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Diabetes Self-Management Using Mobile Apps: An Empirical Investigation Based On App Reviews And Through Value Sensitive Design Perspective

Majid Dadgar
Washington State University, majid.dadgar@wsu.edu

K.D. Joshi
Washington State Univeristy, joshi@wsu.edu

DIABETES SELF-MANAGEMENT USING MOBILE APPS: AN EMPIRICAL INVESTIGATION BASED ON APP REVIEWS AND THROUGH VALUE SENSITIVE DESIGN PERSPECTIVE

Dadgar, Majid, Washington State University, Todd Hall, Pullman, WA 99164, U.S.A., majid.dadgar@wsu.edu

Joshi, K. D., Washington State University, Todd Hall, Pullman, WA 99164, U.S.A., joshi@wsu.edu

Abstract

Smartphones have penetrated our everyday lives. Novel technologies facilitate self-management of chronic diseases such as diabetes. However, not all the patients are motivated to use technologies to manage their chronic conditions. Patients depend on certain human values to self-manage their conditions and these values are not implicated in the technologies they use. In this research in progress study we draw on value sensitive design methodological and theoretical approach to investigate human responses to self-management technology. We collect app reviews for a diabetes app and schematically code the review. Our findings contribute to designing technologies and systems that account for the human values of the patients-users.

Keywords: Self-Management, Mobile App, Value-Sensitive Design, Chronic Diseases.

1 Introduction

Smartphones have penetrated our everyday lives. 64% of American adults now own a smartphone of some kind, up from 35% in the spring of 2011. 62% of smartphone owners have used their phone in the past year to look up information about a health condition (Smith, 2015). With an emergence and abundance of mobile apps patients use mobile apps for the self-management of their health conditions (Cummings and Turner, 2009; Wickramasinghe, Tatnall and Goldberg, 2011; Vuong et al., 2012; Omar El-Gayar et al., 2013; Waite, Curtis and Nugrahani, 2013). It is estimated that almost 7 million iPhone users have diabetes (Vuong et al., 2012). The FDA predicts that, by 2015, 500 million individuals will use mobile health applications (O. El-Gayar et al., 2013). National and international healthcare policies increasingly seek technological solutions to the challenge of providing care for people with long-term conditions. In a recent effort, Hospital-based app curation platforms have started at Ochsner Health System and the Cleveland Clinic (Comstock, 2015). Cleveland Clinic Innovations, a business unit at the Cleveland Clinic, has partnered with the Global Healthcare Innovations Alliance to launch a new e-commerce platform called ADEO (onadeo.com). Through the website, both caregivers and patients will be able to purchase care tools, including a number of patient-facing mobile apps. Ochsner Health System in New Orleans made headlines last summer when it launched the O Bar, the first "Genius Bar-type" in-person center for learning about health and wellness apps. And toward the end of last year, Morristown Medical Center, a part of the Atlantic Health System in New Jersey, opened up HealtheConnect, an on-site, physical store located just off the hospital's main lobby where patients, family members, and medical professionals can learn about health apps and wearable devices. The apps vary from food and nutrition tracking, to fitness and activity, to apps that help manage chronic conditions like diabetes.

Novel technologies have the potential to change the dynamics of disease monitoring and self-management (Palen, Grudin and Munkvold, 2003; Farmer, Gibson and Hayton, 2005; Pinnock et al., 2007; Quinn et al., 2008; Cummings and Turner, 2009; Gupta et al., 2011; Tran, Tran and White, 2012; Belisario et al., 2013; Omar El-Gayar et al., 2013; Dadgar and Joshi, 2015). We focus on diabetes apps in our study. According to the American Diabetes Association, diabetes costs have exceeded $174 billion, and there are 25.8 million diabetes patients in the U.S. (Tran, Tran and White, 2012). Overall mobile applications can be viable tools for diabetes self-management. Mobile smartphones enable collection of physiological data, they facilitate patient-physician communication, and provide instant and constant resources for the patients to self-manage their chronic conditions (Arsand, Andersson and Hartvigsen, 2007; Bu, Pan and Walker, 2007; Medvedev and Marshall, 2008; Schermer, 2009; Lorig et al., 2012; Bailey et al., 2013; McDermott and While, 2013). These properties improve self-management of long-term chronic conditions and benefit patients to increase their quality of life and decrease number of hospital readmissions (de Barros et al., 2013).

