capabilities or by implementing interaction methods that are confusing, uncomfortable, or socially awkward in public dining contexts. The model must therefore incorporate parameters that evaluate how effectively a design communicates interaction possibilities and supports comfortable engagement.

The Communication Effectiveness Challenge recognizes that displays must effectively convey their intended messages within the brief attention spans typical in dining environments. This challenge extends beyond mere visibility to comprehension and retention of information, particularly when communicating complex concepts such as sustainability information or nutritional data. The model must therefore address factors that influence message clarity, comprehension, and memorability within the constraints of brief engagement periods.

The Action Influence Challenge acknowledges that ultimately, displays must influence user behaviors, bridging the gap between information provision and behavioral change. This is perhaps the most complex challenge, as it involves not only cognitive processing but also motivation, social factors, and contextual constraints that affect decision-making and action. The model must therefore incorporate parameters that evaluate how effectively a design supports the progression from awareness to understanding to action.

These four challenges establish the practical requirements that the introductory affordance-based model must address, serving as evaluation criteria for its effectiveness in real-world application. By explicitly deriving the model requirements from these identified challenges, the relevance cycle ensures that the research remains focused on solving meaningful problems rather than pursuing theoretical interests disconnected from practical needs.

3.2 The Rigor Cycle: Theoretical Foundations and Knowledge Base Contribution

3.2.1 Theoretical Grounding

The rigor cycle of this research draws from three primary theoretical domains, creating a robust foundation for the affordance-based model.

Affordance Theory (Section 2.1) provides the fundamental framework for understanding how design elements suggest action possibilities. Beginning with Gibson's ecological psychology, which introduced the concept of affordances as action possibilities that exist in the environment independent of perception, the research traces the evolution of affordance theory through Norman's adaptation for design, which emphasized perceived affordances as distinct from actual affordances. Contemporary developments in affordance theory further inform the research, particularly those addressing digital and social affordances that extend beyond physical properties to include cultural, social, and learned aspects of affordance perception. This theoretical progression provides essential concepts for understanding how interactive displays communicate action possibilities to potential users.

HCI in public spaces (Section 2.2) research contributes critical insights into the specific challenges and dynamics of interactive displays in public spaces. Studies on display blindness explain why many public displays go unnoticed despite their visibility, while research on interaction reluctance illuminates the social, psychological, and practical barriers that prevent engagement even when displays are noticed. Engagement models such as the Audience Funnel and the Social Learning Model (Section 2.2.3) provide frameworks for understanding how engagement progresses from peripheral awareness to focused interaction, and how social dynamics influence this progression. This body of research informs the model's approach to overcoming the unique barriers to interaction in public spaces, particularly those with complex social dynamics like restaurant environments.

Persuasive Technology (Section 2.3) research provides theoretical foundations for understanding how interactive systems can influence user behavior. Elaboration Likelihood Model (Section 2.3.1) of persuasion distinguish between central and peripheral routes to persuasion, explaining how different types of messages and cues affect decision-making under varying conditions of motivation and ability. Choice architecture from the Nudge Theory (Section 2.3.2) illuminate how the presentation of options can significantly influence decisions without restricting freedom of choice. Self-determination theory (Section 2.3.3) offers insights into intrinsic and extrinsic motivation, highlighting the importance of supporting autonomy, competence, and relatedness to foster sustained engagement to trigger user-driven actions.

These theoretical foundations provide the scientific grounding for the model development, ensuring that the research builds upon established knowledge while addressing identified gaps in the literature. By explicitly connecting the model components to these theoretical foundations, the rigor cycle ensures that the research contributes to scientific discourse rather than merely solving isolated practical problems.

3.2.2 Research Contribution to Knowledge Base

The integration of theories represents a novel synthesis of insights from affordance theory, public interaction research, and persuasive technology into a cohesive framework. While these theoretical domains have developed largely in parallel, this research identifies and leverages their complementary perspectives to create a more comprehensive understanding of how interactive displays function in public spaces. This integration provides an introductory theoretical model that acknowledges the perceptual, contextual and interactive aspects of public displays.

The Quantification Approach developed in this research addresses a methodological gap in the field. By developing a mathematical framework for measuring affordance effectiveness, the research moves beyond qualitative descriptions to provide quantitative metrics that enable systematic evaluation and comparison. This approach operationalizes theoretical concepts into measurable parameters, allowing for more precise analysis of design effectiveness and complementary rigorous testing of theoretical propositions. The mathematical framework also supports evidence-based design decisions by identifying specific areas for improvement and quantifying the expected impact of design changes.

The Contextual Application of these theories to the specific context of self-service restaurant environments represents another valuable contribution. By adapting general theories to this particular setting, the research demonstrates how theoretical principles manifest in specific contexts with unique constraints and opportunities. This contextual application enhances the ecological validity of the theoretical framework and provides practical insights for designers working in similar environments. The research identifies which theoretical principles are most relevant in restaurant contexts and how they should be applied to address the specific challenges of these spaces.

The Comparative Analysis of different interaction levels (passive, active, and two-way) within a unified model represents a methodological innovation that enables more nuanced understanding of interaction design choices (refer to Chapter 5). By evaluating these different approaches using consistent metrics and in the same environmental context, the research provides insights into their relative strengths and weaknesses for different communication goals. This comparative approach moves beyond simplistic prescriptions to provide context-sensitive guidance on when different interaction approaches are most appropriate.

These contributions extend the existing knowledge base by providing both theoretical insights and practical tools for designing and evaluating interactive displays in public spaces. By explicitly articulating these contributions, the rigor cycle ensures that the research not only draws from the scientific knowledge base but also enriches it through new theoretical integrations, methodological approaches, and contextual applications.

3.3 The Design Cycle: Model Development and Evaluation

3.3.1 Model Development Process

The design cycle involved an iterative process of developing and refining the preliminary affordance-based model through multiple stages of conceptualization, formalization, and refinement. The Conceptual Model Development phase synthesized insights from the theoretical foundations to identify key components and parameters of affordance effectiveness. This process began with a comprehensive review of the literature to extract relevant concepts and principles, followed by a systematic organization of these concepts into a coherent model. The initial conceptualization identified four primary components of affordance effectiveness—visual, perceived, contextual, and interaction affordances—each addressing distinct but interconnected aspects of how interactive displays communicate action possibilities and support engagement (refer to Chapter 4).

The Parameter Definition phase involved defining specific, measurable parameters for each component of the model, ensuring comprehensive coverage of relevant factors. For each component, the research identified key parameters that influence affordance effectiveness, drawing from both theoretical principles and empirical findings in the literature. These parameters were refined through preliminary testing to ensure they were both theoretically sound and practically measurable. The definition process also involved establishing clear criteria for evaluating each parameter, creating a structured approach to assessment that could be consistently applied across different designs and contexts.

The Mathematical Formulation phase developed quantitative metrics and formulas for evaluating affordance effectiveness, enabling systematic comparison of design alternatives. This process involved creating measurement scales for each parameter, determining appropriate weighting factors to reflect their relative importance, and developing formulas that combine these measurements into meaningful composite scores. The mathematical model was designed to capture both the individual contribution of each parameter and their interactive effects, acknowledging that affordance effectiveness emerges from the interplay of multiple factors rather than their simple summation. The formulation also incorporated contextual factors as modifiers rather than direct components, reflecting their role in enhancing or inhibiting the effectiveness of design elements rather than constituting design elements themselves.

The Validation Approach Design phase created a structured approach for testing the model across different interaction levels and communication goals. This involved developing experimental protocols, defining measurement methods, and establishing criteria for evaluating the model's predictive and explanatory power. The validation approach was designed to test both the internal validity of the model (whether its components and relationships are logically consistent and theoretically sound) and its external validity (whether it accurately predicts and explains real-world outcomes). The approach also incorporated mechanisms for model refinement based on empirical findings, ensuring that the model could evolve in response to new insights rather than remaining static.

This iterative development process involved multiple refinements based on expert feedback, preliminary testing, and alignment with theoretical principles. Each iteration enhanced the model's comprehensiveness, precision, and practical applicability, moving from abstract theoretical concepts to a concrete, operational framework for design and evaluation. The design cycle thus represents the creative heart of the research, where theoretical insights are transformed into practical tools through systematic development and refinement.

3.3.2 Evaluation Strategy

The evaluation strategy employs an experimental approach to assess the model's effectiveness, combining experimental implementation with data collection and analysis methods. The Experimental Implementation involved designing and implementing three distinct experiments utilizing interactive displays at Flavoria restaurant, each representing a different interaction level (active, passive, two-way). Experiment 1, the Rush Information Screen, exemplified passive interaction by providing real-time information about restaurant occupancy without requiring explicit user input. This implementation tested the model's applicability to displays focused primarily on information provision rather than direct interaction. Experiment 2, the Intentions Poll, represented active interaction by inviting users to express their sustainability intentions through a simple touch interface. This implementation tested the model's applicability to displays requiring explicit but straightforward user input. Experiment 3, the Food Waste Pledge, demonstrated two-way interaction by engaging users in a more complex dialogue about food waste reduction, with personalized feedback based on user inputs. This implementation tested the model's applicability to displays supporting extended engagement and personalized communication.

3.3.3 Experimental Design

The experimental validation consisted of three progressive experiments, each exploring different levels of user engagement and testing different aspects of the affordance-based design model. This structured approach allowed for systematic validation of the model across a spectrum of interaction types and design challenges.

Experiment 1: Passive Communication (Rush Meter) The first experiment focused on passive communication through a rush meter display that showed real-time information about restaurant occupancy and recommended dining times. This experiment tested the model's effectiveness in designing for attention capture and information communication without requiring direct user interaction. The primary focus was on visual and perceived affordances, with secondary attention to contextual adaptation.

The rush meter was implemented on a 88-inch display mounted at the main entrances to the building and restaurant, where it would be visible to diners as they approached the restaurant. The display showed current occupancy levels using a color-coded vertical scale (green for low occupancy, yellow for moderate, red for high) with a dynamic indicator showing the current level. Recommended dining times were highlighted on a timeline above the meter, indicating periods of typically lower occupancy.

Data collection for this experiment focused on rush-peak temporal charts, where a baseline was taken before the start and during the experiment for possible changes in dining time distribution. A survey was conducted during the experiment to qualitatively assess the affordances of the screen.

Experiment 2: Active Input (Animated Poll) The second experiment explored active input through an animated polling interface that gathered diners' intentions. This experiment tested the model's effectiveness in designing for direct interaction, focusing particularly on interaction affordances and the conversion from passive viewing to active engagement. The secondary focus was on social context influences.

The animated poll was implemented on a 88-inch touchscreen displays positioned at the entrances to the building and the restaurant. The display featured an animated interface that posed simple question about intended restaurant choice("Will you eat at Flavoria today?") with visually appealing, touchable response options. The interface included animated elements to signal interactivity and social proof indicators showing number of people who participated.

Data collection for this experiment focused on conversion rate (percentage of possible diners who proceeded to interact). A survey was conducted during the experiment to qualitatively assess the affordances of the screen.

Experiment 3: Two-Way Communication (Food Waste Pledge) The third experiment investigated two-way communication through an interactive food waste pledge system. This experiment tested the model's effectiveness in designing for more complex, dialogue-based interactions, integrating all components of the affordance-based model. The focus was on guiding users through a multi-step interaction process that culminated in a personal commitment to reduce food waste.

The food waste pledge system was implemented on a 88-inch display positioned at the entrance to the food service area, and the dining hall where diners made decisions about food selection. The display featured an interactive interface, relatable to everyday food items (bread/tomato/pizza) that had to be cut with a knife and a social proof of number of people who participated. After cutting with the knife on-screen, the interaction provided information about food waste impact and invited users to make specific pledges about waste reduction behaviors ("I will only take what I can eat"), and provided personalized feedback and reinforcement.

Data collection for this experiment focused on conversion rate (percentage of possible diners who participated) and pledge completion (percentage of users who also completed the entire pledge process), and sustainability impact (changes in food waste levels following the intervention). A survey was conducted during the experiment to qualitatively assess the affordances of the screen.

Each experiment ran for three weeks. The experiments were conducted sequentially over a six-week period during the academic semester to ensure consistent user population and operational conditions.

3.4 Data Collection and Analysis Methods

An integrated approach to data collection was employed to capture both quantitative and qualitative aspects of user engagement with the interactive displays. This comprehensive approach provided rich, triangulated data that enabled thorough evaluation of the model's effectiveness across different dimensions.

3.4.1 Interaction Metrics

Each interactive display was equipped with a PostGres API to log the time series data that automatically recorded interaction data, providing objective measurements of engagement patterns without relying on human observation. This automated data collection was particularly valuable for capturing comprehensive interaction data across all hours of operation. Please note that for Experiment 1, there was no active interaction required from user, and therefore, no data was logged for it from the screen.

Completion rates were calculated by analyzing the percentage of interactions that were completed as intended. For Experiment 2, this meant tapping the polling buttons. For Experiment 3, this involved progressing through the knife-cutting and then the pledge button to make a commitment. These completion metrics helped assess the effectiveness of the interaction design in guiding users through the intended process without abandonment.

3.4.2 User Surveys

Brief surveys were administered to diners after their meal to collect data on user motivations and affordances that likely matter to them. These surveys provided insights into the qualitative aspects of the user experience that might not be apparent through observation or interaction logs alone. The questions for each experiment were also optimized, starting from general in Experiment 1 to more in-depth in Experiment 3.

The question for each experiment was directed at users to understand their motivations for interaction, the clarity of affordances, and potential aspects to dive into for future experiments. These questions helped assess the subjective quality of the interaction experience and build a possible understanding between observed behavior and user perceptions.

Surveys were administered using tablet devices positioned near the restaurant waste stations.

3.4.3 Model Validation Analysis

A specific analysis process was developed to validate the affordance-based model, testing its prescriptive accuracy, practical utility, and real-world impact. This validation analysis provided a systematic assessment of whether the model achieved its intended purpose of guiding effective interactive screen design.

Model validation tested the mathematical model's predictions against actual engagement data to assess predictive accuracy. For each display implementation, affordance effectiveness scores were calculated using the model's formulas and compared with observed engagement metrics. Statistical measures of predictive accuracy, including correlation coefficients and mean absolute error, were used to quantify how well the model's predictions aligned with real-world outcomes. This validation process provided evidence of the model's ability to predict engagement outcomes based on design characteristics.

