Interactive Affordance of Integrative Internet Social Media Platform Use by Patients and Physicians: A Mixed-Method Approach

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Abstract

Background: Integrative internet social media platform (IISMP) integrates the features of mobile and social media technologies as well as the legacy healthcare systems to support healthcare processes for patients and physicians that enables patient-centered care. To better understand the use of IISMP, especially the digital interactions between patients and physicians, we develop the concept of interactive affordance and use a mixed-method approach to identify and present the interactive affordance patterns based on patient event logs, physician-patient online consultation conversation texts, interviews, and focused group from a large hospital.

Objective: This study proposes a new type of affordance, referred to as interactive affordance, which represents the interactions between physician and patient when they both use IISMP for providing care to the patient. We identify interactive affordance patterns and investigate their impacts on organizational changes in the healthcare context.

Methods: We use a mixed-method approach to analyze various data collected from both primary and secondary sources. The data includes 45,147 archival healthcare event logs, 13,332 conversation texts, 15 interviews, and eight focus groups data from a large hospital that has implemented an IISMP. We use grounded theory analysis, process mining, text mining, and social network analysis to identify interactive affordance patterns and their impacts on healthcare processes and outcomes.

Results: Based on the results from text mining, processing mining, social network, and ground coding analysis, we identify virtual healthcare consultation between patient and physician using IISMP as interactive affordance. The analysis results from the mixed-method approach confirm that interactive affordance, virtual consultation affordance, of IISMP use contributes to the changes in the communication and decision-making processes between patients and physicians. The virtual consultation affordance promotes patient-centered care by increasing patient's access to care, empowerment, and engagement.

Conclusions: The concept of interactive affordance is proposed as a new type of affordance to represent the interactions between patients and physicians emergent by using IISMP in healthcare organizations. This new affordance type explains organizational changes toward patient-centered care.

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Original Manuscript

Patient Use of Hospital Mobile Health Portals: Affordance Types and Their Determinants

Abstract:

Background: Mobile health portals (MHP) are becoming increasingly important and popular among healthcare organizations for engaging and retaining patients. However, their success hinges on patient acceptance and usage. Many organizations face ongoing challenges with low patient adoption and utilization of MHP. While affordance theory offers a useful theoretical perspective for exploring patient perceptions and uses of MHP, there is a gap in research that empirically investigates the various types of affordances and their determinants.

Objective: This study categorizes affordances into three types: general, contextual, and behavioral. We develop and empirically test a research model explaining how patient absorptive capacity and the innovativeness of hospital MHP impact these three types of affordances and the relationships among them.

Methods: This study uses survey data (n=401) collected from four large hospitals in China to test the research model and hypotheses.

Results: General affordance was significantly affected by patient absorptive capacity (b=.191, P<.01) and MHP innovativeness (b=.567, P<.01). Contextual affordance was significantly influenced by patient absorptive capacity (b=.148, P<.01) and general affordance (b=.484, P<.01), but not by MHP innovativeness (b=.036, P>.05). Behavioral affordance was significantly influenced by contextual affordance (b=.430, P<.01) and general affordance (b=.140, P<.01). General affordance and contextual affordance mediate the effects of patient absorptive capacity and the innovativeness of hospital MHP on behavioral affordance.

Conclusions: Patient absorptive capacity and the innovativeness of MHP in hospitals predict the three types of affordances. Additionally, interesting relationships exist among general, contextual, and behavioral affordances. To increase patient utilization of MHP, health organizations should holistically manage the three types of affordances, their determinants, and their relationships.

Keywords: hospital mobile health portals, affordance, general affordance, contextual affordance, behavioral affordance, patient absorptive capacity, mobile health portal innovativeness

Patient Use of Hospital Mobile Health Portals: Affordance Types and Their Determinants

Introduction

There is growing interest in patient-centered care within the healthcare industry, accompanied by a shift towards prioritizing patient experience and satisfaction in the digital age [1, 2]. Health organizations invest in interaction, collaboration, and knowledge sharing with patients through mobile social media to enhance self-management [3, 4]. While mobile social media-enabled applications provide convenience and mobility for patients, their implementation and usage are complex, presenting significant challenges for health organizations aiming for success in these efforts [5]. Despite substantial investments in mobile social media technology development, the outcomes of these investments vary [2]. Low adoption rates, underutilized features, and poor user experience often lead to unsatisfactory results [6-8]. The factors underlying the mixed results of these investments are not yet fully understood.

While early research on information system usage concentrated on technology functionalities and user behaviors, recent studies have introduced the concept of affordance to capture the holistic nature of user adoption and technology use, emphasizing the interactions between material and social aspects of user-system interaction [2, 4,9, 10, 11]. Affordance has been examined as a foundational concept for designing information systems [12], explaining technology-induced organizational changes and innovations [13, 14], and addressing users' perceptions of system functionalities [4, 15-17]. Despite the growing application of affordance concepts in the research literature, there remains a lack of understanding about the conceptualization and types of affordances, the relationships between different types, and their determinants [4].

To address the gaps in the literature, this research expands the existing conceptualization of affordance by categorizing it into three types: general, contextual, and behavioral affordances. We develop and test a research model concerning the social and technical determinants of these three types of affordances. On the social side, we examine users' ability to understand and accept new technology; on the technical side, we consider the innovativeness of the MHP [18]. We empirically test our research model in the context of patient use of hospital MHP. This paper aims to answer the following research question: What are the relationships among social and technical determinants and the three types of affordances in the context of patient use of hospital MHP?

The context of this research involves a mobile social media-enabled MHP utilized by patients. These patient MHP are embedded applications within China's widely used social media platform, WeChat [19]. Patients can use the MHP to schedule doctor appointments, check in upon arrival at the hospital, make payments, access medical records, view lab results, refill prescriptions, consult with doctors online, and engage with other patients in online communities [7]. We collected survey data from 401 patients across four large hospitals in China to examine the effects of patient absorptive capacity and hospital mobile health portal innovativeness on the three types of affordances and the relationships among these affordances.

Our results reveal that contextual and general affordance are significant predictors of behavioral affordance, with contextual affordance being the stronger predictor. This confirms the crucial role that context plays in MHP adoption. The findings also suggest a partial mediation effect of general affordance on behavioral affordance. Absorptive capacity has a positive effect on both contextual and general affordance. Interestingly, technological innovativeness positively predicts general affordance but not contextual affordance.