Despite these positive effects, not all patients are motivated to use the IT-enabled systems to self-manage their chronic conditions. Main barriers are related to usability problems and the absence of clear triggers to use the technologies (Nijland et al., 2009). For example studies exploring mobile diet monitoring methods have had varying results. One study found no difference in weight loss between PDA and paper journal users (Turner-McGrievy et al., 2013). El-gayar et al. (2013) identify number of issues with diabetes self-management apps. They argue that diabetes apps are not customized to the individual needs of the patients with diabetes and they are very generic. They point out that diabetes apps need to incorporate value-based features such as decision support capabilities. There is a distinct need to employ a user-centered design that will take into account the needs and characteristics of the individual patient (O. El-Gayar et al., 2013). In this research in progress study we draw on Value Sensitive Design (VSD) perspective to identify the needs and desires of the patients with diabetes, which consequently uncovers human values that are important to them. VSD proposed by Friedman et al. (2008) is a framework sensitive to the human values of the system users. It is consisted of three main components, conceptual, empirical, and technical investigations. Based on these investigations

human values are identified and designed in the information systems. VSD is discussed more in the section Theoretical Background. We use VSD framework to schematically analyze data collected from the reviews of a diabetes app to address the following research question, how can we empirically uncover human values and system features in human responses to a healthcare information technology and system?

The paper is organized as follows. In the following section we will introduce VSD and its principles. Next, we will explain our methodology and then we will present our preliminary analysis and findings based on diabetes app reviews. We will finish with conclusion and future work.

2 Theoretical Background

Today nearly two-thirds of Americans own a smartphone and for many these devices are a key entry point to the online world (Smith, 2015). The relevance of studying IT impacts continues as IT diffuses across an increasingly large scope of human activity. Whether seeking to produce general explanation through a "grand" theory, or account for empirical observations through a locally "grounded" theory, researchers must apply or develop theoretical frameworks that correspond to the phenomena being studied. Most theories currently used in IS research do not engage adequately with the material properties of IT artifacts (Robey, Raymond and Anderson, 2012). VSD is a theoretical and methodological framework for designing human values important to the users into the material properties of the information systems (Friedman, Kahn and Borning, 2008). VSD has four main components which we will briefly explain. Human values within the VSD framework have ethical import and they are sensitive to what is important to people in life. Human values uncover interests and desires of the human beings (Borning et al., 2005). VSD provides a systematic methodology to uncover human values based on its three building blocks, conceptual, technical, and empirical investigation (Figure 1). Conceptual investigation is the backbone of VSD and conceptualizes how certain human values are theoretically grounded (Friedman and Nissenbaum, 1996). It is investigated that patients with chronic diseases rely on the human values hope, human welfare, autonomy, trust, and privacy to self-manage their chronic conditions (Dadgar and Joshi, 2015). Empirical investigation focuses on the human response to the technical artifact which is the focus of this study. We investigate human responses to our technical artifact, diabetes app, by analyzing app reviews. The entire quantitative and qualitative methods in social sciences may be applicable for empirical investigation. The third VSD component is technical investigation which involves how existing technological properties and underlying mechanisms support or hinder human values (Denning et al., 2010). The results and findings of our empirical investigation will inform technical investigation for the future work.

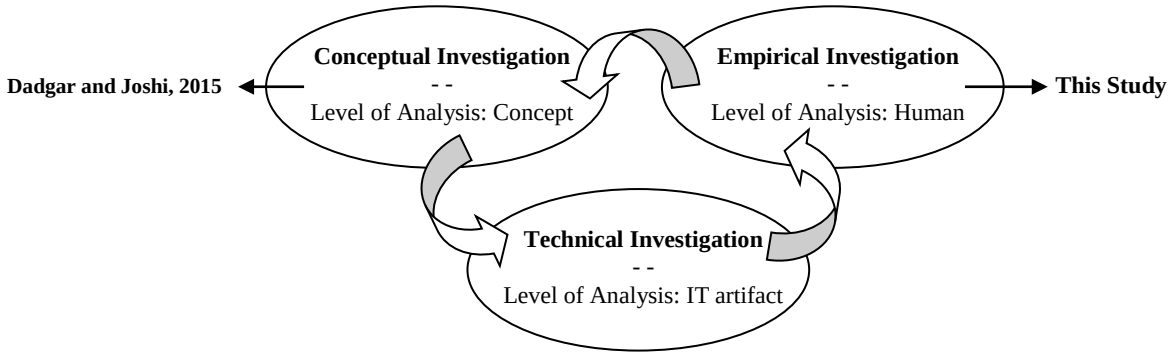

Figure 1. VSD three-part methodology, conceptual, empirical, and technical investigation.