Comparative effectiveness analysis examined how different implementations of the model (across the three experiments) affected engagement. This analysis compared the effectiveness of different affordance strategies for achieving specific communication goals, providing insights into when and how to apply different aspects of the model. By comparing passive, active, and two-way communication approaches within the same overall model, this analysis helped identify the most appropriate strategies for different communication objectives.

This validation analysis provided a comprehensive assessment of the model's effectiveness and value for designers. By examining both the model's predictive accuracy and its practical utility in guiding design decisions, the analysis established whether the model successfully bridged the gap between theoretical understanding and practical application in the specific context of interactive screens in self-service restaurant environments.

Table 3.1 represents the Interaction Level, Data Collected and Survey Question for each of the three experiments.

Experiment Name	**Interaction Level**	**Data Collected**	**Survey Question**
Rush Information Screen (Experiment 1)	Passive Communication	Count of diners on each day; Temporal distribution of diners per day	Which aspects of the screen's information were relevant to you?
Intentions Poll (Experiment 2)	Active Communication	Count of diners on each day; Count of YES interactions; Count of NO interactions	What motivates you to give feedback on a restaurant screen? Choose all that apply.
Food Waste Pledge (Experiment 3)	Two-Way Communication	Count of diners on each day; Count of 1st interactions; Count of 2nd interactions	What elements of an interactive display would encourage you to engage while walking by? Choose all that apply.

Table 3.1: Experiments Overview: Interaction Levels, Data Collected, and Survey Questions

3.5 Ethical Considerations

Interaction with the displays was entirely voluntary. The displays were positioned to allow easy avoidance by those who did not wish to participate, and no negative consequences resulted from non-participation. For the survey component, explicit consent was obtained from all participants, who were informed about the purpose of the research and the use of their data before providing any responses. No personally identifiable information was collected through the displays or surveys. The interaction data was recorded anonymously, with no linking to individual identities.

4 Affordance-Based Design Model

The introductory Affordance-Based Design Model for Interactive Screens (ABD-MIS) presented in this thesis is grounded in a synthesis of theoretical perspectives from ecological approach to affordances, human-computer interaction, and persuasive technology. The model addresses the unique challenges of designing interactive screens for public spaces, with a specific focus on promoting user-driven actions in self-service restau- rant environments. This chapter outlines the conceptual foundation and defines the structure and components of the model.

4.1 Building the Model from Theoretical Foundations

The affordance-based model's mathematical formulations are developed using a systematic synthesis of theoretical insights from the theoretical foundations in Chapter 2 which serve as foundations of this introductory model. Each component and parameter has been directly derived from specific theoretical foundations, creating a model that addresses the unique challenges of designing interactive screens for self-service restaurant environments.

The model's structure reflects the progression of understanding in affordance theory, from Gibson's foundational concepts to contemporary applications in digital environments. The four components—Visual Affordances, Perceived Affordances, Contextual Affordances, and Interaction Affordances—correspond to the major theoretical developments identified in theoretical foundations:

Visual Affordances derive primarily from Gibson's ecological approach (Section 2.1.1) and research on attention capture in public spaces (Section 2.2.2), addressing how physical and visual properties communicate action possibilities.

Perceived Affordances build on Norman's adaptation of affordance theory for design (Section 2.1.2) and Gaver's technology affordances (Section 2.1.3), focusing on how users interpret visual cues based on their experiences and expectations.

Contextual Affordances incorporate insights from contemporary affordance theory (Section 2.1.4) and research on public interaction challenges (Section 2.2.1), acknowledging the critical role of environmental, social, temporal, and activity contexts.

Interaction Affordances integrate Gaver's sequential affordances (Section 2.1.3) with persuasive technology theories (Section 2.3), addressing how interactions unfold over time and how they can satisfy users' psychological needs.

By systematically translating theoretical insights into practical design parameters, this model provides a comprehensive tool for designing and evaluating interactive screens in self-service restaurant environments. The explicit mapping between theoretical foundations and model parameters ensures that the model is both theoretically sound and practically applicable.

Note: Each component also has defined parameters derived from theoretical foundations in Chapter 2 which are discussed in the following Chapter 4.2.

4.2 Model Components, Parameters and Measurement Approach

This section defines the components and parameters of our model. The model consists of four interconnected components, each addressing a distinct but complementary aspect of affordance design:

Visual Affordances: How visual elements communicate interaction possibilities

Perceived Affordances: How users interpret and understand these visual cues

Contextual Affordances: How environmental and situational factors influence affordance effectiveness

Interaction Affordances: How the system supports and rewards user actions

4.2.1 Visual Affordances

Visual affordances represent the physical and visual properties of interactive elements that suggest their function and usability on an interactive screen. These properties directly influence whether users notice interactive elements and understand their purpose. Drawing directly from Gibson's concept of direct perception (KL-2.1.1.B) and Norman's signifiers (KL-2.1.2.C), this component focuses on how visual design communicates action possibilities without requiring conscious interpretation.

Table 4.1 presents the seven parameters for evaluating visual affordances, defining each parameter and showing how each parameter derives from specific theoretical insights identified in the Chapter 2.

Parameter	Description	Key Insights	Key Learning Reference
Animation Effectiveness (A)	How movement and change are used to attract attention and suggest interaction	Dynamic elements can capture attention in competitive environments but must avoid distraction	KL-2.2.1.A (Display Blindness), KL-2.2.2.A (Visual salience factors), KL-2.2.2.B (Novelty effect)
Color Appropriateness (C)	How effectively color is used to attract attention and indicate interactivity	Color choices should align with cultural conventions while providing sufficient contrast to indicate interactive elements	KL-2.1.2.B (Cultural influence on perception), KL-2.2.2.A (Visual salience factors), KL-2.3.1.C (Peripheral Cue Importance), KL-2.3.2.B (Nudging Strategies)
Contrast Ratio (C_t)	How effectively the display stands out from surroundings	Visual distinction from surroundings is necessary to overcome display blindness in attention-competitive environments	KL-2.2.1.A (Display blindness), KL-2.2.2.A (Visual salience factors)

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Parameter	**Description**	**Key Insights**	**Key Learning Reference**
Form Effectiveness (F)	How well the form[1] suggests function	The shape, contour, and dimensionality of elements should directly suggest their action possibilities without requiring conscious interpretation	KL-2.1.1.A (Gibson's relational affordances), KL-2.1.1.B (Direct perception)
Iconography Clarity (I)	How effectively symbols and icons communicate function	Visual symbols must clearly communicate function across diverse user populations with different cultural backgrounds	KL-2.1.2.C (Signifiers as communication), KL-2.2.1.E (User diversity), KL-2.3.1.C (Peripheral Cue Importance)
Layout Optimization (L)	How spatial arrangement guides attention and interaction flow	The arrangement of elements should create a natural interaction sequence and guide users through intended pathways	KL-2.1.3.B (Sequential affordances), KL-2.3.2.A (Choice architecture)

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Parameter	**Description**	**Key Insights**	**Key Learning Reference**
Size Optimization (S)	Whether elements are appropriately sized for visibility and interaction	Element size must accommodate diverse users with different visual capabilities and viewing distances	KL-2.2.1.E (User diversity), KL-2.2.2.A (Visual salience factors)

Table 4.1: Visual Affordance Parameters

Measurement Approach

To enable systematic evaluation and optimization, the model provides a quantitative approach to measuring visual affordance strength. The visual affordance strength (VA) is calculated as:

$$VA = \sum (w_1 F + w_2 C + w_3 S + w_4 C_t + w_5 A + w_6 I + w_7 L)$$

where:

- A = Animation effectiveness (1–5 scale)
- C = Color appropriateness (1–5 scale)
- C_t = Contrast ratio (1–5 scale)
- F = Form effectiveness (1–5 scale)
- I = Iconography clarity (1–5 scale)
- L = Layout optimization (1–5 scale)
- S = Size optimization (1–5 scale)
- $w_1 \dots w_7$ = Relative weights based on context importance

We take the arithmetic mean as each parameter contributes independently and equally towards the Visual Affordance score. The weights ($w_1 \dots w_7$) allow for context-specific customization, recognizing that different elements may have varying importance depending on the specific environment and user population. For example, in a noisy, visually busy dining hall, animation and contrast might receive higher weights than in a quieter, visually simpler environment. This weighting approach allows the model to be adapted to different contexts while maintaining its basic structure and measurement approach.

The scores are to be assigned using the rubric given in Table 4.2.

Parameter	**Score 1 (Poor)**	**Score 3 (Adequate)**	**Score 5 (Excellent)**
Animation Effectiveness (A)	Animation distracts or creates accessibility barriers	Animation provides reasonable indication with basic motion considerations	Animation perfectly balances attention-getting with usability and accessibility
Color Appropriateness (C)	Colors fail to indicate interactivity or violate accessibility standards	Colors provide adequate indication with basic accessibility compliance	Colors perfectly balance attention, accessibility, and cultural appropriateness
Contrast Ratio (C_t)	Poor contrast makes elements difficult to see	Adequate contrast meets accessibility standards	Contrast ensures visibility in real-world usage scenario
Form Effectiveness (F)	Form fails to communicate function or misleads users	Form provides reasonable indication but requires cognitive processing	Form immediately and unambiguously communicates function
Iconography Clarity (I)	Icons fail to communicate function or mislead users	Icons provide reasonable indication but may require learning	Icons immediately communicate function across all user groups

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Parameter	**Score 1 (Poor)**	**Score 3 (Adequate)**	**Score 5 (Excellent)**
Layout Optimization (L)	Layout hinders interaction with chaotic arrangement	Layout provides reasonable guidance with adequate visual hierarchy	Layout creates perfect visual hierarchy and intuitive interaction flows
Size Optimization (S)	Elements too small for effective interaction	Elements meet basic accessibility requirements	Elements optimally sized for all users with excellent space utilization

Table 4.2: Rubric for scoring Visual Affordance Parameters

4.2.2 Perceived Affordances

Perceived affordances address how users interpret and understand the visual cues presented by the system. This component acknowledges Norman's crucial distinction between actual and perceived affordances (KL-2.1.2.A), recognizing that what matters is not just what is possible but what users perceive as possible. This component evaluates how effectively the visual design translates into perceived interaction possibilities.

Table 4.3 presents the six parameters for evaluating perceived affordances, defining each parameter and showing how each parameter derives from specific theoretical insights identified in Chapter 2.

Parameter	Description	Key Insights	Key Learning Reference
Consistency (C_n)	How well interactive elements align with established patterns and conventions	Alignment with familiar patterns reduces cognitive load and leverages users' existing mental models	KL-2.1.2.B (Cultural and experiential influence), KL-2.1.4.B (Socio-cultural embeddedness)
Discoverability (D)	How easily users can identify which elements are interactive	Interactive elements must be clearly distinguished from non-interactive elements to avoid both hidden and false affordances	KL-2.1.3.A (Affordance perceptibility categories), KL-2.2.1.B (Interaction reluctance), KL-2.2.2.E (Brief attention span), KL-2.2.3.B (Engagement Threshold), KL-2.3.2.B (Nudging Strategies)
Feedback Effectiveness (F_b)	How clearly the system communicates that an action is possible or has occurred	Clear feedback reduces uncertainty and confirms successful interactions	KL-2.1.2.C (Signifiers as communication), KL-2.3.2.C (Feedback mechanisms)

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Parameter	Description	Key Insights	Key Learning Reference
Learnability (L_n)	How easily users can learn and remember how to interact with elements after initial exposure	Perceived affordances evolve through user experience and learning, potentially becoming stronger and more intuitive with repeated exposure	KL-2.1.2.D (Learnability)
Mental Model Alignment (M)	How well interactive elements match users' existing understanding of how similar systems work	Affordances are most effective when they build upon users' existing knowledge structures rather than requiring entirely new mental models	KL-2.1.4.E (Mental model alignment)

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Parameter	**Description**	**Key Insights**	**Key Learning Reference**
Recognizability (R)	How readily users can identify an element's function based on its appearance	Users must be able to quickly understand what an element does without prior instruction	KL-2.1.2.A (Perceived vs. actual affordances), KL-2.2.2.C (Content Relevance), KL-2.2.2.E (Brief attention span)

Table 4.3: Perceived Affordance Parameters

Measurement Approach

The perceived affordance strength (PA) is calculated as:

$$PA = f(V) \times (D \times R \times F_b \times C_n \times L_n \times M)^{1/6}$$

where:

- $f(V)$ = Function of visual affordance strength = Arithmetic Mean of V
- C_n = Consistency score (1–5 scale)
- D = Discoverability score (1–5 scale)
- F_b = Feedback effectiveness (1–5 scale)
- L_n = Learnability score (1–5 scale)
- M = Mental model alignment (1–5 scale)
- R = Recognizability score (1–5 scale)

The function f(V) represents the relationship between visual and perceived affordances, recognizing that perceived affordances build upon but are not entirely determined by visual characteristics. The geometric mean of the six perception factors (D, R, Fb, Cn, L, M) is used rather than an arithmetic mean to reflect that a significant deficiency in any one factor can substantially reduce overall perceived affordance strength, even if other factors are strong. This multiplicative approach acknowledges the interdependent nature of these factors and the potential for single-point failures in affordance perception.

The scores are to be assigned using the rubric given in Table 4.4.

Parameter	Score 1 (Poor)	Score 3 (Adequate)	Score 5 (Excellent)
Consistency (C_n)	No consistency in design patterns	Adequate consistency with some confusing variations	Consistency within interface and with external conventions
Discoverability (D)	No distinction between interactive and static elements	Reasonable distinction with some ambiguity about interactivity	Distinction between interactive and non-interactive elements
Feedback Effectiveness (F_b)	No feedback or misleading feedback for interactions	Adequate feedback but may have delays or missing confirmation	Immediate, clear, and appropriate feedback for all interactions
Learnability (L_n)	Users cannot learn or retain interaction patterns	Users can learn patterns but require multiple exposures	Users learn immediately and retain knowledge perfectly
Mental Model Alignment (M)	Interface contradicts user expectations completely	Interface somewhat aligns with user mental models	Perfect alignment with existing user mental models and expectations
Recognizability (R)	Users cannot identify element function from appearance	Users can identify function but may require brief consideration	Users immediately recognize element function without hesitation

Table 4.4: Rubric for scoring Perceived Affordance Parameters

4.2.3 Contextual Affordances

Contextual affordances address how environmental, social, temporal, and activity factors influence affordance effectiveness. This component acknowledges that affordances do not exist in isolation but are embedded in specific contexts that significantly shape their perception and effectiveness. Drawing from Gibson's ecological approach (KL-2.1.1.C) and contemporary research on socio-cultural embeddedness of affordances (KL-2.1.4.B), this component evaluates how well the design accounts for the specific context of self-service restaurant environments.