This study offers two significant contributions. First, we enhance the existing conceptualization of affordance by categorizing it into three types: general, contextual, and behavioral affordances. The paper builds on the relational nature of affordance and captures the contextuality of socio-technical interactions within daily operations in healthcare organizations [2, 4,10, 20]. Second, we provide insights into the relationships between the social and technical determinants and the three types of affordances. More specifically, we empirically test how patient absorptive capacity and perceived technology innovativeness influence patients' general affordance, contextual affordance, and actualized behavioral affordance in the context of hospital MHP [21, 22]. The study results offer actionable guidelines for practitioners involved in the development, integration, and assimilation processes of social media-enabled health management systems [4, 23].

Theoretical Background

Concept of Affordance

The concept of affordance originates from Gibson [24] and is defined as the possibilities and limits for action that a material object offers to an actor. By focusing on the dynamic and contextual nature of user-technology interaction, researchers have defined information technology affordance as a specific form of user-technology interaction. This notion arises from the traditional dichotomy between technological and social determinism, providing a basis for studying the co-evolution of humans and technology [11]. Affordance, as an intermediate approach to understanding technology, both connects and distinguishes itself from Giddens' structuration theory [25], DeSanctis and Poole's adaptive structuration theory [26], and Orlikowski and Scott's social materiality [9]. While these approaches aim to explore the interplay among technology, an actor, and an organization, they emphasize different aspects. Although the sensitivity of affordance in examining issues within the social-technological phenomenon remains an ongoing discussion, its integration with critical theories further refines its perspective for studying social-technical interactions. Affordance, rooted in relational ontology, assigns equal importance to both the social and the material [27].

Types of Affordances

The information systems literature has primarily examined two types of affordances: objective and subjective affordance. Gibson’s [24] original concept of affordance offers objective action possibilities based on an artifact’s functionalities with an actor within an environment. This concept is independent of the actor's experience, knowledge, and culture. Information systems research considers the material aspects of affordance, which are inherently embedded in IT artifacts, as an objective affordance. On a functional level, these material features can be designed and implemented. In contrast, Norman [28] distinguishes objective affordance from perceived affordance in interface design, arguing that perceived affordance reflects an actor's perception of action possibilities rather than the functionalities defined by the artifact. Users’ perceptions of affordance about an IT artifact are referred to as perceived affordance.

The social aspects arising from the interactions between an actor and an artifact must be considered when conceptualizing affordances. Depending on the types and stages of affordance, it can be either stable [29] or emergent [28, 30]. Affordance is intrinsically linked to the contexts in which actors and artifacts interact. Context encompasses an actor's intention, culture, knowledge, and other attributes that generate distinct interpretations of what, when, where, and how the artifacts afford the actors. Although affordance in the information systems field has become more prevalent in recent years, the literature remains unclear about the classification of affordance. Most authors have examined affordance within a specific use case without considering the context's details in defining and applying affordance. However, we argue that, in addition to general affordance, contextual affordance arises from the environment in which interactions are enacted.

In our study, we use “objective affordance” to describe the affordances provided by technological artifacts and “subjective affordance” to refer to the affordances perceived by the actor. We use the term "behavioral affordance" to describe the actual usage by patients. In addition to Norman’s perspective on affordance, many scholars focus on the relational properties of affordance [31]. A critical aspect derived from affordance's relational properties is that an object's affordances can vary from one individual to another [32]. Recognizing the interactions between affordances and technology, scholars often examine specific types of affordances in particular contexts [29, 30]. Although the types and characteristics of affordance have expanded over the years, there remains a lack of understanding regarding the different types of affordances and the relationships among them.

Contextual Affordance

Contextualism emerged as an alternative worldview to mechanism and organism [33]. Although contextualism shares similar ideas with other views, such as transnationalism, constructivism, and perspectivism, it presents an exciting new alternative for understanding human behavior. One of the foundational metaphors of contextualism is the historical event, indicating that human behavior continuously evolves. Each interaction is a unique product of historical activity within the current context, as well as the historical context that influences subsequent interactions [33]. The application of contextualism is rapidly growing. In the fields of cognitive and behavioral psychology, the merits of employing cognitive causality to explain human behavior have been debated for a long time. Some contend it is not merely an empirical issue; the causality must be understood within the researchers' pre-analytic philosophical assumptions [34]. The social, cultural, and institutional context of technology designers and users can influence how users perceive and actualize affordances. From a broader perspective, when evaluating information systems, Stockdale and Standing [35] assert that one should consider both internal and external organizational and environmental contexts.

When utilizing affordance theory, scholars often discuss affordance in terms of interactions among actors, artifacts, or processes, yet they frequently overlook the unique context in which these interactions occur. For instance, Volkoff and Strong [36] argue that affordance represents a specific instance of generative mechanisms. They investigate technology-induced generative mechanisms that interact with affordances during an IT-enabled change process. However, they do not consider non-technology-related generative mechanisms that also interact with affordances. Although emphasizing context when applying affordance is not a new suggestion, a lack of conceptualization of such affordance still exists. Markus and Silver [12] note that no explanation of IT effects would be complete without careful conceptualizations of users and their use environments. These environments include users' characteristics, goals, interpretations of technology, work practices, and institutional contexts.

A technological object should be regarded as a social object rather than just a means of functionality. Affordance links technology and organization, remaining inseparable from an organization's social characteristics, such as expertise, jobs, processes, or structures [13]. Avgerou [37] contends that connecting technology with the context in which it is embedded in information systems research is crucial. Likewise, Stockdale and Standing [35] highlight the necessity for a more extensive contextualized approach to assessing information systems. When scholars consider context, it acts as a bubble that surrounds the interactions between actors and technology. However, perceiving context as a bubble inherently diminishes the distinctions at the individual level and renders it impossible to trace the impacts of such differences back to their origin.