There is a major distinction between VSD and usability premises. Usability investigation is a functionalist approach which prioritizes system use and performance over other metrics. In contrast VSD prioritizes human values with ethical import in the technologies (Friedman, Kahn Jr., et al.,

2006). This contrasts the premises of usability studies from the principles of VSD investigations. Such comparison between usability and VSD highlights the fact that not all the highly usable systems support human values of the users (Friedman, Kahn and Borning, 2008). For example a highly usable functioning system may violate privacy of its users. System designers concerned with implicating human values of the users in the systems may face challenges to balance usability and human values in a system. For example system designers might have to relax the privacy protection to achieve higher levels of usability required for a system (Friedman, Smith, et al., 2006). In this research in progress study we will empirically investigate human responses to the material properties of an IT artifact used to self-manage chronic conditions. Material properties are explained as features of IT, including hardware devices, software interfaces and applications, and communication services (Robey, Raymond and Anderson, 2012). This definition focuses on the functions and capabilities that technology features make available in the potential context of use. We analyze technology reviews to analyze human responses to the material properties because reviews capture desires and needs of the system users (Hoon et al., 2012; Fu et al., 2013; Chen et al., 2014). There are limitations to this approach which we will discuss in the conclusion. In the next section we will discuss our methodology, preliminary analysis and findings.

3 Method

We aim to uncover the relationships between the human values and system features evident in the human responses reflected in the app reviews. We investigate what conditions, materials properties or system features, lead to what levels of human values and self-management dimensions. Toward this aim, there are two methods available for qualitative data analysis, coding and qualitative content analysis (Gläser and Laudel, 2013). We choose coding over content analysis as it better aligns with the aim of this study because it provides the best way to apply our coding schema to analyze app reviews. Using the coding method, researcher reads the text, app reviews, interprets it, finding the relationship with coding schema, and decides whether there is a relevant information (Glaser and Strauss, 1967; Kelle, 1997; Gläser and Laudel, 2013). Codes, for example, keywords and phrases, represent a specific information assigned to segments of text (Miles and Huberman, 1994).

3.1 Research Context

We based our technology selection on searching and finding the most popular diabetes app in the Apple app store, and two diabetes app review papers, El-gayar et al. (2013) and Waite et al. (2013). We limited our convenient technology selection to Apple app store to remove the possible effects of different mobile operating systems or device capabilities and differences. For the future study we will collect diabetes app reviews from other mobile platforms and app stores to increase sample size and provide comparisons between different apps. Our sampling resulted in 5 apps with high diabetes self-management and usability standards. Next we rated the 5 final diabetes apps based on their primary care and secondary features for the patients with diabetes and their Apple app store characteristics. Results as of April 5, 2015 are shown in Table 1. The diabetes app with the highest score, Glucose Buddy, was chosen. Next we collected Apple app reviews for Glucose Buddy for the course of 1/1/2008 to 4/1/2015 using an API request. Our API request resulted in about 1600 reviews along with the user IDs, review title, rating (1 to 5 stars), location, and dates. Next we compiled all the data in an Excel file for the coding step based on our coding schema. We discuss coding schema under Preliminary Coding and Analysis.