Table 4.5 presents the six parameters for evaluating contextual affordances, defining each parameter and showing how each parameter derives from specific theoretical insights identified in the Chapter 2.

[1] Form: The form of an object is its tactile properties

Parameter	**Description**	**Key Insights**	**Key Learning Reference**
Cultural Factors (C_f)	How cultural norms and expectations influence affordance perception	Cultural factors shape interpretation of visual elements and acceptability of interaction behaviors	KL-2.1.4.B (Socio-Cultural Embeddedness)
Physical Environment (P_e)	How environmental factors influence affordance effectiveness	Factors such as lighting, viewing distance, and ambient noise significantly impact affordance perception	KL-2.1.1.C (Environmental influence), KL-2.2.2.D (Proximity Zones), KL-2.2.3.A (Proximity-based phases)

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Parameter	Description	Key Insights	Key Learning Reference
Social Context (S_c)	How social presence affects affordance effectiveness	Social factors can both inhibit (embarrassment) and facilitate (honeypot effect) interaction	KL-2.1.3.C (Social dimension of affordances), KL-2.1.4.B (Socio-Cultural Embeddedness), KL-2.2.1.C (Social dynamics), KL-2.2.3.C (Honeypot Effect), KL-2.3.1.C (Peripheral Cue Importance), KL-2.3.2.D (Social proof)
Task Context (T_c)	How well display function relates to users' primary tasks and goals	Alignment with users' existing activities and goals increases relevance and engagement	KL-2.2.1.D (Competing distractions), KL-2.2.2.C (Content relevance), KL-2.3.1.B (Context-Dependent Processing), KL-2.3.3.B (Motivation Types)

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Parameter	**Description**	**Key Insights**	**Key Learning Reference**
Temporal Factors (T_f)	How timing and repeated exposure influence affordance effectiveness	Affordance perception changes over time through learning and adaptation	KL-2.1.4.C (Temporal evolution), KL-2.2.2.B (Novelty Effect), KL-2.3.1.B (Context-dependent processing)
User State (U_s)	How time pressure and competing priorities affect affordance effectiveness	Urgency influences attention allocation and willingness to engage with non-essential elements	KL-2.2.1.D (Competing Distractions)

Table 4.5: Contextual Affordance Parameters

Measurement Approach

The contextual influence (CA) is calculated as:

$$CA = (P_e \times S_c \times T_f \times U_s \times T_c \times C_f)^{1/6}$$

where:

- C_f = Cultural factors score (0.5–1.5 scale, with 1 being neutral)
- P_e = Physical environment score (0.5–1.5 scale)
- S_c = Social context score (0.5–1.5 scale)
- T_c = Task context score (0.5–1.5 scale)
- T_f = Temporal factors score (0.5–1.5 scale)
- U_s = User state score (0.5–1.5 scale)

The scale for contextual factors ranges from 0.5 (highly inhibiting) through 1.0 (neutral) to 1.5 (highly facilitating), reflecting that contextual factors can either enhance or impede affordance effectiveness. The geometric mean is used to reflect the multiplicative rather than additive nature of contextual influences, where a single highly inhibiting factor can significantly reduce overall affordance effectiveness regardless of other contextual strengths. This approach acknowledges the potential for contextual factors to create bottlenecks in affordance perception and effectiveness, guiding designers to address the most inhibiting factors first.

The scores are to be assigned using the rubric given in Table 4.6.

Parameter	**Score 0.5 (Inhibiting)**	**Score 1.0 (Neutral)**	**Score 1.5 (Facilitating)**
Cultural Factors (C_f)	Design violates cultural norms or uses inappropriate symbols	Culturally neutral design with no significant associations	Design aligns with cultural expectations and values
Physical Environment (P_e)	Poor lighting, excessive noise, uncomfortable positioning severely impair use	Standard environmental conditions with no significant impact	Optimal lighting, quiet environment, ergonomic positioning enhance use
Social Context (S_c)	Privacy concerns or social taboos prevent interaction	No significant social influence on interface use	Social proof and assistance encourage interaction
Task Context (T_c)	Interface severely distracts from or conflicts with primary tasks	Interface has neutral relationship to user's primary goals	Interface directly supports and advances primary task completion
Temporal Factors (T_f)	Extreme time pressure or poor timing severely limit interaction	Standard time constraints with neutral timing conditions	Ample time and optimal timing enhance interaction effectiveness
User State (U_s)	Low energy, poor focus, or physical distress prevent effective use	Average energy and attention levels with standard performance	High energy, excellent focus, and optimal condition enhance performance

Table 4.6: Rubric for scoring Contextual Affordance Parameters

4.2.4 Interaction Affordances

Interaction affordances address how the system supports and rewards user actions once they decide to engage. This component evaluates the quality of the interaction experience itself, focusing on how well the system supports users through the interaction process and provides appropriate rewards for engagement. Drawing from Gaver's sequential affordances (KL-2.1.3.B) and Self-Determination Theory's emphasis on psychological needs (KL-2.3.3.A), this component assesses whether interactions are physically appropriate, cognitively efficient, emotionally rewarding, and well-sequenced.

Table 4.7 presents the six parameters for evaluating interaction affordances, defining each parameter and showing how each parameter derives from specific theoretical insights identified in Chapter 2.

Parameter	Description	Key Insights	Key Learning Reference
Adaptability (A_d)	Whether required physical actions are comfortable and socially acceptable	Required actions must align with users' physical capabilities and social comfort in public settings	KL-2.1.1.A (Relational nature of affordances), KL-2.2.1.B (Interaction reluctance), KL-2.2.3.B (Engagement Threshold)
Engagement Level Appropriateness (E_l)	How information and options are revealed gradually as users engage more deeply with the information	Progressive disclosure reduces initial complexity while rewarding continued engagement	KL-2.3.3.C (Engagement Level Appropriateness)
Error Tolerance (E_t)	How well the system prevents, detects, and helps users recover from errors	Error-tolerant designs reduce frustration and support successful completion of interactions	KL-2.2.3.D (Error Tolerance)

Continued on next page

Parameter	**Description**	**Key Insights**	**Key Learning Reference**
Input Modality Appropriateness (I_m)	How interactions satisfy psychological needs for autonomy, competence, and relatedness	Interactions should provide intrinsic satisfaction and support users' psychological needs	KL-2.3.3.A (Basic psychological needs), KL-2.3.3.B (Motivation types)
Interaction Complexity (I_c)	How well the system accommodates different interaction styles and user preferences	Flexible interactions support diverse user needs and preferences, increasing accessibility	KL-2.2.3.B (Engagement Threshold)
Response Time (R_t)	How mentally demanding interactions are	Interactions should minimize unnecessary cognitive load, especially in attention-competitive environments	KL-2.2.1.F (Transient interaction), KL-2.3.1.A (Dual processing routes)

Table 4.7: Interaction Affordance Parameters

Measurement Approach

The interaction affordance strength (IA) is calculated as:

$$IA = (I_m \times R_t \times I_c \times E_t \times A_d \times E_l)^{1/6}$$

Where:

- A_d = Adaptability (1–5 scale)
- E_l = Engagement level appropriateness (1–5 scale)
- E_t = Error tolerance (1–5 scale)
- I_m = Input modality appropriateness (1–5 scale)
- I_c = Interaction complexity (1–5 scale)
- R_t = Response time optimization (1–5 scale)

As with other components, the geometric mean is used to reflect the multiplicative relationship between factors, where a significant deficiency in any one aspect can substantially reduce overall interaction affordance strength. This approach guides designers to address the weakest aspects of interaction design first, recognizing that interaction affordances are only as strong as their weakest component. The scores are to be assigned using the rubric given in Table 4.8.

Parameter	**Score 1 (Poor)**	**Score 3 (Adequate)**	**Score 5 (Excellent)**
Adaptability (A_d)	Interface fails to accommodate user differences or needs	Interface provides basic adaptation with standard accessibility options	Interface perfectly adapts to diverse user needs and contexts
Engagement Level Appropriateness (E_l)	Severe under-engagement or over-stimulation prevents effective use	Adequate engagement level appropriate for basic task completion	Perfect engagement level maintains optimal attention and motivation
Error Tolerance (E_t)	No error prevention or recovery mechanisms available	Basic error handling with adequate prevention and recovery	Error prevention with recovery mechanisms (including edge cases)
Input Modality Appropriateness (I_m)	Interface uses inappropriate input methods for context	Interface supports standard input methods adequately	Interface supports most natural input methods for context
Interaction Complexity (I_c)	Interaction is too complex for most users	Interaction is somewhat complex but manageable for most users	Interaction is simple for most of the users
Response Time (R_t)	Very slow response	Adequate response times	Immediate response

Table 4.8: Rubric for scoring Interaction Affordances Parameters

4.3 Mathematical Model for Affordance Measurement

The overall affordance effectiveness (OA) of an interactive screen is calculated by combining the three main affordance components:

$$OA = PA \times CA \times IA$$

where:

- PA = Perceived affordance strength, where PA incorporates the Visual Affordance Strength (VA) as defined in Section 4.2.2
- CA = Contextual influence
- IA = Interaction affordance strength

This multiplicative model reflects the interdependent nature of the components, where a significant deficiency in any one component can substantially reduce overall affordance effectiveness regardless of strengths in other areas. For example, even a display with strong visual and perceived affordances will be ineffective if contextual factors strongly inhibit interaction (e.g., if placed in an area where users are too rushed or distracted to engage).

The model provides a quantitative approach to evaluating and comparing different design options, allowing designers to identify specific areas for improvement and make data-driven decisions about design trade-offs. It also enables systematic testing of the relationship between affordance characteristics and engagement outcomes, providing a foundation for evidence-based design practices. The maximum possible score for the model is 187.5.

To illustrate the application of the mathematical model, consider two alternative designs for an interactive display in a university restaurant: Design A (a conventional text-based menu interface) and Design B (a visual card-based interface with enhanced graphics). We will use dummy values for the purpose of illustration.

Design A:

Visual Components:

Feature	**Score**
Form (F)	4/5
Color (C)	5/5
Size (S)	4/5
Contrast (C_t)	4/5
Animation (A)	3/5
Iconography (I)	5/5
Layout (L)	4/5
Weighted Average	**4.2/5**

Table 4.9: Visual Components for Design A

Perception Components:

Feature	**Score**
Discoverability (D)	4/5
Recognizability (R)	3/5
Feedback (F_b)	4/5
Consistency (C_n)	3/5
Learnability (L_n)	4/5
Mental model alignment (M)	3/5

Table 4.10: Perception Components for Design A

Contextual Factors:

Feature	**Score**
Physical environment (P_e)	1.2 (slightly facilitating)
Social context (S_c)	0.9 (slightly inhibiting)
Temporal factors (T_f)	0.8 (inhibiting)
User state (U_s)	1.0 (neutral)
Task context (T_c)	0.9 (slightly inhibiting)
Cultural factors (C_f)	1.1 (slightly facilitating)

Table 4.11: Contextual Factors for Design A

Interaction Components:

Feature	**Score**
Input modality (I_m)	4/5
Response time (R_t)	5/5
Interaction complexity (I_c)	4/5
Error tolerance (E_t)	3/5
Adaptability (A_d)	2/5
Engagement level (E_l)	4/5

Table 4.12: Interaction Components for Design A

Design B:

Visual Components:

Feature	**Score**
Form (F)	5/5
Color (C)	4/5
Size (S)	5/5
Contrast (C_t)	5/5
Animation (A)	4/5
Iconography (I)	4/5
Layout (L)	4/5
Weighted Average	**4.5/5**

Table 4.13: Visual Components for Design B

Perception Components:

Feature	**Score**
Discoverability (D)	5/5
Recognizability (R)	4/5
Feedback (F_b)	5/5
Consistency (C_n)	3/5
Learnability (L_n)	3/5
Mental model alignment (M)	4/5

Table 4.14: Perception Components for Design B

Contextual Factors:

Feature	**Score**
Physical environment (P_e)	1.2 (slightly facilitating)
Social context (S_c)	1.1 (slightly facilitating)
Temporal factors (T_f)	0.7 (strongly inhibiting)
User state (U_s)	1.0 (neutral)
Task context (T_c)	0.8 (inhibiting)
Cultural factors (C_f)	1.1 (slightly facilitating)

Table 4.15: Contextual Factors for Design B

Interaction Components:

Feature	**Score**
Input modality (I_m)	5/5
Response time (R_t)	4/5
Interaction complexity (I_c)	2/5
Error tolerance (E_t)	4/5
Adaptability (A_d)	3/5
Engagement level (E_l)	3/5

Table 4.16: Interaction Components for Design B

Calculating the affordance effectiveness for each design:

Design A:

- f(VA) = 4.2
- $PA = 4.2 \times (4 \times 3 \times 4 \times 3 \times 4 \times 3)^{\frac{1}{6}} = 4.2 \times 3.44 = 14.45$
- $CA = (1.2 \times 0.9 \times 0.8 \times 1.0 \times 0.9 \times 1.1)^{\frac{1}{6}} = 0.97$
- $IA = (4 \times 5 \times 4 \times 3 \times 2 \times 4)^{\frac{1}{6}} = 3.56$

- $OA = 14.45 \times 0.97 \times 3.56 = 49.85$

Design B:

- f(VA) = 4.5
- $PA = 4.5 \times (5 \times 4 \times 5 \times 3 \times 3 \times 4)^{\frac{1}{6}} = 4.5 \times 3.89 = 17.51$
- $CA = (1.2 \times 1.1 \times 0.7 \times 1.0 \times 0.8 \times 1.1)^{\frac{1}{6}} = 0.95$
- $IA = (5 \times 4 \times 2 \times 4 \times 3 \times 3)^{\frac{1}{6}} = 3.31$
- $OA = 17.51 \times 0.95 \times 3.31 = 54.97$

In this example, Design B achieves a higher overall affordance effectiveness (OA) score (54.97 vs. 49.85), representing a 10.3% improvement over Design A. This advantage stems primarily from Design B's superior perceived affordances (17.51 vs. 14.45), driven by excellent discoverability (5/5 vs. 4/5) and feedback effectiveness (5/5 vs. 4/5). Design B also benefits from better visual affordances (4.5/5 vs. 4.2/5), particularly in form effectiveness (5/5 vs. 4/5) and size optimization (5/5 vs. 4/5). However, the analysis reveals critical trade-offs between the designs. While Design A suffers from weaker recognizability (3/5) and mental model alignment (3/5), it compensates with simpler interaction complexity (effectively 4/5 vs. 2/5 for Design B) and better response time (5/5 vs. 4/5). Design B's enhanced visual appeal comes at the cost of increased interaction complexity, which may overwhelm users in time-pressured environments, evident by its stronger negative impact from temporal constraints (0.7 vs. 0.8 contextual factor). The contextual analysis further reveals that both designs face similar environmental challenges, with temporal factors being the primary inhibitor (0.8 and 0.7 respectively). Design B shows improved social context acceptance (1.1 vs. 0.9), suggesting its visual enhancements make it more socially acceptable for public use. This detailed breakdown enables designers to make targeted improvements: Design A could benefit from enhanced visual elements and better feedback mechanisms, while Design B requires simplification of interaction patterns to reduce cognitive load in fast-paced restaurant environments.