Based on the discussion above, we define general affordance as distal, continuous, rigorous, and stable. It does not change rapidly over time and reflects an individual's conventional preferences, making it long-term. It serves as a baseline in contrast to contextual affordance, which is immediate, disruptive, unstable, and easy to alter, rendering it short-term and primarily influenced by the interactions' contexts. When contextual affordance is present, the general affordance for a patient is temporarily modified, and the context of the interaction may influence the behavioral outcome of this patient. We define contextual affordance as the perceived action possibilities provided to the patient by hospital MHP in specific healthcare contexts during the interactions. In contrast, general affordance refers to the perceived action possibilities available to a patient by hospital MHP in a general sense. Both general and contextual affordances are subjective by nature.

Diffusion of Innovation

The Diffusion of Innovation theory [38, 39, 40] seeks to explain how, why, and at what rate innovations and technologies spread. The theory has been used to assess behaviors related to adopting new technological innovations. Diffusion is defined as a process by which an innovation is communicated through specific channels among social system members over time.

Rogers further proposes five characteristics of innovation that influence its adoption: relative advantage, compatibility, complexity, trialability, and observability. In addition to these five characteristics, prior conditions such as previous practice, needs, innovativeness, and social system norms are also considered in adoption research [41]. A technology’s innovativeness reflects users' assessments of MHP.

Absorptive Capacity

Absorptive capacity refers to one’s ability to identify, assimilate, and exploit knowledge from the environment [42]. While absorptive capacity is based on organizational learning, it is a multilevel and transdisciplinary construct that explains innovation exploitation and exploration orientations [43]. Absorptive capacity consists of two aspects: potential and realized. Potential absorptive capacity pertains to acquiring and assimilating useful knowledge, whereas realized AC involves transforming and exploiting knowledge to produce desired outcomes [44].

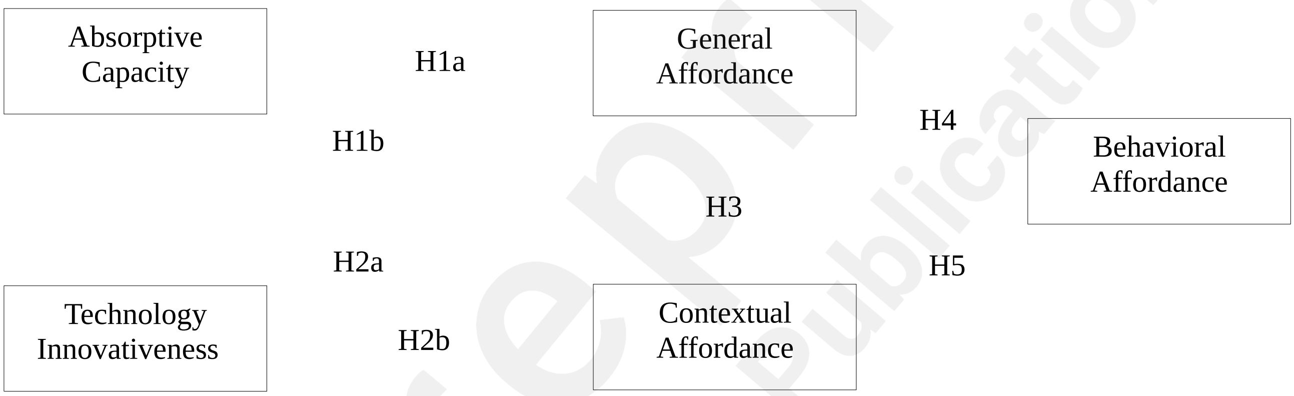
Absorptive capacity encompasses the recipients’ capacity to absorb the knowledge transferred during this process. Absorptive capacity influences implementation performance by enabling recipients to assimilate and apply the knowledge [46]. In our research, absorptive capacity maintains its original definition and illustrates the degree to which a patient can identify, assimilate, and exploit the knowledge of the hospital MHP.

Research Model and Hypotheses

From a socio-technical perspective, we aim to examine how individual absorptive capacity and technological innovativeness influence the three types of affordances and their relationships. Figure 1 illustrates our research model and specific hypothetical relationships.

The effect of a patient's absorptive capacity on subsequent affordances is represented by hypotheses 1a and 1b; the impact of technology innovativeness on subsequent affordances is outlined in hypotheses 2a and 2b; the relationship between general affordances and contextual affordances is explained by hypothesis 3; finally, the influences of general and contextual affordances on behavioral are specified in hypotheses 4 and 5.

Figure 1. Research Model



Absorptive Capacity and General Affordance

Absorptive capacity is the ability to identify, assimilate, and exploit knowledge from the environment [42]. Implementing any information system can be considered a process of knowledge transfer. For knowledge transfer to be effective, direct and intimate interaction is required between the sources and the recipients [45]. Absorptive capacity captures the recipients' ability to absorb the knowledge transferred during the process. At the individual level, patients' absorptive capacity directly influences how they evaluate the patient portal when they engage with the system.

General affordance refers to patients evaluating what they can do with the MHP before using it. The perception of these potential actions made available to patients by the MHP largely depends on their experience with similar technologies. For example, if someone has prior exposure to WeChat, they will likely assess what the patient portal can provide, given that the MHP is integrated with WeChat. Absorptive capacity plays a crucial role in explaining subsequent adoption and usage of the patient portal, even before users interact with the MHP [46]. Therefore, we propose:

Hypothesis 1a: Patient absorptive capacity is positively related to general affordance.

Absorptive Capacity and Contextual Affordance

Contextual affordance is patients’ evaluations of what they can do with the MHP at the point of actual interaction, which is deeply embedded within the contexts. Patients still possess general affordance. However, the perception of these possible actions afforded to patients by the MHP is adjusted to fit the contexts. For instance, if a person wants to pay their medical bills with the MHP using a credit card, the hospital's payment system only allows debit card payments. Paying through the patient portal becomes unavailable in this specific context. Most research treats absorptive capacity as an independent variable that may affect system adoption, implementation, and integration [47]. Previous studies note that absorptive capacity influences the intention to use a particular technology [48]. The effects of absorptive capacity on general affordance should fully translate to contextual affordance in any use case [49]. We propose that absorptive capacity will have specific effects on contextual affordance.

Hypothesis 1b: Patient absorptive capacity positively relates to patient-perceived contextual affordance.