(Waite, Curtis and Nugrahani, 2013)	(O. El-Gayar et al., 2013)	Technology (Diabetes Mobile App)				
		Diabetes Diary	GluCoMo	Rapid Calc	Glucose Buddy	GlucoSuccess
Primary Care	Medication	1	1	1	1	1
	Blood Glucose	1	1	1	1	1
	Monitoring	1	1	1	1	1
	Diet Management	1	1	1	1	1
	Physical Exercise	0	0	0	1	0
Secondary Features	Education	0	1	1	1	0
	Weight BMI	0	0	0	0	1
	Blood Pressure	0	0	0	1	0
	Communication	0	1	1	1	0
	Social Networking	0	1	0	1	0
	Integration with PHR	0	0	0	0	0
	Alert/Reminders	1	1	1	1	1
	Tagging	1	0	0	0	0
	Decision Support	0	0	1	0	0
	Security	0	1	1	0	1
App store Characteristics	iOS/platform	iOS	iOS	iOS	iOS	iOS
	Number of ratings	41	83	23	1,627	67
	Average Rating	~3.5/5	~2/5	~4.5/5	~4.5/5	~3/5
	Latest Version	2.0.0	1.0.12	2.1.2	3.7.0	1
	Cost	$2.99	$0.99	$7.99	Free	Free
Total Score		6	9	9	10	7

Table 1. Technology Sampling

3.2 Sampling

In our study we have collected and analyzed reviews for a diabetes app (Figure 2). We have controlled for the type of device and mobile operating systems by collecting reviews only for a diabetes app in Apple app store. We have retrieved all the reviews for a popular diabetes app of Glucose Buddy using an API request. About 1600 reviews for the time span of 1/1/2008 to 4/1/2015 are collected. Glucose Buddy is selected through a systematic technology selection (See subsection Research Context).

Several studies have used technology reviews. For example, Fu et al. (2013) propose a system that can analyze user ratings and reviews in mobile app markets at three different levels of detail, inconsistencies in reviews, reasons why users like or dislike a given app, and evolution of app reviews over time. Chen et al. (2014) present a novel computational framework for app review mining which first extracts informative app reviews and discards irrelevant ones, and then groups and prioritizes informative reviews. Hoon et al. (2012) analyze millions of app reviews on the app store and estimate what portion of words are used to express sentiments in the reviews. Their findings show that users express negative reviews more than positive ones. Vasa et al.'s (2012) analysis of app reviews show that users leave longer comments when they poorly rate an app. They also find that in certain categories, such as entertainment or health and fitness, the depth of reviews are significantly higher.

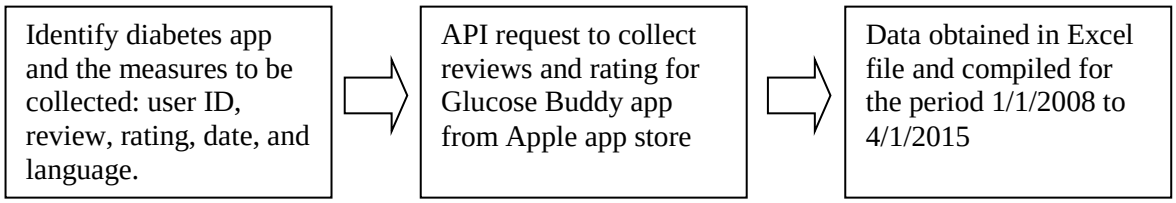

Figure 2. Data Collection Process

We have developed a coding schema (See subsection Preliminary Coding and Analysis - Table 2) based on the principles of VSD, human values, self-management dimensions, and system features (Dadgar and Joshi, 2015).

3.3 Preliminary Coding and Analysis

Data collected from app reviews from Apple app store are coded schematically. The coding schema (Table 2) is developed based on the human values, self-management dimensions, and system features for the patients with chronic diseases (Dadgar and Joshi, 2015) and further refined and expanded based on the VSD principles and nature of the collected data. In our coding schema human values important to the patients with chronic diseases and their relevant self-management dimensions are incorporated to identify the system features which can support them. Select number of coded reviews and preliminary analysis and findings are discussed in the next subsection. We have used coding strategy recommended by Miles and Huberman (1994) to code app reviews based on our coding schema. Their coding strategy is Matrix Display. Matrix Display is a systematic coding strategy to make sense of data based on coding schema and in relation to the research question.