5 Experiments

This chapter presents the core empirical work of this thesis: a series of three field experiments conducted at the Flavoria restaurant. These experiments were designed to explore the practical application of the affordance-based model developed in Chapter 4 and to investigate how different communication strategies, implemented on interactive public screens, influence user engagement in a self-service restaurant (SSR) setting. The primary goal was to understand how to effectively communicate messaging and engage diners using these screens, with a secondary goal of promoting sustainability-related actions among diners. The experiments progressively increased interaction complexity, moving from passive information displays to active polling and finally to a two-way communicative sustainability pledge.

Each experiment involved developing and deploying a specific interface on large digital touch screens within Flavoria. In addition, a tablet kiosk next to lifts in the building was also used. Data was collected through system logs and supplementary surveys to understand user motivations and actions. The affordance-based model was applied to analyze the design of each experimental interface, providing a structured way to evaluate its potential effectiveness based on perceived, contextual, and interaction affordances. The results of each experiment are presented alongside the model analysis and raw data to demonstrate how key metrics were derived.

5.1 Experiment 1: Rush Information Screen (Passive Communication)

5.1.1 Experiment Design and Goals

The first experiment focused on passive communication, aiming to influence diner behavior without requiring any direct interaction. The goal was to reduce congestion during peak lunch hours by encouraging diners to either arrive earlier or later than the busiest period (11:00 to 12:30). An interface was designed to display the current estimated wait time and suggest less busy periods (between 10:30-11:00 as "Early Lunch" and 12:30-13:00 as "Late Lunch"). During busy times (estimated 10+ minutes wait), a prominent "Busy" indicator was displayed. The primary objective was to achieve a measurable shift (target: 5% increase) in the proportion of diners arriving during the Early Lunch slot (10:30-11:00) and Late Lunch slot (12:30 to 13:00) compared to a baseline[1] period. Random times in the Early Lunch and Late Lunch time range were shown to make the information feel realistic. Table 5.1 demonstrates the different states of the experiment at specific time intervals.

All the three experiments had Finnish as the default language and the option to switch to English, except for Experiment 1 where the language auto switched between Finnish and English almost every 60 seconds.

[1]Baseline Period: time in the past for benchmarking purposes before the experiment became live

Time	Status	Estimated Waiting Time	Reference Figure
10:30–11:00	Moderate	5 minutes	Figure 5.2
11:00–12:15	Busy	10+ minutes	Figure 5.3
12:15–12:30	Moderate	5 minutes	Figure 5.2
12:30–13:30	Quiet	0 minutes	Figure 5.4
13:30–10:30	Closed	N/A	Figure 5.1

Table 5.1: Estimated Waiting Times Throughout the Day

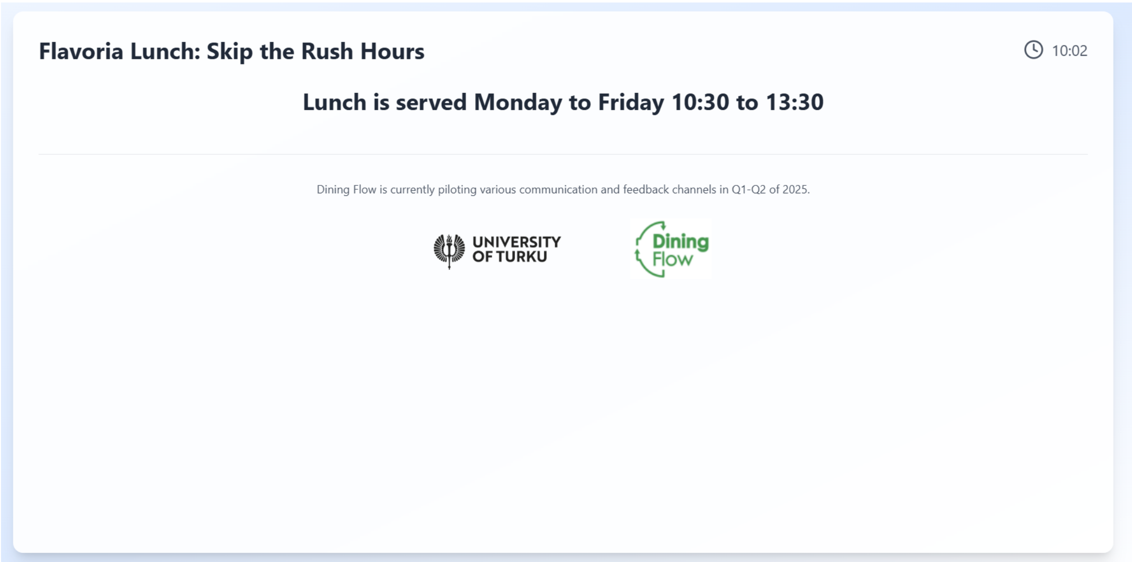

Figure 5.1: Experiment 1 – Closed State

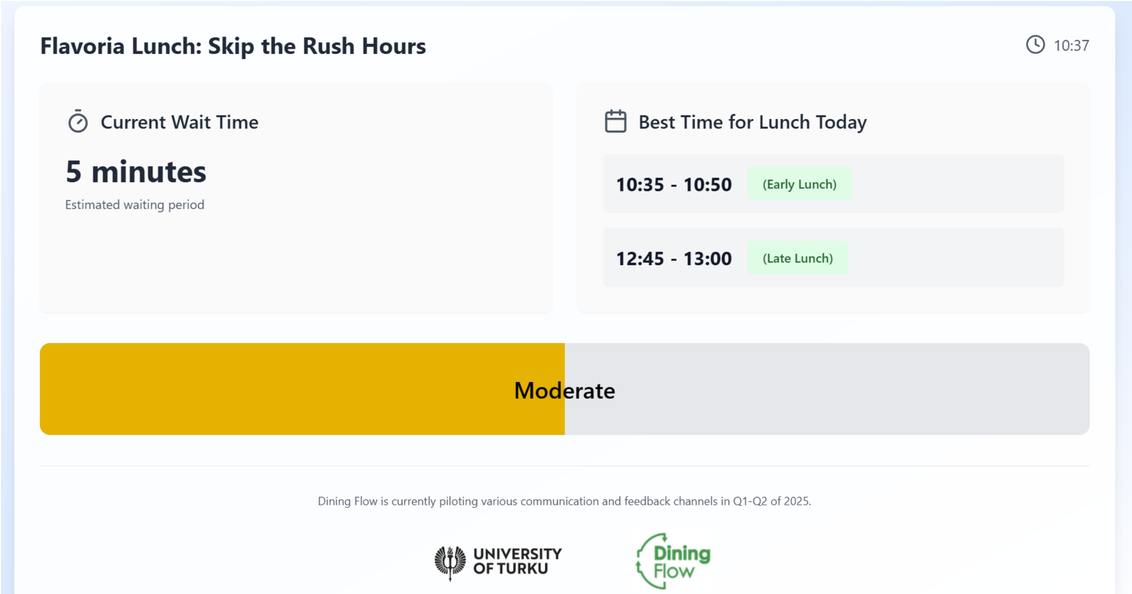

Figure 5.2: Experiment 1 – Moderate State

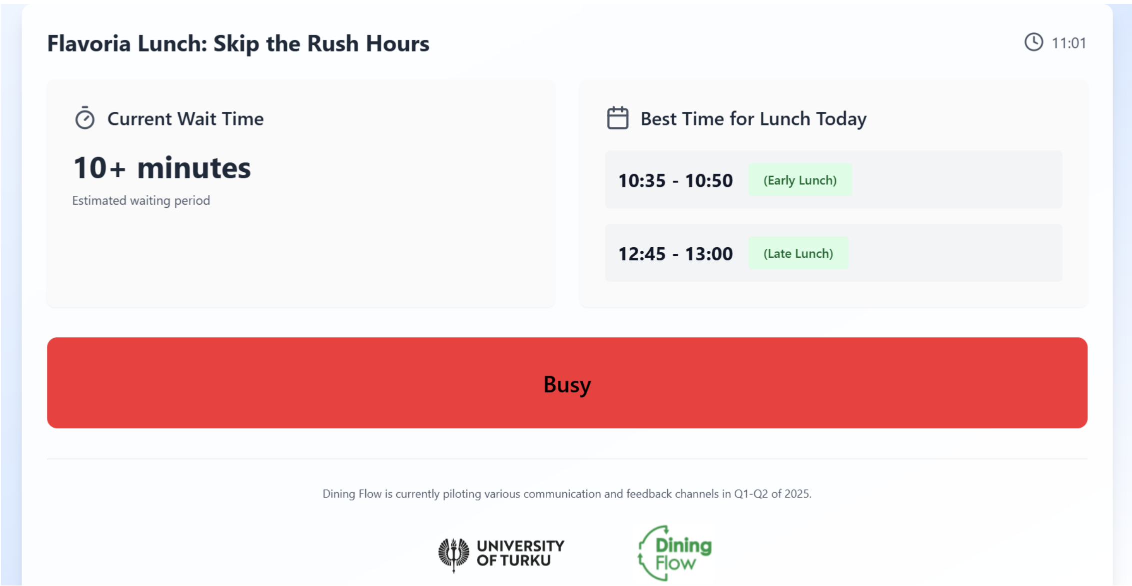

Figure 5.3: Experiment 1 – Busy State

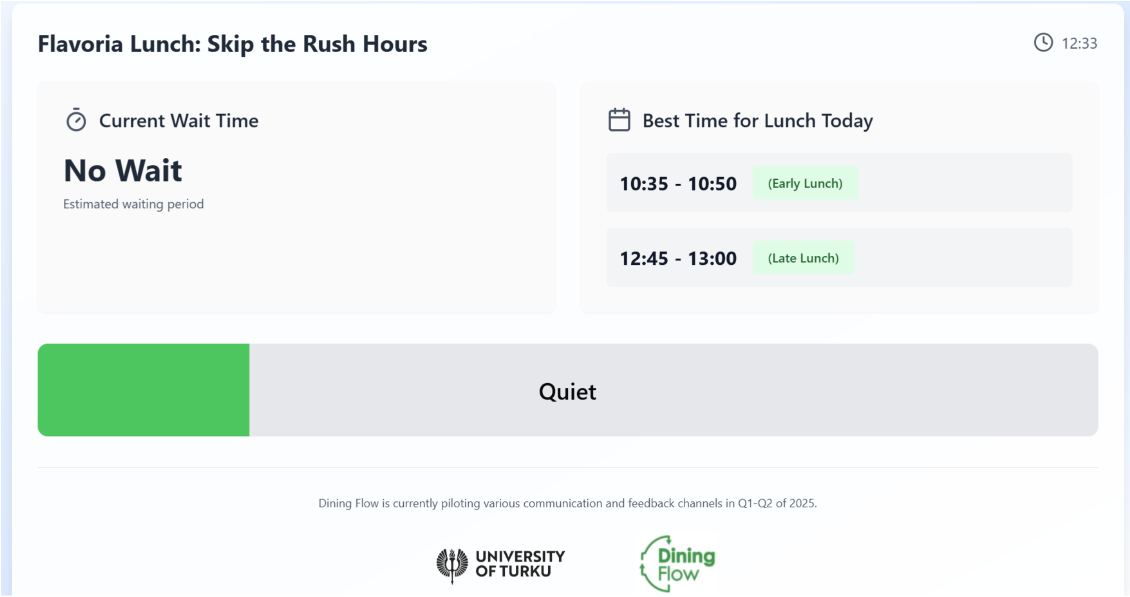

Figure 5.4: Experiment 1 - Quiet State

5.1.2 Affordance Model Application

The affordance-based model developed in Chapter 4 was applied to evaluate the design of the Rush Information Screen:

- **Visual Affordances (VA):** The design employed clear text, standard icons, good contrast, and a logical layout, resulting in a strong average visual affordance score ($VA \approx 3.29/5$). The detailed parameter assessment is shown in Table 5.3.

- **Perceived Affordances (PA):** The screen was discoverable and the information recognizable. Feedback was limited to data updates, but learnability was high (no interaction needed). This yielded a good perceived affordance score ($PA \approx 13.09$). The detailed parameter assessment is shown in Table 5.4.

- **Contextual Influence (CA):** The physical environment could be distracting, and users might be rushed. However, the information's high temporal relevance (just before lunch) and direct relation to the task (choosing lunch time) were facilitating factors. The overall contextual influence was estimated to be slightly facilitating ($CA \approx 1.06$). The detailed parameter assessment is shown in Table 5.5.

- **Interaction Affordances (IA):** As a passive display, interaction complexity was minimal (IC=5). However, input modality, response time, adaptability, and engagement level were inherently low due to the lack of interaction. This resulted in a low interaction affordance score ($IA \approx 1.76$). The detailed parameter assessment is shown in Table 5.6.