Technology Innovativeness and General Affordance

Based on the diffusion of innovation theory [38], scholars have empirically examined the significant associations between technology innovativeness characteristics (relative advantage, compatibility, complexity, trialability, and observability) and IT adoptions across industries [41, 50]. Research has reported a positive effect of technology innovativeness on mobile application adoption intention through perceived usefulness and ease of use [23, 51]. In our study, we analyze the effects of MHP innovativeness characteristics on usage through the lens of affordance.

In a broader sense, patients assess the compatibility between their daily lives and WeChat MHP, evaluate the practicality of utilizing WeChat MHP as their primary healthcare management tool, and anticipate the potential outcomes of adopting the patient portal based on technological innovation [23]. The technological innovations that encompass relative advantage, compatibility, complexity, trialability, and observability should influence patients' general perceptions and understanding of what they can or cannot do with MHP. Patients ought to be able to foresee the benefits and drawbacks of the MHP [49]. This idea aligns with prior research [51], indicating a positive correlation between technological innovation and users’ general affordance. We propose:

Hypothesis 2a: Patient-perceived technology innovativeness of MHP is positively related to patient general affordance.

Technology Innovativeness and Contextual Affordance

When a patient is provided with the opportunity to use the MHP in a specific context, they should be able to quickly form an opinion on how they can leverage the patient portal to their advantage and which functionalities they intend to use. With these specific goals, patients can move forward with their interactions. The concept of contextual affordance differs from general affordance. In cases where patients engage with the MHP's functionalities, the evaluation of such a fit will be constrained to the actual functionalities of the MHP and other contextual factors, such as time, location, and internet access. We propose:

Hypothesis 2b: Patient perceived technology innovativeness of MHP is positively related to patient contextual affordance.

General Affordance and Contextual Affordance

As discussed earlier, contextual and general affordances are distinctive and affect each patient's behavior differently. Contextual affordance is more immediate, emerging, and prone to change. The time for it to be in effect is when a patient must decide whether to use the MHP. The more stable and distal general affordance serves as the patient's baseline for contextual affordance. When a patient is in a specific context of using the MHP, contextual affordance is derived from the interaction between the patient's general affordance and the specific contextual factors. As such, contextual affordance is influenced by and modified from general affordance.

In a scenario where a patient has some prior exposure to WeChat before a hospital visit, they may assume that an MHP can provide functionalities such as making an appointment, viewing test results, and consulting a doctor based on their experiences with similar products or feedback from family and friends [20]. Hypothetically, the patient wants to make an appointment a month away. Upon interacting with the MHP, the patient discovers that they cannot schedule an appointment more than one week in advance. The general affordance of the MHP shifts to contextual affordance in this instance. The same affordance becomes either unavailable or irrelevant to the patient at the point of use because the context has changed. Consistent with the state-trait distinction in cognitive psychology, we suggest that contextual affordance is state-like while general affordance is trait-like [52]. Therefore, we propose:

Hypothesis 3: Patient general affordance is positively related to contextual affordance.

General Affordance and Behavioral affordance

In general, how patients perceive what MHP can do for them influences how they will use it [4]. Contextual affordance describes the perceived action possibilities afforded to the patient by the MHP when they need to interact with it in a specific use context. Therefore, contextual affordance contributes to the subsequent behavioral affordance (e.g., what functionalities of the MHP the patient uses and how often they use them). In this research, behavioral affordance is defined as the actualized affordance that denotes the actual usage of the MHP. We propose:

Hypothesis 4: Patient general affordance is positively related to behavioral affordance.

Contextual Affordance and Behavioral affordance

The concept of contextual affordance is inherently subjective. When Norman [28] describes subjective affordance, he refers to the actor's general perception of the artifact's action possibilities. He addresses the idea of conventions (culture) from a systems design perspective and suggests that designers should depend on conventional interpretations during the design process. In contrast, contextual affordance encompasses cultural-historical factors that influence an individual actor's perception. Previous research shows that affordance positively affects behaviors. In the context of our study, it directly impacts how a patient interacts with the MHP. This affordance in action, referred to as behavioral affordance, transforms subjective affordance into actual usage [4]. We propose:

Hypothesis 5: Patient contextual affordance is positively related to behavioral affordance.

Research Methodology

Data Collection

The survey data used to test our research hypotheses were collected in four leading urban hospitals in China. At the time of our data collection, all hospitals had implemented a WeChat-based MHP. A research team member randomly reached out to patients in the hospital to ask them to participate in the survey. Those patients who agreed to participate completed the questionnaire onsite. In total, 401 complete survey responses were collected and used in this study. The sample characteristics are summarized in Table 1.

Table 1. Sample characteristics

Gender	N (%)		
Male	182 (45.4%)		
Female	211 (52.6%)		
Missing	8 (2.0%)		
Age Group	N (%)	Purpose for Visit	N (%)

<18	5 (1.2%)	First timer	118 (29.4%)
18-30	184 (45.9%)	Follow up	113 (28.2%)
31-40	86 (21.5%)	Accompany	139 (34.7%)
41-50	45 (11.2%)	Not specified	18 (4.5%)
>50	57 (14.2%)	Missing	13 (3.2%)
Missing	24 (6.0%)		
Education Level	N (%)	Employer Type	N (%)
Doctoral	4 (1.0%)	Government	12 (3.0%)
Graduate	30 (7.5%)	State-owned	33 (8.2%)
Bachelor	139 (34.7%)	Private-owned	123 (30.7%)
Technical College	65 (16.2%)	Foreign owned	67 (16.7%)
Vocational	22 (5.5%)	Civil Enterprises	23 (5.7%)
Senior High	62 (15.5%)	Small business	66 (16.5%)
Junior High	33 (8.2%)	Farmer	32 (8.0%)
Primary School	34 (8.5%)	Others	30 (7.5%)
Missing	12 (2.9%)	Missing	15 (3.7%)

Measurement

Measurement items were adapted from the extant literature and further validated using our study sample. The measurement items used to assess each construct are presented in the Appendix. Absorptive capacity and technology innovativeness were specified as reflective measures, while preference, contextual affordance, general affordance, and behavioral affordance were specified as formative measures. We used a Likert scale ranging from 1 to 7 (1 indicates strongly disagree, and 7 indicates strongly agree).