Human Values	**Definition of Value** (Friedman, Kahn and Borning, 2008)	**Self-management Dimensions** (Evidences extracted from literature through value-sensitive lens)
Hope	Refers to a primarily future oriented expectation of attaining personally values goals which will give meaning, are subjectively considered possible, and depend on personal activity or characteristics, and external factors (e.g. resource availability) (Schrank *et al.*, 2012)	- improve problem solving skills of the patients - facilitate goal setting, planning, and achieving a goal - guide patients to prepare their action plan in achieving their health goals - create internal motivation to overcome disease barriers - provide social and peer support for the patients from family, community, and friends. - provide access to educational and information resources about the disease, treatment, and its conditions. - improve decision making skills for the patients regarding their health conditions. - increase knowledge of the patients about the disease - provide feedback about patient's progress in managing conditions - support and educate patients in coping with negative emotions imposed by the disease. - eliminate cognitive and attitudinal barriers toward self-management - eliminate uncertainty about meaning of life
Human Welfare	Refers to people's physical activity, material, and psychological well-being	- self-management should be cost-effectiveness of the - eliminate distress and anxiety in the patients caused by the disease conditions - improve mental and physical health conditions - facilitate self-monitoring of disease symptoms - support and educate patient in overcoming depression - educate and guide patients in adapting lifestyle

		- provide ways to increase treatment adherence - improved self-management skills
Universal Usability	Refers to making all people successful users of information technology	- provide adaptive self-management in low income countries - provide culturally adaptable self-management methods - support racial/ ethnic minorities in the self-management process - provide support for the patients from underserved groups - create more flexible self-management methods that are not mostly for well-educated higher income white adults - support the needs of gender and age differences - support adjusting life-style and mitigate conflict with cultural norms - design culturally appropriate self-management methods - provide self-management instructions, resources, and commands in non-English languages
Trust	refers to expectations that exist between people who can experience goodwill, extend goodwill toward others, feel vulnerable, and experience betrayal	- facilitate reliable conditions for the patients to actively create partnerships with professional health providers - facilitate reliable conditions for patients to easier participate in treatment decision making - improve reliable conditions which can help patients to effectively communicate with health providers
Autonomy	Refers to people's ability to decide, plan, and act in ways that they believe will help them to achieve their goals	- empower patient so that they can self-manage - increase confidence of patient in managing - encourage patient to take responsibility for his/her chronic condition - improve self-efficacy of self-management - patients are experts about their own lives - allow patients to define their problems which can be eye-opening - customize and tailor self-management to patient's needs - respond to patients' individual needs - mitigate limited presence of "self" in self-management
Privacy	refers to patient's concerns about medical data, and nonintrusive environment for treating, measuring, and monitoring chronic diseases	- Do no transmit personal data of the patient to clinic - provide different levels of access to data for technical staff, clinicians, and patients - allow patient to have control over transmission of data and the extent to which others have access to the data

Table 2. Coding Schema

Our preliminary analysis is conducted as follows. First we start with breaking down each review into separate statements. Next we break down each statement into value phrases that can relate to the underlying meanings and definitions of self-management dimensions. The review statements are broken into value phrases and coded based on what could be improved, what reviewer complained about that the app is lacking or the feature that should be added to the app. Revealed self-management dimensions relate to a human value based on our coding schema. And ultimately we identify how and to what extent such self-management dimensions are designed into the diabetes app. Self-management dimensions translate into system features that are implicated or not implicated or are liked or disliked by app users which are reflected in user reviews.

3.4 Preliminary Findings

In this section we provide examples of our preliminary findings which will showcase our coding strategy based on our coding schema to address our research question (Table 3). User Bpbell75's review, for example, reads that "This app works great for sugar tracking and it tracks sugar pretty nice

for free not sure how much more useful the pro version is but that appears a bit pricy". The phrase in which a value is revealed, based on our coding schema, is "ability to track sugar for free". Tracking blood sugar and the fact that the app is free relate to the self-management dimensions "self-monitoring" and "cost-effective self-management" respectively. These two self-management dimensions are part of the human value "Human Welfare". There are reviews in which users complain or dislike certain features in the app or they wish for the feature that the app is lacking. For example user Ted Ninja complains that old settings in the app are paid features in the latest version or even they do not exist. Ted further explains two features that are no longer free in the app, "These included setting up alarms to remind me to take my insulin and check my BG afterwards (manual entries would trigger these alerts) and ACTUALLY SYNCING MY LOGS both ways with the server." Based on our coding schema, we break down this statement into two value phrases, 1) "to remind me" which translates into the self-management dimension "feedback", 2) "ACTUALLY SYNCING MY LOGS both ways with the server." which relates to the self-management dimension "coping with negative emotions" (Upper case words in this value phrase show the frustration of the user which show the negative emotions in the user). These two value phrases relate to the human values hope and human welfare, respectively. And ultimately value phrases show how they can be implicated in the app as features. User mentions that "reminders to take my insulin and check my BG afterwards (manual entries would trigger these alerts)" as app features help him to self-monitor his blood glucose levels. And "SYNCING MY LOGS both ways with the server." makes it easier for the user to keep records of his blood glucose levels. Automatic syncing of blood glucose logs will avoid negative emotions imposed by the tedious self-management process of diabetes. User Timbletastic reviews that the app "is easy way to keep track of blood glucose levels, but shame the technical support is so poor - no answer to emails." In this review user is complaining about the poor technical support for the app. Any kind of support during the self-management process is associated with the self-management dimension "social and peer support" and this self-management dimension is part of the value hope. Such findings provide insights for the development of healthcare apps, specifically diabetes apps.