Component	**Estimated Score**
Visual Affordance (VA)	3.29
Perceived Affordance (PA)	13.09
Contextual Influence (CA)	1.06
Interaction Affordance (IA)	1.76
Overall Affordance (OA = PA x CA x IA)	**24.42**

Table 5.2: Affordance Model Score Summary - Experiment 1

Parameter	**Score**	**Reasoning**
Form Effectiveness	4/5	Clear text hierarchy, use of status bar and standard information display format immediately communicates informational purpose
Color Appropriateness	3/5	Standard color scheme with adequate contrast but limited use of attention-directing colors
Size Optimization	3/5	Text size appropriate for viewing distance but could be larger for better accessibility
Contrast Ratio	4/5	High contrast between text and background ensures good readability in various lighting
Animation Effectiveness	1/5	No animation used; static display lacks dynamic elements to draw attention
Iconography Clarity	4/5	Standard icons (clock, bar) immediately recognizable and contextually appropriate
Layout Optimization	4/5	Logical hierarchical layout with clear information grouping and visual flow
Average (VA)	**3.29/5**	

Table 5.3: Experiment 1: Scoring for Visual Affordances (VA) Parameters

Parameter	**Score**	**Reasoning**
Recognizability	4/5	Information display format immediately recognizable as dining hall status board
Discoverability	5/5	Prominent positioning and size make screen highly discoverable to approaching diners
Feedback Effectiveness	2/5	Limited to data updates only; no interactive feedback mechanisms available
Consistency	4/5	Consistent with standard informational displays found in institutional settings
Learnability	5/5	No learning required; immediate comprehension of displayed information
Mental Model Alignment	5/5	Aligns well with users' expectations of digital information boards
Geometric Mean (GM)	**3.98**	
PA = VA × GM	**3.29 × 3.98 = 13.09**	

Table 5.4: Experiment 1: Scoring for Perceived Affordances (PA) Parameters

Parameter	**Score**	**Reasoning**
Physical Environment	0.9	Potentially distracting dining hall environment with ambient noise and movement
Social Context	1.0	Neutral social factors; no privacy concerns for viewing public information
Temporal Factors	1.3	Highly facilitating as information is most relevant just before lunch periods
User State	1.0	Neutral user state; no special cognitive or physical demands for viewing
Task Context	1.2	Directly relevant to lunch planning and dining decisions
Cultural Factors	1.0	Culturally neutral information display appropriate for diverse university population
Geometric Mean (CA)	**1.06**	

Table 5.5: Experiment 1: Scoring for Contextual Affordances (CA) Parameters

Parameter	**Score**	**Reasoning**
Adaptability	1/5	No adaptive features; static display cannot adjust to user needs or preferences
Response Time	1/5	Not applicable for passive display; no user-initiated interactions possible
Input Modality Appropriateness	1/5	No input modalities available; purely passive information consumption
Error Tolerance	3/5	No interaction errors possible, but also no error recovery mechanisms
Interaction Complexity	5/5	Minimal complexity due to complete absence of interactive elements
Engagement Level Appropriateness	2/5	Low engagement appropriate for informational display but limits user involvement
Geometric Mean (IA)	**1.76/5**	

Table 5.6: Experiment 1: Scoring for Interaction Affordances (IA) Parameters

The overall affordance score ($OA \approx 24.42$ out of a theoretical maximum of 187.5) is relatively low, primarily dragged down by the minimal interaction affordances inherent in a passive display. While perception was good and context slightly helpful, the lack of engaging interaction limited the design's potential effectiveness according to the model. A summary of scores for the model components is given in Table 5.2.

5.1.3 Results

The experiment ran from March 3rd to March 14th, 2025, following a baseline data collection period (February 17th-28th). Diner arrival times were logged automatically. Table 5.2 shows the distribution of diners across 15-minute intervals during the baseline and experiment periods.

Time Slot	**Baseline % (Feb 17–28)**	**Experiment % (Mar 3–14)**	**Change (%)**
10:30–10:45	5.4%	6.7%	+1.3%
10:45–11:00	4.4%	6.3%	+1.9%
10:30–11:00 Total	**9.8%**	**13.0%**	**+3.2%**

Table 5.7: Experiment 1 Results (10:30–11:00)

Time Slot	**Baseline % (Feb 17–28)**	**Experiment % (Mar 3–14)**	**Change (%)**
12:30–12:45	8.0%	7.4%	-0.6%
12:45–13:00	6.8%	5.3%	-1.5%
12:30–13:00 Total	**14.8%**	**12.7%**	**-2.1%**

Table 5.8: Experiment 1 Results (12:30–13:00)

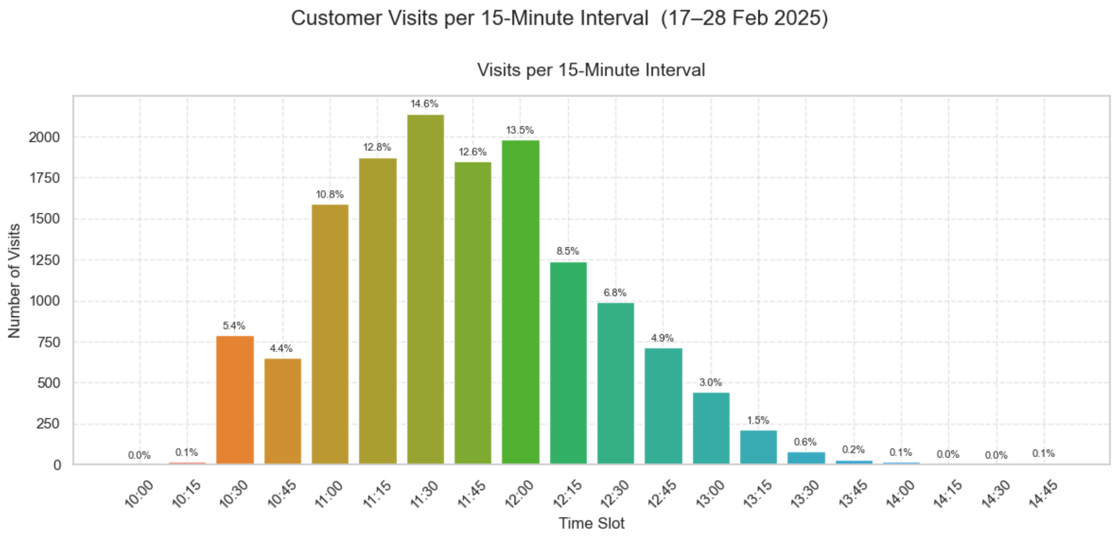

Figure 5.5: Experiment 1 - Diner Distribution by time - Feb 17 to Feb 28, 2025

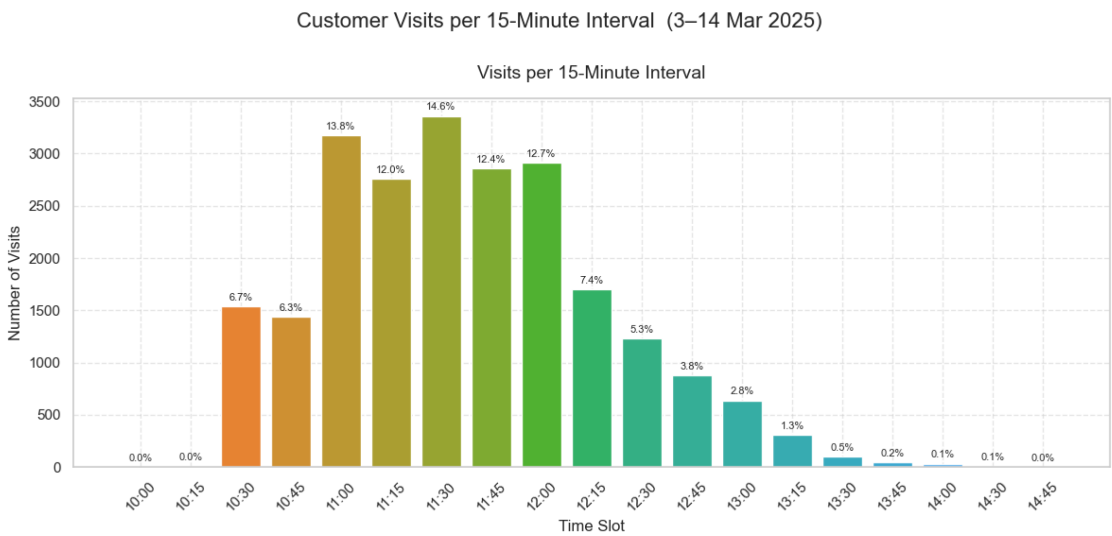

Figure 5.6: Experiment 1 - Diner Distribution by time - Mar 3 to Mar 14, 2025

The primary metric was the change in the percentage of diners arriving between 10:30 - 11:00 and 12:30 - 13:00. This was calculated by summing the percentages for the 10:30-10:45 and 10:45-11:00 for Early Lunch and 12:30-12:45 and 12:45-13:00

for Late Lunch slots in both periods and finding the difference as shown in Table 5.1 and Table 5.2 respectively.

The experiment resulted in a 3.2% increase in diners arriving during the targeted Early Lunch slot. While this indicates some influence, it fell short of the 5% target. Correspondingly, there was a 2.1% decrease in arrivals during the later 12:30-13:00 period.

A survey (N=322) explored motivations for interacting (Table 5.5). The survey question was: "Which aspects of the screen's information were relevant to you?"

Information Aspect	**Count**	**Percentage (%)**
Current wait time	102	31.7%
Suggested times for lunch	87	27.0%
Progress bar showing current rush	90	28.0%
No input required from me	76	23.6%
Location of the screen	73	22.7%
Nothing in particular	75	23.3%

Table 5.9: Experiment 1 Survey - Motivations for Giving Feedback (N = 322)

Note: Multiple selections allowed.

The results show that the core information (wait time, suggested times, rush level) was considered relevant by roughly a quarter to a third of respondents. The fact that no input was required was also noted as relevant by nearly a quarter, suggesting an appreciation for the passive nature in some users.

5.1.4 Discussion

Experiment 1 demonstrated that passive information display could influence action from diners, achieving a 3.2% shift towards the desired early lunch period. However, it did not meet the 5% target, suggesting limitations to this approach. The Late

Lunch also represents a decrease in number of people during the experiment rather than an increase, which can be attributed to low relevance of Late Lunch or diners unable to change their lunch times to a later slot.

The low overall affordance score ($OA \approx 24.42$), particularly the low interaction affordance ($IA \approx 1.76$), aligns with this outcome. While the information was perceived well and contextually relevant, the lack of active engagement may have limited its persuasive impact. The challenge of capturing attention and influencing decisions passively remains.

5.2 Experiment 2: Intentions Poll (Active Communication)

5.2.1 Experiment Design and Goals

Building on the findings from Experiment 1 and insights from the initial survey about user motivations (favoring instant actionable messaging - current wait times), Experiment 2 introduced active communication (requiring input from users). The goal was to gauge diner intentions to eat in Flavoria ("Are you eating at Flavoria today?") and gather data to potentially improve demand forecasting and reduce food waste in the future. The interface presented a simple question with two large, tappable buttons: YES and NO. The primary goal was to achieve a daily interaction rate (percentage of diners interacting, specifically those answering YES) of at least 5%.

Figure 5.7 represents a screenshot of the design for this experiment.

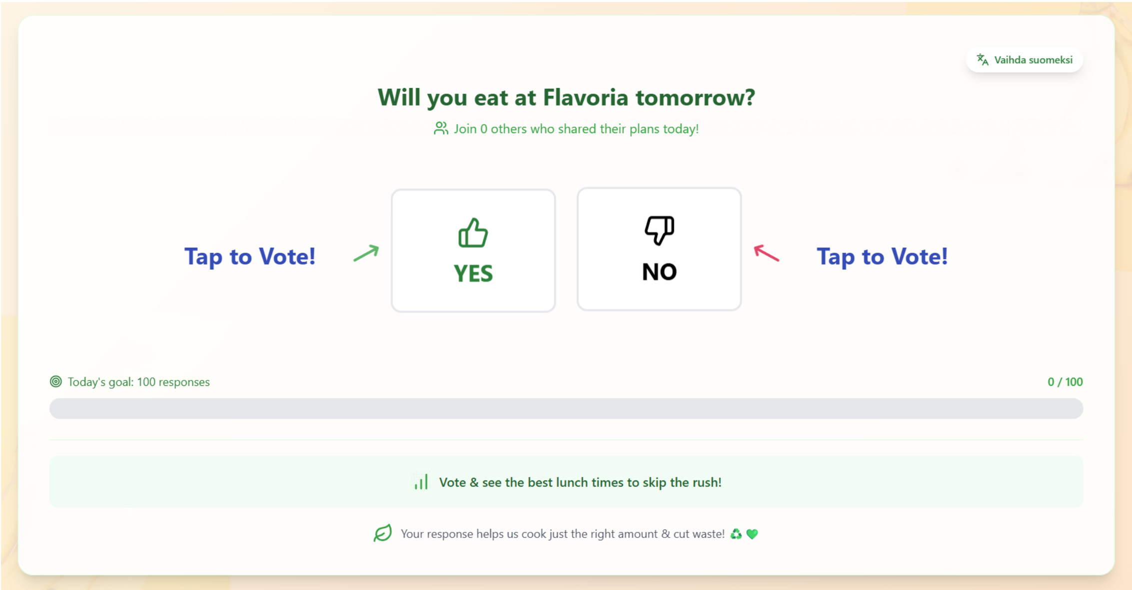

Figure 5.7: Experiment 2 Screen

5.2.2 Affordance Model Application

The affordance-based model developed in Chapter 4 was applied to evaluate the design of the Intentions Poll interface.

- **Visual Affordances (VA):** Large, clear buttons with standard icons and high contrast contributed to a strong visual score ($VA \approx 4.0/5$). The detailed parameter assessment is shown in Table 5.11.
- **Perceived Affordances (PA):** The simple poll format was highly recognizable and learnable. Immediate feedback (visual change, counter update) was provided. This led to a high perceived affordance score ($PA \approx 17.24$). The detailed parameter assessment is shown in Table 5.12.
- **Contextual Influence (CA):** The quick interaction minimized disruption in the busy environment. The task was relevant, and social stigma was low. Contextual influence was slightly facilitating ($CA \approx 1.03$). The detailed parameter

assessment is shown in Table 5.13.

- **Interaction Affordances (IA):** Simple touch input, immediate response, and very low complexity were strengths. However, the interaction was not adaptive. The engagement level was higher than passive viewing but still relatively simple. This resulted in a moderate interaction affordance score ($IA \approx 3.62$). The detailed parameter assessment is shown in Table 5.14.