For absorptive capacity, four items from previous research [43, 53, 54] were adopted to capture the ability of a patient to recognize, assimilate, and apply new knowledge. The unit of analysis for previous instruments on absorptive capacity was mostly organizational; thus, we modified the items to an individual level in our study context. For technology innovativeness, we adapted items from widely accepted instruments [55] on perceptions of adopting an information technology innovation based on the five innovation characteristics proposed by Rogers [38]. We modified the items to fit within our study context.

We adapted and employed measures based on previous research [3,4,10,36] for general, contextual, and behavioral affordance. General affordance was assessed using four items that capture patients' perceptions—without referring to their specific medical conditions—regarding MHP features that enable them to schedule appointments, make payments, interact and consult with doctors online, and access hospital information. Contextual affordance was evaluated with four items that gauge patients' perceptions, in relation to their own specific medical conditions, about their ability to use the MHP for scheduling appointments, making payments, accessing lab results and medical records, and asking medical staff questions online. Behavioral affordance was examined using four items that reflect the patients' actual utilization of MHP to make appointments with their preferred doctors, make payments, access lab results, consult with doctors online, and make payments.

We conducted three rounds of Q-sorting procedures on the initial measures. As a part of the pre-test, we conducted field observations and interviews at the research sites. We pilot-tested the survey items with subject experts and patients to ensure their clarity and scope coverage for our study.

Data Analysis

The study employs structural equation modeling using partial least square (PLS) analysis with the SmartPLS software. We first performed measurement validations, including testing Cronbach's alpha, composite reliability, average variance extracted, cross-loadings, and HTMT for reflective measurements and testing VIF, weights, and item significance for formative measurements.

Measurement Validation

Reliability for Reflective Constructs

Cronbach's alphas for all reflective constructs were satisfactory. The absorptive capacity subscale consisted of 4 items (α = 0.89). The technology innovativeness subscale consisted of 5 items (α = 0.92). Overall, both reflective constructs demonstrate high reliability. In addition to Cronbach's alpha, Rho_A coefficient, and Fornell and Larcker [56] composite reliability (CR) for the reflective constructs were also found to be highly reliable since the two coefficients (rho_A > 0.92, CR > 0.92) met the suggested minimum value of 0.7. In some cases, CR is preferred over Cronbach's alpha as CR offers a better estimate of variance shared by the respective indicators, and it uses the item loadings obtained within the nomological network [57]. In either case, the reliability indexes for the two reflective constructs were satisfactory in this study. Table 2 presents outer loadings, AVEs, Cronbach's alpha, rho_a, and rho-c for the two reflective constructs.

Table 2. Outer Loadings, AVEs, Cronbach's Alpha, Rho_a, and Rho-c Results

Reflective Constructs	Indicators	Outer Loadings	AVE	Cronbach's α	rho_a	rho_c
Absorptive Capacity (AC)	AC1	0.857	0.744	0.889	0.939	0.921
	AC2	0.865				
	AC3	0.871				
	AC4	0.857				
Tech Innovativeness (TI)	TI1	0.847	0.748	0.916	0.918	0.937
	TI 2	0.859				
	TI 3	0.870				

TI 4	0.884
TI 5	0.864

Convergent Validity

Convergent validity refers to the extent of agreement among two or more measures of the same construct. Evidence of convergent validity is evaluated by examining the Average Variance Extracted (AVE), which indicates the ratio of total variance explained by the latent variable. An AVE of 0.5 or greater signifies satisfactory convergent validity, as the latent construct accounts for, on average, 50% or more of the variance in the observed variables [56]. In addition to AVE, outer loadings are employed to evaluate convergent validity. Indicators derived from the same construct should exhibit higher loadings on their respective constructs. The standardized outer loadings should ideally be 0.7 or higher, though a minimum of 0.5 is required [58] to establish convergent validity. All indicators of our two reflective constructs met these benchmarks. Results demonstrate that the AVEs for reflective constructs were 0.86 and 0.87, and all outer loadings were 0.85 or greater. These findings indicate that the scales used for absorptive capacity and technological innovativeness constructs showcased convergent validity. Moreover, the cross-loading analysis reveals that all indicators loaded highly on their corresponding constructs and relatively low on other constructs within the model. The results of cross-loadings validated the findings of Fornell and Larcker's criterion. Table 2 presents the cross-loadings of the items along with a summary of the convergent validity assessment and the cross-loadings of the items.

Table 3. Convergent Validity Test

	Absorptive Capacity	Technology innovativeness
AC1	0.86	0.36
AC2	0.87	0.35
AC3	0.87	0.31
AC4	0.86	0.49
TI1	0.48	0.85
TI2	0.39	0.86
TI3	0.35	0.87
TI4	0.37	0.88
TI5	0.39	0.86

Discriminate Validity

Discriminant validity is the extent to which a specific construct is distinct from the other constructs in the model [59]. It is evaluated using the test provided by

Fornell and Larcker [56], which compares the pairwise correlations between factors with the variance extracted estimates for the constructs that make up each pair. Discriminant validity is considered adequate when constructs have an AVE loading greater than 0.5, indicating that the construct accounts for at least 50% of the measurement variance [60]. Furthermore, discriminant validity is confirmed if the diagonal elements are significantly higher than the off-diagonal values in the corresponding rows and columns. The diagonal elements represent each construct's square root of the AVE score. Our results demonstrate that our two reflective constructs exhibit sufficient discriminant validity.

The heterotrait-monotrait (HTMT) ratio of correlations is another criterion for assessing discriminant validity in variance-based structural equation modeling [61]. The analysis of cross-loadings may not reliably identify the lack of discriminant validity in real-world research contexts, as they tend to have unacceptably low sensitivity in their assessment [61]. The HTMT approach estimates the correlation between constructs. If the indicators of two constructs show an HTMT value of less than one, the true correlation between them is likely different from one, indicating that they should indeed differ. It is generally accepted that the HTMT value should be below 0.85 [62] or 0.9 [63]. Our HTMT value of 0.49 for the reflective constructs was well beneath the cut-off point of 0.85. The HTMT test corroborates the results from Fornell-Larcker and the analysis of cross-loadings. Therefore, we established discriminant validity for our reflective constructs.