Value Statements – what a diabetic patient considers to be important in self-management of his/her chronic conditions	**Value Revealed**	**Value Category**	**Self-management Dimension**	**Value Implicated (or Not) in Current Design**
"This app works great for sugar tracking …. it tracks sugar pretty nice for free …"	Value the ability to track sugar for free	Human Welfare: Patients' physical activity, material, and psychological well-being	- Cost-effectiveness of the self-management (free app) - Self-monitoring of sugar levels (sugar tracking)	Human welfare value is implicated through its features that allow patients to self-monitor their sugar levels for free and it contributes to their physical wellbeing.
"These included setting up alarms to remind me to take my insulin and check my BG afterwards…"	Value the reminders	Hope: future oriented expectation of attaining personal values & goals	- Feedback (in forms of reminders)	The value of Hope is implicated in the reminder feature that alerts patients to take the insulin.
" [it] ACTUALLY SYNCS MY LOGS both ways with the server."	Value the automated record keeping assistance	Hope: future oriented expectation of attaining personal values & goals	- Coping with negative emotions (in forms of facilitating log recording)	The Apps ability to automatically sync logs without manually entering the logs alleviates the anxiety and frustration of record keeping.

" … easy to keep track of blood glucose but the technical support is so poor …"	Value the support provided during the self-management process	Hope: future oriented expectation of attaining personal values & goals	- Social and peer support	Hope is not implicated because of poor technical support. A good technical support would help sustain hope to stick with the self-management process

Table 3. Examples of our preliminary findings coded based on coding schema

4 Conclusion and future Work

In this research in progress study, building on Value Sensitive Design (VSD) principles and premises and expanding on the work by Dadgar and Joshi (2015), we develop a coding schema. Our coding schema is sensitive to the human values important to the patients with chronic diseases, self-management dimensions, and features of self-management systems. We use our coding schema to analyze the reviews of a diabetes app in the Apple store. Our preliminary findings show to what extent human values important to the patients with diabetes are designed in the IT artifact which they use to self-manage their chronic conditions. Findings of our research enable app developers to design diabetes apps that are sensitive to the value of the diabetes patients. Our work introduces a new methodology based on Value Sensitive Design (VSD) to analyze user reviews of an IT artifact. This new analytical approach based on VSD contributes to the body of research that attempts to analyze technology reviews in order to gain insights and system design.

We recognize number of limitations for using app reviews as the main source of data analysis and insights about using IT artifacts in the self-management of chronic diseases such as diabetes. App reviews reflect what app users desire to say about a given app. This can be an advantage of using app reviews and gaining insight about a certain IT artifact. At the same time, the context of use and the background of the users are not always provided with the reviews of this kind. Some reviews provide a background of the user-patient with a lot of details and some reviews are short and do not cover much details.

For the future, we will complement findings from this study with in-depth interviews with the diabetes patients who use information technologies and users in the self-management of their chronic diseases and conditions. We will complete this research in progress by coding all the app reviews and aggregating the findings. Ultimately we will design a mobile for diabetes patients based on the insights that we gain from analyzing the diabetes app reviews. Future studies can collect app reviews from users in other countries and test for the impact of cultural differences on human values. In addition app reviews can be collected from other mobile platforms which will increase the sample size and it will provide a robust guidelines for comparing and testing value-sensitive medical apps across mobile platforms and devices.

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