Component	**Estimated Score**
Visual Affordance (VA)	4.0
Perceived Affordance (PA)	17.24
Contextual Influence (CA)	1.03
Interaction Affordance (IA)	3.62
Overall Affordance (OA = PA x CA x IA)	**64.28**

Table 5.10: Estimated Scores for Affordance Components

Parameter	**Score**	**Reasoning**
Form Effectiveness	5/5	Large, clear buttons immediately communicate interactive voting functionality
Color Appropriateness	4/5	Strong color distinction between YES/NO options with good accessibility compliance
Size Optimization	4/5	Button size optimized for touch interaction with adequate spacing
Contrast Ratio	4/5	High contrast ensures visibility across different lighting conditions
Animation Effectiveness	4/5	Animated used for voting buttons and "Click to Vote" messaging
Iconography Clarity	4/5	Standard icons (Thumbs Up and Thumbs Down) universally recognizable
Layout Optimization	3/5	Simple two-button layout functional but basic in visual hierarchy
Average (VA)	**4.0/5**	

Table 5.11: Experiment 2: Scoring for Visual Affordances (VA) Parameters

Parameter	**Score**	**Reasoning**
Recognizability	5/5	Voting interface pattern immediately recognizable from familiar polling systems
Discoverability	5/5	Prominent buttons and clear call-to-action make interaction highly discoverable
Feedback Effectiveness	4/5	Immediate visual feedback through button state changes and counter updates
Consistency	4/5	Consistent with standard polling interfaces and voting paradigms
Learnability	4/5	Simple interaction pattern learned immediately with minimal cognitive load
Mental Model Alignment	4/5	Aligns well with users' mental models of voting and opinion polling
Geometric Mean (GM)	**4.31**	
PA = VA × GM	**4.0 × 4.31 = 17.24**	

Table 5.12: Experiment 2: Scoring for Perceived Affordances (PA) Parameters

Parameter	**Score**	**Reasoning**
Physical Environment	1.0	Adequate screen positioning with manageable environmental distractions
Social Context	1.1	Slightly facilitating due to low social stigma and visible participation by others
Temporal Factors	1.0	Quick interaction minimizes disruption during busy dining periods
User State	1.1	Positive user state for brief, low-commitment engagement
Task Context	1.0	Relevant to sustainability awareness but not directly tied to immediate dining tasks
Cultural Factors	1.0	Culturally appropriate for diverse university population
Geometric Mean	**1.03**	

Table 5.13: Experiment 2: Scoring for Contextual Affordances (CA) Parameters

Parameter	**Score**	**Reasoning**
Adaptability	2/5	Basic feedback mechanisms but no personalization or adaptive features
Response Time	5/5	Immediate response to touch input with instant visual feedback
Input Modality Appropriateness	5/5	Touch input perfectly suited for simple binary choice interaction
Error Tolerance	3/5	Clear choices reduce errors but no undo mechanism for accidental selections
Interaction Complexity	5/5	Optimal complexity for simple voting task; no unnecessary complications
Engagement Level Appropriateness	3/5	Moderate engagement appropriate for quick opinion polling
Geometric Mean (IA)	**3.62/5**	

Table 5.14: Experiment 2: Scoring for Interaction Affordances (IA) Parameters

The overall affordance score ($OA \approx 64.28$) is considerably higher than Experiment 1, reflecting the introduction of well-designed active interaction. The model suggests this design has significantly better potential for engagement. A summary of scores for the model components is given in Table 5.10.

5.2.3 Results

The experiment ran from March 17th to March 28th, 2025. Interaction data (total interactions, YES/NO counts) and total diner numbers were logged daily (Table 5.5).

Date	**Diners**	**Interactions**	**Said YES**	**Said NO**	**% YES to Diners**
17 Mar 2025	782	60	34	26	4.35%
18 Mar 2025	673	60	32	28	4.75%
19 Mar 2025	762	112	77	35	10.10%
20 Mar 2025	572	84	37	47	6.47%
21 Mar 2025	631	70	45	25	7.13%
24 Mar 2025	785	68	42	26	5.35%
25 Mar 2025	665	60	31	29	4.66%
26 Mar 2025	756	62	37	25	4.89%
27 Mar 2025	593	72	30	42	5.06%
28 Mar 2025	564	74	45	29	7.98%
Totals	**6783**	**722**	**410**	**312**	**Avg: 6.04%**

Table 5.15: Experiment 2 Daily Interaction Data (March 17–28, 2025)

The key metric, "% YES Interactions to Diners," was calculated daily as `(Number who said YES / Number of Diners) * 100`. For example, on March 19th: `(77 / 762) * 100 = 10.10%`.

The average daily interaction rate over the experiment period was 6.04%. This successfully met and exceeded the 5% target. Interaction rates varied daily, peaking at 10.10%.

A survey (N=658) explored motivations for interacting (Table 5.8). The survey question was: "What motivates you to give feedback on a restaurant screen? Choose all that apply."

Motivation	**Count**	**Percentage (%)**
Give instant feedback with one tap	261	39.7%
Improve my dining experience	195	29.6%
Engage in playful interactions	160	24.3%
Support food sustainability efforts	127	19.3%
See the impact of my choice	101	15.3%
Know how many participated	15	2.3%
I avoid touching screens	21	3.2%
None of the above	95	14.4%

Table 5.16: Experiment 2 Survey - Motivations for Interacting (N = 658)

Note: Multiple selections allowed.

The primary motivators were the ease of giving instant feedback (39.7%), improving the dining experience (29.6%), and engaging in playful interactions (24.3%). Supporting sustainability was also a notable factor (19.3%). These insights were valuable for validating what aspects of the screen worked well, as well as, what aspects to take care of when designing the subsequent experiment.

5.2.4 Discussion

Experiment 2 successfully demonstrated the effectiveness of simple active communication. The 6.04% average interaction rate significantly surpassed the outcome of Experiment 1 and met the target, aligning with the higher affordance score predicted by the model ($OA \approx 64.28$). The ease of interaction (single tap), animations (bouncing buttons - playfulness) and instant feedback reflected in the design were key drivers, as confirmed by the survey. This highlights the importance of strong interaction affordances ($IA \approx 3.62$) compared to the passive display ($IA \approx 1.76$). The results suggest that even simple active engagement can be substantially more effective than passive information display for capturing user attention and eliciting a response in an SSR environment.

5.3 Experiment 3: Food Waste Pledge (Two-Way Communication)

5.3.1 Experiment Design and Goals

Experiment 3 implemented a two-way communication strategy focused on reducing food waste. The interface invited users to slice off relatable food items, tomatoes (Figure 5.8), bread (Figure 5.9), and pizza (Figure 5.10), using a digital knife and then pledge (Figure 5.11) to take only as much food as they could eat. This reflected playfulness and instant feedback insights we gained from Experiment 2. Information on flavoria's food waste was shared after the gesture to add to the narrative. The design incorporated social proof (displaying the number of pledgers). The goals were to achieve an initial interaction rate between 5-10% of daily diners and a pledge completion rate (percentage of those who started the interaction and completed the pledge) of at least 50%.

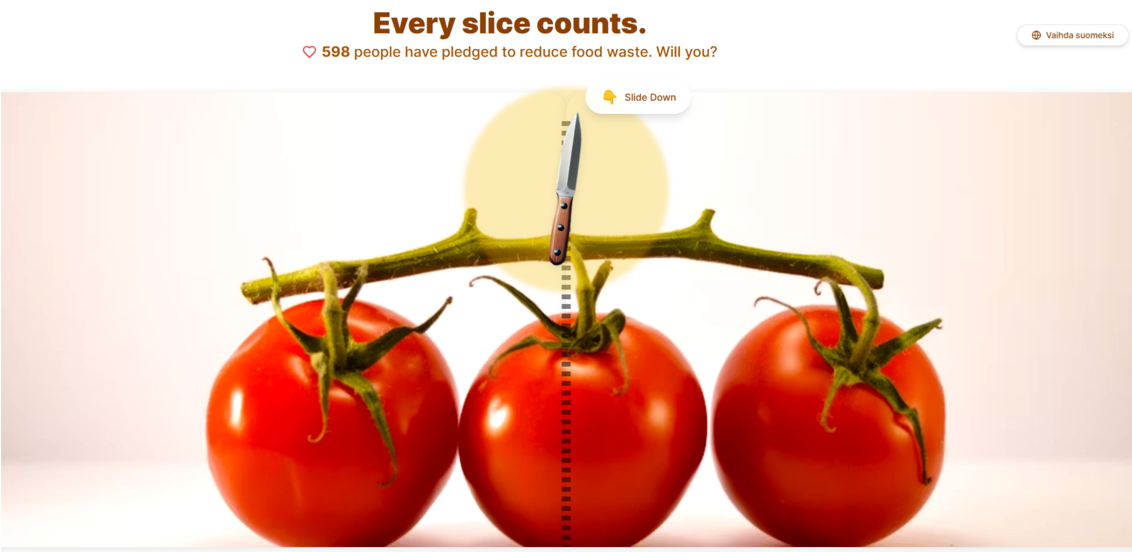

Figure 5.8: Experiment 3 - Step 1 - Tomatoes

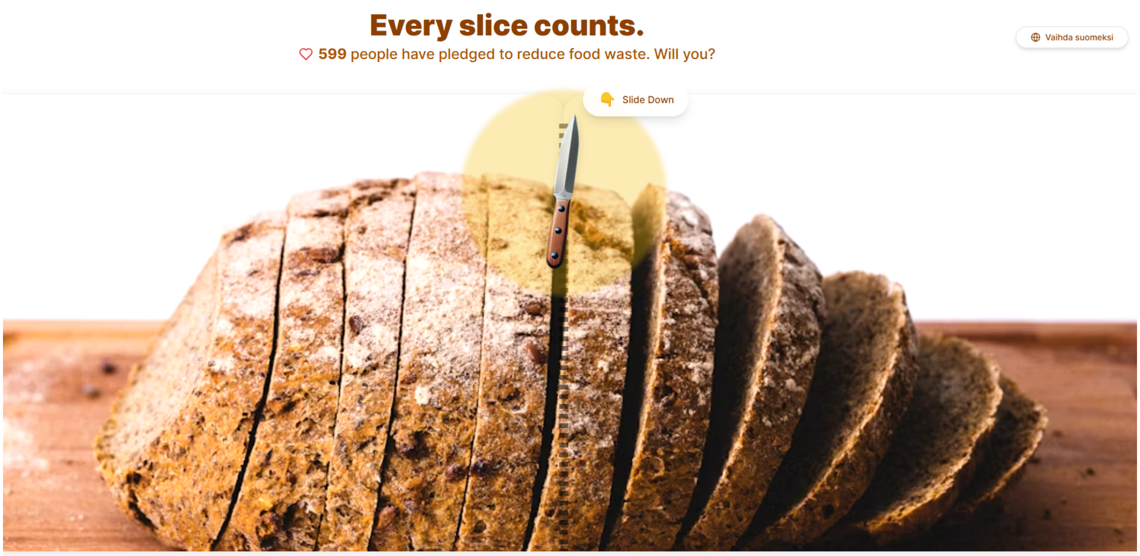

Figure 5.9: Experiment 3 - Step 1 - Bread

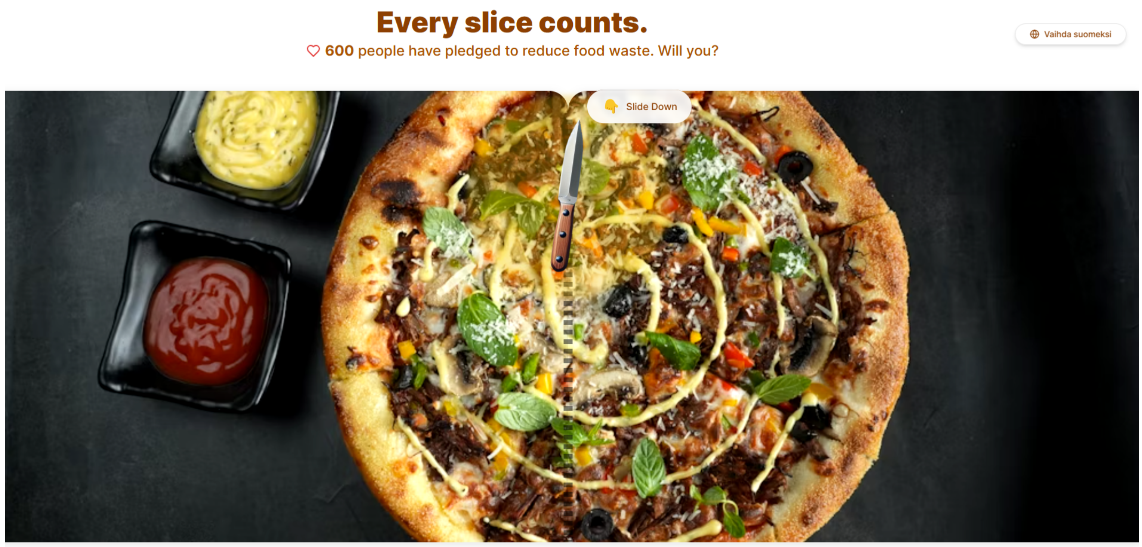

Figure 5.10: Experiment 3 - Step 1 - Pizza

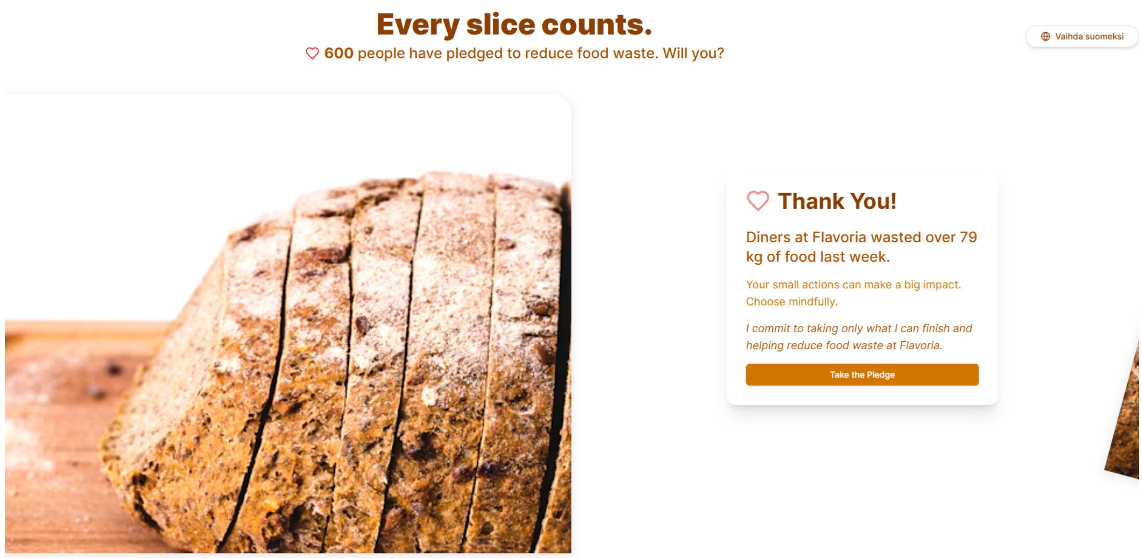

Figure 5.11: Experiment 3 - Step 2 - Bread (Same applies to Tomatoes and Pizza)

5.3.2 Affordance Model Application

The affordance-based model developed in Chapter 4 was applied to evaluate the design of the Food Waste Pledge Screen.