VIF and P-Values for Formative Constructs

Multi-collinearity is particularly relevant to formative indicators [64] because the formative measurement model relies on multiple regression; thus, the stability coefficients of the indicators are influenced by sample size and the strength of intercorrelations among the indicators. Extreme collinearity among the indicators complicates the separation of the distinct variance explained by the latent variable for each indicator. The VIF value should exceed 0.20. Various upper-bound values have been utilized. Nevertheless, in our tests, each indicator's tolerance (VIF) values were significantly below the standard cut-off threshold of 10 [64]. Therefore, multicollinearity was not a concern in our formative constructs.

Table 4. Multi-collinearity Test for Formative Constructs

	Indicators	VIF	Outer Weights	p-value
General Affordance (GA)	GA1	2.086	0.467	0.000
	GA2	2.468	0.308	0.000
	GA3	2.018	0.236	0.001
	GA4	1.530	0.179	0.012
Contextual Affordance (CA)	CA1	3.059	-0.096	0.443
	CA2	1.406	0.215	0.007
	CA3	2.008	0.399	0.000
	CA4	2.828	0.644	0.000

Behavioral Affordance (BA)	BA1	2.526	0.425	0.003
	BA2	3.613	0.343	0.060
	BA3	3.449	0.170	0.315
	BA4	1.874	0.199	0.096

The outer weight is used to measure the contribution of an indicator to a construct with the latent variable scores as the dependent variable and formative indicators as the independent variable in a multiple regression analysis. The values of outer weight express each indicator's relative contribution to the construct. We observed small to moderate weights for most of the items, from 0.11 to 0.61. One or more indicators would likely have had low or even non-significant outer weights when many indicators were forming a single construct.

We retained all items and then used bootstrapping to test further if the formative measurement models' outer weights differed significantly from zero. The results showed a significant p-value (< 0.05) for most formative indicators. Three items in behavioral affordance were insignificant, with p-values at 0.07, 0.08, and 0.33; one item in contextual affordance ($p = 0.37$) was insignificant. However, items with insignificant outer weights are not automatically removed because they may have altered the latent construct's meaning. Even with the insignificant p-values, we decided to retain the items as they uniquely contribute to the construct theoretically. It was suggested that if the theory-driven conceptualization of the constructs strongly supports the indicator, it should be retained. Because the subject experts confirmed our items' content validity, neither of the two items was removed. Table 4 presents the VIF values and outer weights for each formative indicator.

Structural Model Testing

After validating the measurement modeling, the next step is testing the hypothesized relationships among various latent constructs in the structural model. First, we examine the model fit, followed by the coefficient of determination, path coefficients, and mediating effects [65].

Model Fits

Two absolute fit measures, chi-square and standardized root mean square residual (SRMR), and a relative fit measure, the Normal Fit Index (NFI), are used to evaluate the model fit. The model presents a significant chi-square ($\chi 2 = 565.7$, $p < .001$). The result suggests that the reproduction of the correlation matrix based on the sample data's path coefficients is significantly different from the hypothesized model. A significant chi-square implies that the observed and implied variance-covariance matrices differ and may be due to sampling variation. Jöreskog and Sörbom [66] and Bentler [67] both advise against the sole use of the chi-square in judging the model's overall fit because of the chi-square's sensitivity to sample size. As the sample size increases, power increases. Consequently, the chi-square test uncovers small discrepancies between the observed and predicted covariances and suggests that the model does not fit the data. A good-fitting model could be rejected owing to trivial but statistically significant differences between the observed and predicted values. Since the chi-square model fit criterion is sensitive to sample size, the SRMR is also interpreted. The SRMR for our model was 0.056 which was below the recommended value of .080, and the model was considered a good fit. The relative fit measure Norm Fit Index (NFI) assessed the model by comparing the $\chi 2$ value of the model to the $\chi 2$ of the null model [68]. Values for NFI range between 0 and 1, with 1 indicating a perfect fit. Our data analysis derived an NFI value of 0.90, which indicates an acceptable model fit.

Hypothesis Testing

Our next data analysis step was to provide evidence supporting the theoretical model as exemplified by the model's structural portion [69]. A significant emphasis in PLS analysis is on variance explanation and establishing the significance of all path estimates. The R^2 value of the endogenous constructs is used to assess the predictive power of the structural model; it represents the amount of variance in the construct in question that the model explains. Table 5 illustrates the R^2 of the endogenous constructs. The sample consists of n = 401, with $R^2 = 0.273$. 27.3% of the variance in behavioral affordance was explained by contextual and general affordance, absorptive capacity, and technological innovativeness.

Our Hypotheses 1a and 1b propose that the level of patients' absorptive capacity positively affects general and contextual affordances, respectively. The structural model analysis results, presented in Table 5, show that the paths from the absorptive capacity to general affordance (β=.191, $p<0.01$) and contextual affordance (β=.148, $p<0.01$) were significant, supporting our hypotheses H1a and H1b. Such results indicate that the increased ability of a patient to recognize, assimilate, and apply new knowledge contributed to the number of action possibilities the patient perceives in contexts before and after the interactions.