- **Visual Affordances (VA):** Engaging imagery, clear elements, and animation resulted in a good visual score ($VA \approx 4.0/5$). The detailed parameter assessment is shown in Table 5.18.

- **Perceived Affordances (PA):** Discoverability was good, but the novel slicing interaction slightly reduced recognizability and learnability compared to the simple poll. Strong multi-step feedback and social proof were positives. The perceived affordance score ($PA \approx 15.64$) was good, but slightly lower than Experiment 2 ($PA \approx 17.24$). The detailed parameter assessment is shown in Table 5.19.

- **Contextual Influence (CA):** The interaction took slightly longer, potentially impacted by the busy environment. However, the visible social proof and relevance to sustainability values were facilitating. Contextual influence was estimated as slightly facilitating ($CA \approx 1.06$). The detailed parameter assessment is shown in Table 5.20.

- **Interaction Affordances (IA):** The novel gesture input was engaging but less standard and potentially less error-prone as only single option (gesture of slicing) vs the two options in Experiment 2. The two-step process increased complexity (IC=2). Adaptability (progress indication, social proof) and engagement level (playful, meaningful) were higher than in Experiment 2. This resulted in a higher interaction affordance score ($IA \approx 3.98$). The detailed parameter assessment is shown in Table 5.21.

Component	**Estimated Score**
Visual Affordance (VA)	4.0
Perceived Affordance (PA)	15.64
Contextual Influence (CA)	1.06
Interaction Affordance (IA)	3.98
Overall Affordance (OA = PA x CA x IA)	**65.98**

Table 5.17: Affordance Model Score Summary - Experiment 3

Parameter	**Score**	**Reasoning**
Form Effectiveness	4/5	Engaging food imagery and clear interactive elements communicate slicing functionality
Color Appropriateness	4/5	Vibrant, appealing colors that enhance food imagery and maintain accessibility
Size Optimization	5/5	Optimal sizing for gesture interaction with adequate touch targets
Contrast Ratio	4/5	Good contrast between interactive elements and background imagery
Animation Effectiveness	4/5	Effective slicing animation provides clear feedback and enhances engagement
Iconography Clarity	4/5	Food imagery and slicing metaphor intuitive though novel in digital context
Layout Optimization	3/5	Two-step layout guides users but could be more streamlined
Average (VA)	**4.0/5**	

Table 5.18: Experiment 3: Scoring for Visual Affordances (VA) Parameters

Parameter	**Score**	**Reasoning**
Recognizability	3/5	Novel slicing interaction reduces immediate recognition compared to standard patterns
Discoverability	5/5	Engaging visuals and clear prompts make interaction highly discoverable
Feedback Effectiveness	5/5	Excellent multi-step feedback with visual progress and social proof elements
Consistency	3/5	Less consistent with standard interfaces due to novel gesture interaction
Learnability	4/5	Requires brief learning period for gesture interaction but intuitive metaphor helps
Mental Model Alignment	4/5	Slicing metaphor is intuitive in dining context
Geometric Mean (GM)	**3.91**	
PA = VA × GM	**4.0 × 3.91 = 15.64**	

Table 5.19: Experiment 3: Scoring for Perceived Affordances (PA) Parameters

Parameter	**Score**	**Reasoning**
Physical Environment	1.0	Standard dining hall environment adequate for slightly longer interaction
Social Context	1.2	Facilitating due to visible social proof and positive peer influence on sustainability
Temporal Factors	0.9	Slightly inhibiting due to longer interaction time during busy periods
User State	1.1	Positive user state for engaging, meaningful interaction
Task Context	1.2	Relevant to sustainability values and food waste awareness
Cultural Factors	1.0	Culturally appropriate sustainability messaging for university population
Geometric Mean	**1.06**	

Table 5.20: Experiment 3: Scoring for Contextual Affordances (CA) Parameters

Parameter	**Score**	**Reasoning**
Adaptability	5/5	Good adaptive features including progress indication and social proof
Response Time	5/5	Excellent response to gesture input with immediate visual feedback
Input Modality Appropriateness	4/5	Gesture input engaging and appropriate though less standard than touch
Error Tolerance	4/5	Minimal chances of error as only single gesture (slicing) required
Interaction Complexity	2.5/5	Complex due to two-step process and novelty but intuitive
Engagement Level Appropriateness	4/5	High engagement level appropriate for meaningful sustainability interaction
Average	**3.98/5**	

Table 5.21: Experiment 3: Scoring for Interaction Affordances (IA) Parameters

The overall affordance score ($OA \approx 65.98$) was slightly higher than Experiment 2. While perceived affordance was marginally lower due to the novel interaction, the increased engagement and adaptability within the interaction affordance component slightly boosted the overall score. The model predicted this design would be similarly or slightly more effective than the simple poll. A summary of scores for the model components is given in Table 5.17.

5.3.3 Results

The experiment ran from April 14th to April 28th, 2025 (excluding holidays). Please note that 18 April 2025 and 21 April 2025 were Easter holidays and therefore have been excluded. System logs tracked the number of diners initiating the interaction (1st interaction) and those completing the pledge (2nd interaction). Daily data is shown in Table 5.10.

Date	**Diners**	**1st Interactions**	**2nd Interactions (Pledge)**	**% 1st / Diners**	**% 2nd / 1st**
14 Apr 2025	635	54	37	8.50%	68.52%
15 Apr 2025	665	47	29	7.07%	61.70%
16 Apr 2025	657	37	22	5.63%	59.46%
17 Apr 2025	389	57	42	14.65%	73.68%
22 Apr 2025	646	43	17	6.66%	39.53%
23 Apr 2025	591	45	24	7.61%	53.33%
24 Apr 2025	771	37	16	4.80%	43.24%
25 Apr 2025	555	64	33	11.53%	51.56%
28 Apr 2025	632	31	10	4.91%	32.26%
Totals	**5541**	**415**	**230**	**Avg: 7.49%**	**Avg: 55.42%**

Table 5.22: Experiment 3 Daily Interaction Data (April 14–28, 2025)

Key metrics were calculated as follows:

- **Daily % 1st Interaction** $= \left(\frac{\text{Number of 1st Interactions}}{\text{Number of Diners}}\right) \times 100$
- **Daily % Pledge Completion** $= \left(\frac{\text{Number of 2nd Interactions}}{\text{Number of 1st Interactions}}\right) \times 100$
- **Overall Average % 1st Interaction** $= 7.49\%$ (Average of daily percentages)
- **Overall % Pledge Completion** $= \left(\frac{\text{Total 2nd Interactions}}{\text{Total 1st Interactions}}\right) \times 100 = \left(\frac{230}{415}\right) \times 100 = 55.42\%$

The average initial interaction rate was 7.49%, falling within the 5-10% target range. The overall pledge completion rate was 55.42%, exceeding the 50% target.

A survey (N=123) explored motivations for interacting (Table 5.11). The survey question was: "What elements of an interactive display would encourage you to engage while walking by? Choose all that apply."

Motivations	**Count**	**Percentage**
Messaging that connects to my personal values	31	25.2%
Visuals that create an emotional impact	11	8.9%
Interactions that relate to real-life	25	20.3%
Knowing the impact of my input	40	32.5%
Interact with a screen in different ways than pushing a button	18	14.6%
See what happens after I interact with a screen	23	18.7%
None of the above	45	36.6%

Table 5.23: Experiment 3 Survey - Motivations for Interacting (N = 123)

Note: Multiple selections allowed

The primary motivators were knowing the impact of input (32.5%) and connection to personal values (25.2%). It must be noted that number of participants to this survey was low (N=123) due to holiday season and therefore holds low statistical significance. This particular survey was very long and combined with survey questions of another experiment in parallel and the high number of "None of the above" may be attributed to the length of this survey. With that said, as the last experiment, the results of this survey are not used in any follow-up experiments in the context of this thesis.

5.3.4 Discussion

Experiment 3 successfully engaged users in a more complex, two-way interaction focused on a sustainability goal. Both target metrics were met: the initial interaction rate (7.49%) was comparable to the simpler poll in Experiment 2, and the pledge completion rate (55.42%) was strong, indicating that users who started the interaction were likely to follow through. This outcome aligns well with the high affordance score predicted by the model ($OA \approx 65.98$). Despite the slightly increased complexity and novelty of the interaction compared to Experiment 2, the engaging nature, clear feedback, social proof, and alignment with user values (sustainability) contributed to its success. This suggests that more complex, meaningful interactions can be effective in SSR environments if designed carefully, leveraging factors like playfulness and value alignment to maintain engagement through multiple steps.

5.4 Cross-Experiment Analysis

Comparing the three experiments reveals a clear trend: increasing the level of interaction and engagement, guided by the affordance model, led to a communication that triggered higher user participation rates. Table 5.24 summarizes the results of the three experiments.

Experiment	**Communication Type**	**Key Result Metric**	**Result Achieved**	**Target Met?**	**Affordance Score (OA)**
1: Rush Screen	Passive	% Shift to Early Lunch and Late Lunch (Target: 5%)	+3.2% and -2.1%	No	24.42
2: Intentions Poll	Active	Avg. Daily Interaction % (Target: 5%)	6.04%	Yes	64.28
3: Food Waste Pledge (Initial Interaction)	Two-Way	Avg. Daily Interaction % (Target: 5-10%)	7.49%	Yes	65.98
3: Food Waste Pledge (Pledge Completion)	Two-Way	Overall Completion % (Target: 50%)	55.42%	Yes	Same as Initial Interaction (65.98)

Table 5.24: Summary of Experiment Results and Model Scores

The Rush screen (Experiment 1) had the lowest affordance score and failed to meet its target. Introducing simple active interaction (Experiment 2) dramatically increased the affordance score and successfully met its engagement target. Further increasing interaction complexity while further adding engagement elements like playfulness and value alignment (Experiment 3) maintained a high initial interaction rate and achieved a high completion rate for the second step, aligning with the highest affordance score.

6 Discussion

This chapter synthesizes the findings from the Flavoria experiments presented in Chapter 5, interpreting the results within the broader context of the research goals and the affordance-based model developed in Chapter 4. The primary aim was to develop and evaluate the model's utility in designing screens for diners' engagement in self-service restaurant (SSR) environments (RQ1) and explore communication strategies in the context of SSRs to trigger user driven actions (RQ2).

Furthermore, this discussion will reflect on the contributions of this work to the field of Human-Computer Interaction (HCI), particularly concerning the design and evaluation of interactive public displays.

6.1 RQ1: Integrating Theories for a Quantifiable Model

RQ1: How insights from affordance theory, human-computer interaction, and persuasive technology are integrated to build a comprehensive quantifiable model for designing interactive screens in public Self-Service dining environments?

Chapter 4 detailed the development of the affordance-based model, which directly addresses RQ1. The model integrates key concepts from several theoretical domains:

1. **Affordance Theory:** The model fundamentally synthesizes affordance theory for digital public displays by operationalizing Gibson's ecological psychology

principles [1], Norman's design-oriented affordance concepts [2], Gaver's technology affordances [23] and contemporary developments in affordance theory (refer to Section 2.1.4). Rather than treating affordances as abstract relational properties, the model decomposes them into measurable components. Visual affordances capture the immediate perceptual cues that suggest interaction possibilities, incorporating form effectiveness, color appropriateness, size optimization, contrast ratios, animation effectiveness, iconography clarity, and layout optimization.

The model's treatment of Perceived Affordances represents a theoretical contribution, as it bridges Gibson's [1] ecological affordances with Norman's [2] perceived affordances through quantifiable parameters. By measuring recognizability, discoverability, feedback effectiveness, consistency, learnability, and mental model alignment, the model provides a structured approach to evaluating how successfully an interface communicates its interaction possibilities to users.

2. **Human-Computer Interaction (HCI) in Public Spaces:** The integration of HCI principles specifically addresses the unique challenges of public display interaction, where traditional usability heuristics must be adapted for brief, often interrupted interactions in complex environments. The model incorporates established HCI principles—including public interaction, attention capture and maintenance, and engagement models (refer Section 2.2)—while recognizing that public displays require different evaluation criteria than traditional desktop or mobile interfaces.

   The Contextual Affordance component represents a novel contribution to HCI literature by systematically quantifying environmental influences on interface effectiveness. By measuring physical environment factors, social context influences, temporal constraints, user state variations, task context relevance, and cultural appropriateness, the model addresses a critical gap in public display design where contextual factors are often acknowledged but but difficult to systematically evaluate.

3. **Persuasive Technology):** The model's integration of persuasive technology principles addresses the reality that many public displays aim to influence user action rather than simply provide information or entertainment. By incorporating elements from the Elaboration Likelihood Model **Cacioppo1984**, Nudge Theory [44], and Self-Determination Theory [47] within the Interaction Affordance component, the model provides a tool for evaluating persuasive effectiveness alongside traditional usability metrics.

   This integration is particularly evident in the model's treatment of engagement level appropriateness, adaptability features, and error tolerance mechanisms, which collectively support persuasive goals while maintaining user autonomy and positive experience. The model recognizes that effective persuasion in public contexts requires careful balance between influence and user agency.

Quantification: The model achieves quantification by assigning scores (typically 1-5 for perceptual/interaction factors, 0.5-1.5 for contextual factors) to each sub-component based on design analysis and heuristics. These scores are then combined using geometric means and multiplicative formulas (`OA = PA × CA × IA`) to produce an overall affordance effectiveness score (OA). This quantification, while based on estimations, provides a structured way to compare different designs and understand the relative strengths and weaknesses related to affordance perception and interaction potential, as demonstrated in the Chapter 5 analysis (e.g., comparing $OA \approx 24.42$ for Experiment 1, $OA \approx 64.28$ for Experiment 2, and $OA \approx 65.98$ for Experiment 3).