Table 5. Path Analysis Results

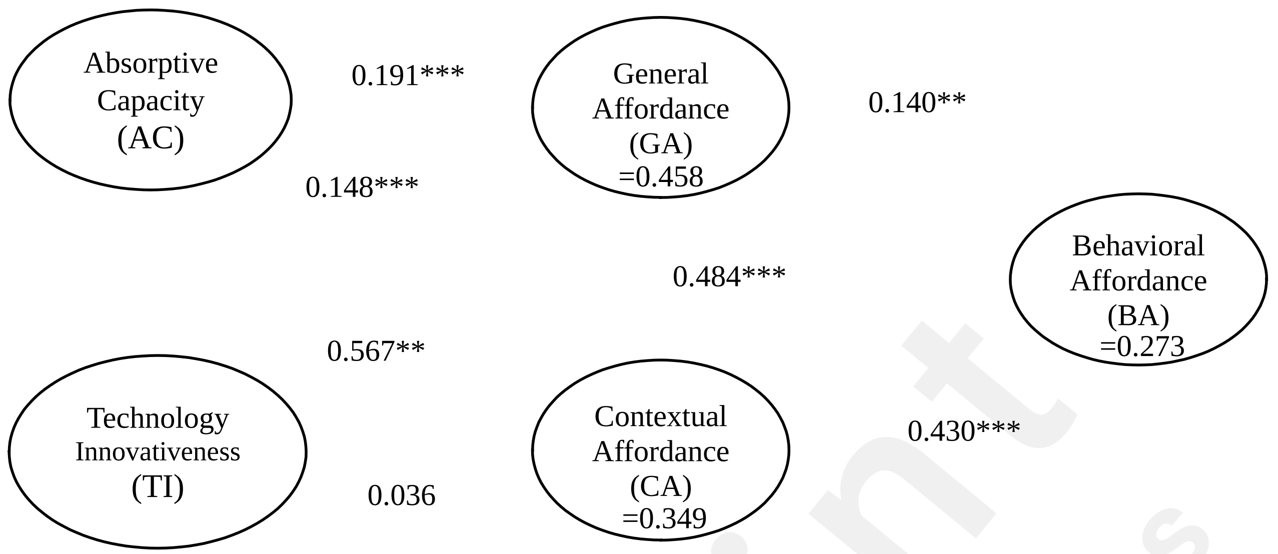
Path	Original sample	Sample Mean	SD	T statistics	p-values
AC -> GA	0.191	0.193	0.047	4.116	0.000
AC -> CA	0.148	0.149	0.053	2.812	0.005
TI -> GA	0.567	0.568	0.047	11.971	0.000
TI -> CA	0.036	0.034	0.062	0.578	0.564
GA -> CA	0.484	0.488	0.064	7.527	0.000
GA -> BA	0.140	0.138	0.057	2.471	0.014
CA -> BA	0.430	0.439	0.059	7.312	0.000

Our Hypotheses 2a and 2b propose that the degree of perceived technology innovativeness for patients positively affects general and contextual affordances, respectively. Our results show that the path from technology innovativeness to general affordance (β=0.567, $p<0.01$) was significant, supporting our hypothesis 2a was not supported. The path from absorptive capacity to contextual affordance (β=.0.036 p>0.05) was significant, supporting our hypothesis H2b that the degree of perceived technology innovativeness has a positive influence on GA but not CA. Such results suggest that the increased level of efficiencies gained by the MHP compared to other tools, as perceived by the patient, contribute to the number of action possibilities the patient perceives in contexts before the interactions; however, that effect becomes insignificant closer to the time when interactions occur. Even though the path from technology innovativeness to contextual affordance is not significant, we decided to keep it since it demonstrates the context's critical role in how patients perceive the MHP.

We hypothesize that the degree of GA positively affects CA. We observe a significant path from GA to CA (β=0.484, p<0.01), supporting hypothesis H3 that GA positively influences CA. These results indicate that the increase in action possibilities perceived by the patient in contexts before interactions enhances the number of action possibilities perceived during those interactions.

We further hypothesize that the degree of CA and GA has a positive effect on behavioral affordance (BA). The paths from CA to BA (β=0.430, p<0.01) and GA to BA (β=0.140, p<0.05) are both significant, supporting hypotheses H4a and H4b that the degree of CA and GA positively influences behavioral affordance. This result indicates that an increased number of action possibilities the patient perceives in contexts before and after the interactions contributes to realizing affordance. The details of the path model are presented in Figure 2.

Figure 2. Structural Equation Estimate Results



Mediating Analyses

Through mediation analysis, we gain insight and develop a deeper understanding of the mechanisms of action regarding MHP usage through the lens of affordance [70]. This information further enriches our comprehension of the effects of affordance, potentially guiding the discovery of more effective and cost-efficient strategies to enhance patient portal adoption. The details are presented in Tables 6,7 and 8.

Absorptive capacity had a significant direct effect on behavioral affordance (β = 0.246, t = 4.333, $p < 0.001$), while technological innovativeness did not (β = -0.003, t = 0.052, p = 0.959). Contextual (β = 0.430, t = 7.312, $p < 0.001$) and general affordance (β = 0.140, t = 2.471, p = 0.014) positively influenced behavioral affordance.

Table 6. Direct Effects

Direct Effects	Original sample	Sample Mean	SD	T statistics	p-values
AC -> BA	0.246	0.247	0.057	4.333	0.000
TI -> BA	-0.003	-0.001	0.061	0.052	0.959

Absorptive capacity had a significant indirect effect on behavioral affordance (β = 0.103, t = 3.786, $p < 0.001$), indicating partial mediation through affordances. Technological innovativeness also had a significant indirect effect on behavioral affordance (β = 0.152, t = 4.204, $p < 0.001$), but since its direct effect was not significant, general and contextual affordances fully mediated this relationship.

Table 7. Total Indirect Effects

	Original sample	Sample Mean	SD	T statistics	p-values
AC -> BA	0.103	0.104	0.027	3.786	0.000
TI -> BA	0.152	0.152	0.036	4.204	0.000

Table 8. Specific Indirect Effects

	Original sample	Sample Mean	SD	T statistics	p-values
AC -> GA -> BA	0.011	0.010	0.012	0.878	0.380
AC -> GA -> CA -> BA	0.035	0.036	0.012	3.043	0.002
AC -> CA -> BA	0.057	0.058	0.022	2.593	0.010
TI -> GA -> BA	0.032	0.029	0.035	0.902	0.367
TI -> GA -> CA -> BA	0.106	0.109	0.023	4.690	0.000
TI -> CA -> BA	0.014	0.014	0.025	0.551	0.582

These results suggest that general and contextual affordances play a crucial role in translating absorptive capacity and technological innovativeness into behavioral affordance. While absorptive capacity directly influences behavioral affordance through general and contextual affordances, technological innovativeness impacts behavioral affordance only through general and contextual affordances. This underscores the importance of designing MHPs that enhance affordance perception to facilitate patient engagement and adoption.

Discussion

Relatively little empirical research has explicitly investigated how contextual affordances influence technology adoption. This study responds to calls for research that examines different contexts when analyzing the relationship between technology (the artifact) and actors (the social) [9, 21, 72]. Adopting a socio-technical perspective, this study also addresses the need to use the lens of affordance to examine its actualization in healthcare contexts [73]. Strong and Volkoff [73] introduced the concept of a bundle of interrelated and interacting affordances. Consistent with this concept, rather than assuming that affordance is a singular, stable construct, we further differentiate contextual affordance from general affordance. We tested their effects by utilizing MHP across four large hospitals in China.

Theoretical Contributions

We identify two important predeterminant factors of affordances, whereas previous research generally treats affordances as independent variables [74, 75]. The contingency hypotheses for absorptive capacity and technology innovativeness capture how patients form affordances for the MHP. Consistent with previous research [46, 51], absorptive capacity captures the user's capability in evaluating MHP, whereas technology innovativeness captures the technology side of MHP [72]. They both play important roles in forming patients' affordance. Interestingly, technology innovativeness is only significant in determining general affordance but not contextual affordance. The results from our data suggest that patients' evaluation of MHP based on diffusion of innovation theory only determines general affordance. However, when the patients interact with MHP, the effects become insignificant. This result is consistent with Strong and Volkoff [73] suggesting that other factors, such as users' goals and immediate outcomes, will affect the actualization of affordance. These other factors are captured in our contextual affordance construct but not general affordance.

We further distinguish three affordance constructs in the healthcare research contexts: general affordance, contextual affordance, and behavioral affordance. General affordance is conceptualized as the patients' evaluation of what they can do with the MHP before specific use in a given context. The perception of these possible actions afforded to the patients by MHP largely depends on patients' experience with similar technology. On the other hand, contextual affordance is defined as the patients’ evaluation of what they can do with the MHP at the point of interaction that is inherently embedded within the interactions' contexts. Contextual affordance and general affordance are distinctive and affect patient behavior differently. Contextual affordance is more immediate and unstable and subject to change. The time for it to be in effect is when a patient must decide whether to use the patient portal. When contextual affordance is present, the more stable and distal general affordance serving as the patient's baseline will be temporarily adjusted. We shift the focus from the main treatment of affordance from functionalities or features of systems to examine the action possibilities of contextualized affordance, accounting for both the baseline affordance and the affordance in action. This notion is different from previous empirical affordance research [74, 76].

Practical Implications

MHP serves as a powerful tool for organizations to achieve a competitive advantage and adapt to ever-changing patient demands [71]. While MHP investments seem advantageous for some organizations, results for others are mixed due to insufficient consideration of context when adopting, implementing, and disseminating these technologies [9]. Through the lens of affordance, we urge organizations to incorporate contextual elements into their planning and evaluation of technological investments and usage [72]. Health organizations may be able to translate MHP investments into enhanced patient adoption and usage when contextual aspects are given thorough consideration [2, 72, 77]. Our study results support our hypothesis that the positive effects of affordance influence the realized behavioral affordance of the MHP.

The concept of behavioral affordance aligns with prior research advocating for a nuanced distinction between affordance and its actualization in a dynamic process [73, 78]. Our results suggest that general affordance influences patient behavioral affordance through contextual affordance. This implies that patients' decisions to use the MHP are contingent not only on the general affordance they possess before utilizing it but also on the contextual affordance established during the interaction [72, 77]. Furthermore, our findings reveal that contextual affordance has a more significant impact on behavioral affordance than general affordance. Patients' decisions to use the MHP are firmly rooted in contextual affordance at the specific moment of interaction rather than in the level of general affordance prior to those interactions [2]. Additionally, we observe that technological innovativeness affects general affordance more than it influences contextual affordance, while absorptive capacity has a greater impact on contextual affordance than on general affordance.

Limitations and Future Research

Due to our study's limitations, the research results should be interpreted with caution. While this study represents one of the early studies to examine the three types of affordances empirically, the sample was drawn from four large hospitals in China. As such, the results should not be considered generalizable without further validation across other populations of hospitals and countries. Future research should examine the generalizability of our research findings in other types of hospitals and countries.

Conclusion

This study provides significant insights into the factors influencing the adoption and use of hospital MHP by categorizing affordances into general, contextual, and behavioral types. Our research demonstrates that patient absorptive capacity and the innovativeness of hospital MHP are key predictors of these affordances. Specifically, absorptive capacity was found to positively influence both general and contextual affordances, which in turn positively affect behavioral affordance. The findings highlight the critical role that contextual factors play in system adoption, as contextual affordance emerged as a stronger predictor of behavioral affordance than general affordance. The study also reveals that while technology innovativeness is a significant predictor of general affordance, its influence on contextual affordance is minimal. This suggests that the immediate context of system use plays a more crucial role in patient behavior than the perceived innovativeness of the technology itself. These findings underscore the importance of considering both the technical and social dimensions of affordances in the design and implementation of MHP. For practitioners, this research offers actionable guidelines for improving patient portal adoption by emphasizing the management of contextual affordances at the point of interaction.

Appendix 1. Measurement Items

Construct	Items	Key Source(s)
Absorptive Capacity	1. I have frequent interactions with new mobile applications 2. I collect information on new mobile applications through informal means 3. I periodically scan for new mobile applications to use	[43,44,53,54]

	4. I quickly analyze and interpret available mobile technology	
Tech Innovativeness	1. I think using the hospital's MHP to arrange medical appointments is better than other methods. 2. I believe using the hospital's MHP has significantly improved the quality of my medical visits. 3. I find the hospital's MHP very easy to use. 4. I believe using the hospital's MHP aligns well with my habits. 5. I am able to try using the MHP to handle my medical needs.	[17,38,55]
General Affordance	The hospital's MHP should let patients to… 1. Schedule doctor appointments online anytime, anywhere. 2. Make payments online anytime, anywhere. 3. Interact and consult with doctors online anytime, anywhere. 4. Access hospital-published health education information and medical news online anytime, anywhere.	[3,4,10,36]
Specific Affordance	Based on my specific medical condition, I believe using this hospital's MHP makes it easy to… 1. Schedule an appointment with the doctor I want to see online. 2. Pay all medical-related fees online. 3. Access all my lab reports and medical records online. 4. Ask medical staff questions via text messages at any time.	[3,4,10,36]
Behavioral Affordance	I use… 1. the appointment function to make an appointment with the doctor I want to see in my healthcare process 2. the lab function to access my lab reports in my healthcare process 3. the consulting function to communicate with my doctor in my healthcare process 4. the payment function to pay for my healthcare related cost in my healthcare process	[3,4,10,36]

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