Therefore, RQ1 is addressed through the systematic integration of these theoretical insights into a structured, quantifiable model specifically tailored for designing and evaluating interactive screens in the complex context of SSR environments.

6.2 RQ2: Utilizing the Model for Different Interaction Levels

RQ2: How a model for designing interactive screens based on its affordances is utilized when designing different levels of communication interaction (passive, active, and two-way) on interactive public screens to support user-driven actions?

The three experiments conducted at Flavoria directly explored the application of the affordance-based model across different interaction levels, addressing RQ2:

Passive Communication (Experiment 1 - Rush Meter [Section 5.1]): The model was used to analyze a design focused on conveying information without requiring direct user input. The analysis highlighted relatively lower scores for Interaction Affordance ($IA \approx 1.76$) due to the lack of direct manipulation or feedback loops beyond information display. While Perceived Affordance ($PA \approx 13.09$) was reasonable, the overall score ($OA \approx 24.42$) was the lowest, reflecting the limited engagement potential. The results (+3.2% and -2.1% shift in diners) showed some impact, but the model accurately predicted its lower effectiveness compared to more interactive designs. This demonstrates the model's utility in identifying the limitations of purely passive displays when aiming for significant behavioral influence.

Active Communication (Experiment 2 - Poll [Section 5.2]): The model guided the design towards incorporating stronger interaction affordances. The simple tap interaction, playful animations, and immediate feedback resulted in a significantly higher Interaction Affordance score ($IA \approx 3.62$) compared to Experiment 1. This, combined with good Perceived Affordance ($PA \approx 17.24$) and slightly facilitating Context ($CA \approx 1.03$), led to a much higher overall score ($OA \approx 64.28$). The empirical results validated this, with a 6.04% average interaction rate exceeding the target. This shows the model's effectiveness in designing for simple, direct interactions and predicting their higher engagement potential.

Two-Way Communication (Experiment 3 - Food Waste Pledge [Section 5.3]): This experiment involved a more complex, multi-step interaction (slicing gesture + pledge button). The model analysis reflected this complexity. While Visual ($VA \approx 4.0$) and Interaction Affordances ($IA \approx 3.98$ - boosted by adaptability and engagement factors like social proof and playfulness) were strong, the novel gesture slightly lowered Perceived Affordance ($PA \approx 15.64$) compared to the simple poll due to reduced recognizability and learnability. The overall score ($OA \approx 65.98$) was only marginally higher than Experiment 2, predicting similar overall effectiveness despite the richer interaction. The results supported this, with the initial interaction rate (7.49%) meeting the goal, and a high pledge completion rate (55.42%) demonstrating successful engagement through the two-step process. This highlights the model's ability to handle more complex interactions, identify trade-offs (e.g., novelty vs. learnability), and evaluate designs involving sequential steps and persuasive elements like commitment.

Across the three experiments, the model provided a framework to:

Analyze and Compare: Quantify and compare the affordance profiles of designs with different interaction levels.

Identify Strengths/Weaknesses: Pinpoint specific areas (e.g., low interaction affordance in Experiment 1, slightly lower perceived affordance in Experiment 3) for potential improvement.

Guide Design: Inform design decisions by highlighting the importance of specific factors (e.g., feedback, playfulness, social proof) identified as key drivers in the survey results and reflected in the model's components.

Predict Effectiveness: The relative overall scores (OA) generally aligned with the observed engagement levels, suggesting the model has predictive utility.

Therefore, RQ2 is addressed by demonstrating the model's practical application in analyzing, designing, and predicting the effectiveness of interactive screens across passive, active, and two-way communication strategies in an SSR setting.

6.3 Interpretation of Findings

The results from the Flavoria experiments offer several key insights when interpreted through the lens of the affordance-based model:

Interaction Matters: The stark difference in engagement between the passive display (Experiment 1) and the interactive displays (Experiment 2 & 3) underscores the importance of designing for interaction, even simple taps, to capture attention and elicit responses in busy public environments. The model captured this primarily through the Interaction Affordance (IA) component.

Simplicity vs. Richness: Experiment 2 demonstrated that a simple, well-designed active interaction (single tap poll) can be highly effective ($OA \approx 56.2$, 6.04% interaction). Experiment 3 showed that a richer, two-way interaction (gesture + pledge) could achieve similar initial engagement ($OA \approx 57.9$, 7.49% interaction) and facilitate a deeper commitment (55.42% completion), but the added complexity slightly impacted perceived affordances (P). This suggests a trade-off designers must navigate, which the model helps articulate.

Context is Crucial but Difficult: While the model includes Contextual Influence (C), its impact was estimated as only slightly facilitating ($CA \approx 1.02 - 1.06$) in these experiments. Real-world SSR environments are complex and dynamic, making it challenging to consistently create highly facilitating contexts. The model acknowledges this, but precisely controlling or predicting context remains difficult.

Model Sensitivity: The model proved sensitive enough to differentiate between the three designs, with the overall scores reflecting the increasing complexity and engagement potential from passive to active to two-way communication. The component scores (PA, CA, IA) helped explain *why* the overall scores differed.

Beyond Interaction Rate: Experiment 3 highlighted that success isn't just about initial interaction but also about task completion in multi-step processes. The high pledge completion rate suggests the design successfully maintained engagement beyond the initial novel gesture, likely due to factors like social proof and clear progress indication, captured under the model's Adaptability sub-component.

6.4 Contribution to HCI

This thesis contributes to the HCI field, particularly the study of public displays and interaction design, in several ways:

Introductory Quantifiable Model: The primary contribution of this research is the development of the introductory quantifiable affordance-based model specifically designed for evaluating interactive public displays. While affordance theory has been influential in HCI since Gaver's work on technology affordances [23] and Norman's design-oriented approach [30], its application has remained largely qualitative and subjective for design of interactive screens in public spaces, limiting its utility for systematic design evaluation in this context. This research addresses a fundamental methodological gap identified by Hartson [28] and Kaptelinin and Nardi [29], who emphasized the need for systematic evaluation methods.

The model transforms abstract affordance concepts into measurable parameters through systematic decomposition across four dimensions: Visual, Perceived, Contextual, and Interaction Affordances. The mathematical formulation ($OA = PA \times CA \times IA$), parameter definitions for each component and their scoring rubric (refer to Chapter 4) represents a significant theoretical advancement by capturing the multiplicative relationships between affordance components, reflecting empirical evidence that deficiencies in any parameter or component can dramatically impact overall effectiveness. This approach provides foundations for quantitative affordance research that enables statistical analysis, comparative evaluation, and predictive modeling—advancing affordance research from descriptive to predictive science.

Bridging Theory and Practice: This research demonstrates how multiple theoretical domains can be systematically integrated into practical design tools without losing theoretical rigor. The HCI literature contains extensive theoretical knowledge about attention capture, engagement models, and public interaction (refer to Section 2.2), but translating this knowledge into systematic design practices remains challenging, particularly for public displays where traditional usability evaluation methods often prove inadequate [11], [12]. The model serves as a sophisticated translation layer between abstract theoretical concepts and concrete design decisions, addressing what Müller [13] identified as a critical need for systematic design frameworks in public display research.

The integration of persuasive technology principles addresses the reality that many public displays aim to influence user action. By incorporating elements from the Elaboration Likelihood Model [42], Nudge Theory [44], and Self-Determination Theory [47] within the interaction affordance component, the model provides a framework for evaluating persuasive effectiveness alongside traditional usability metrics. The empirical validation through real-world deployment provides crucial evidence that theory-driven design approaches can achieve measurable improvements in user engagement and behavior change.

Communication Interactions in SSR Context: This research provides the systematic empirical investigation of user engagement with different communication interaction levels (passive, active, two-way) on public displays specifically within self-service restaurant environments. While previous research has examined public display interaction in various contexts [7], [19], the research addresses the gap identified by Alt [11] regarding the need for context-specific evaluation of public display effectiveness.

The systematic comparison reveals that simple active interactions (6.04% engagement rate) often achieve higher initial engagement than complex two-way interactions (7.49% initial rate but 55.42% completion rate), providing crucial guidance for public display designers. This insight challenges assumptions about the relationship between interaction complexity and effectiveness, suggesting that optimal interaction design depends on specific engagement goals. The empirical data contributes valuable baseline data for the public display research community, demonstrating that well-designed public displays can achieve 5-10% engagement rates in busy public environments.

Demonstration of Model Utility: The systematic application of the affordance-based model across three distinct experiments provides compelling evidence for its utility in analyzing diverse interaction paradigms and predicting their relative effectiveness. The model's predictive capabilities are demonstrated through consistent alignment between affordance scores and observed user engagement: the passive display's low score ($OA \approx 24.42$) correctly predicted limited impact, while interactive designs' higher scores ($OA \approx 64.28$ and 65.98) accurately predicted greater engagement potential.

The model's sensitivity to design differences enables systematic design optimization by identifying specific improvement opportunities. For example, it correctly identified that Experiment 1's low interaction affordances limited impact, while Experiment 3's reduced perceived affordances due to novel gestures represented a specific refinement area. This diagnostic capability addresses what Huang [14] identified as a need for systematic methods to understand when and why public displays succeed or fail, establishing the framework's broad applicability across diverse interaction styles [12].

Focus on User-Driven Actions: This research shifts the focus of public display research from passive information consumption toward designing for meaningful user-driven actions and behavior change. The framing of success in terms of user-driven actions rather than simple attention metrics represents a methodological contribution. This addresses limitations in previous research that often focused on attention capture without considering meaningful outcomes [17].

The systematic investigation of how different interaction paradigms support user agency provides crucial insights for designing empowering rather than manipulative public displays. The finding that two-way interactions achieve high completion rates (55.42%) when users overcome initial barriers demonstrates that well-designed complex interactions can support meaningful commitment and user action. The focus on sustainability (food waste in Experiment 3) demonstrates how public displays can address societal challenges through user-driven action, contributing to growing literature on technology-mediated sustainability interventions [21], [22].

6.5 Limitations and Future Work

While this research provides valuable insights, several limitations should be acknowledged:

Model Subjectivity: The quantification within the model relies on estimated scores, introducing a degree of subjectivity. While applied consistently across experiments, different evaluators might assign slightly different scores.

Contextual Complexity: The model attempts to capture context, but the dynamic and multifaceted nature of public SSR environments makes precise quantification challenging. The estimated Contextual Influence (C) scores were relatively neutral; there's likelihood that the impact is more pronounced (positive or negative) effects than captured.

Short Experiment Duration: The experiments ran for limited periods (typically two weeks). Longer-term studies would be needed to understand novelty effects, sustained engagement, and lasting behavioral changes.

Specific Setting: Findings are derived from a single SSR setting (Flavoria). While the principles are likely transferable, generalizability to other public dining environments requires further investigation.

Physical Layout Constraints: Due to the existing physical infrastructure and layout limitations of the dining hall, screens could not be positioned at optimal user-facing locations. This constraint may have affected the natural discovery and interaction patterns that would occur with ideally positioned displays, potentially underestimating the true effectiveness of interactive screen's affordances in real-world scenario.

Focus on Affordances: The model centers on affordances. Other factors influencing behavior (e.g., deep-seated habits, personal values beyond survey responses, menu variations) were not explicitly modeled or controlled for.

Future work could address these limitations:

Refining Model Quantification: Explore methods for more objective scoring, potentially involving user testing or expert panels for calibration.

Deeper Contextual Analysis: Investigate contextual factors more deeply, for example using sensor data or more detailed observational methods to refine the Contextual Influence (C) component.

Longitudinal Studies: Conduct longer-term deployments to assess sustained engagement and habit formation.

Cross-Context Validation: Apply and test the model in different SSRs or other public settings (e.g., transportation hubs, retail environments).

Integrating Other Theories: Explore integrating the affordance model with other behavioral models (e.g., Theory of Planned Behavior, COM-B) for a more holistic understanding of user actions. Therefore, we position our model as an introductory model.

Adaptive Interfaces: Investigate adaptive interfaces where affordances change based on real-time context or user interaction history, potentially optimizing engagement dynamically.

7 Conclusion

This thesis set out to explore the design of interactive screens in self-service restaurant (SSR) environments, aiming to enhance user engagement and support user-driven actions. Grounded in affordance theory and integrating insights from HCI and persuasive technology, a quantifiable affordance-based model was developed to guide and evaluate the design of such interfaces.

The core contribution of this work is the affordance-based model itself, which provides a structured model for analyzing the potential effectiveness of interactive public displays in SSRs by considering perceived affordances, contextual influences, and interaction affordances. The model was developed in response to RQ1, demonstrating how diverse theoretical concepts can be integrated into a practical, quantifiable tool for designers and engineers.

To address RQ2, the model was applied in a real-world SSR setting (Flavoria) through three distinct field experiments representing passive, active, and two-way communication strategies. The passive information display (Experiment 1) showed limited impact, aligning with its lower affordance score. The active poll (Experiment 2) achieved significant engagement with a simple interaction, validated by a higher affordance score. The two-way communication (Experiment 3), despite its increased complexity, also successfully met engagement goals, demonstrating the model's ability to evaluate richer interactions and associated trade-offs. The overall affordance scores calculated using the model ($OA \approx 24.42$ for Experiment 1, $OA \approx$

64.28 for Experiment 2, $OA \approx 65.98$ for Experiment 3) generally correlated with the observed engagement levels, suggesting the model holds predictive utility.

These experiments demonstrated that even simple active interactions can be significantly more effective than passive communication displays in capturing user attention and seeking responses in busy public settings. Furthermore, well-designed two-way interactions can facilitate deeper engagement and commitment, supporting goals like promoting sustainable behaviors (e.g., reducing food waste). The findings highlight the importance of carefully designing interaction affordances, providing clear feedback, and leveraging persuasive elements like playfulness and social proof, factors explicitly considered within the developed model.

In conclusion, this research offers both a theoretical contribution through the novel affordance-based model and practical insights derived from its application in a real-world SSR environment. The model provides a valuable tool for HCI practitioners designing interactive systems for public spaces, while the empirical findings offer guidance on creating engaging communication experiences that can effectively support user-driven actions. While limitations exist, particularly concerning model subjectivity and contextual complexity, this work lays a foundation for future research refining the model and further exploring the design of effective and engaging interactive public displays.

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Appendix A

The code repository URLs for the three experiments is available at:

`https://github.com/ismailvohra/interactive-screens-ssr`