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MEASURING EXPECTATION FOR AN AFFORDANCE GAP ON A SMARTPHONE USER INTERFACE AND ITS USAGE AMONG OLDER ADULTS

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Abstract: *The smartphone has become a ubiquitous mobile communication tool that plays a crucial role in the daily lives for Malaysian older adults. However, it is not easy for older adults to learn new interaction modes and adopt the smartphone user interface. In this paper, we aim to examine the affordances of a smartphone user interface and its usage by older adults through the lens of Norman's execution/evaluation action cycle (EEAC) framework. A mobile-user interaction study was administered with four tasks. A paired sample* t*-test was conducted to analyze the affordance gap between different levels of expectation. The results revealed that three tasks (making phone calls, adding contacts, and using WhatsApp) were statistically different; the exception was installing mobile apps. The results underscore the importance of mobile apps designers incorporating older adults' needs and expectations as a means to reduce the affordance gap.*

Keywords: *affordance, expectation, older adults, execution/evaluation action cycle, smartphone user interface.*

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INTRODUCTION

Malaysia will be joining the advanced countries in becoming an aged nation by 2035 (Hamid, 2019; Sinnadurai, 2019). This study indicates that 15%, or 5.6 million people, of the Malaysian population will be aged 60 years and above, with an increase in life expectancy due to better health care and improved standards of living.

Mobile technologies such as smartphones have become necessary tools in most societies. Growing numbers of people also have to adopt and use a mobile phone for communication and functional tasks (mobile apps) these days. Given the widespread, prevalent, and ubiquitous nature of technologies such as smartphone devices and broadband services, these gadgets have penetrated and influenced all walks of life, including those of the older adult cohort. Older adults, aged 60 and above, were not raised in the digital era; however, they now represent a market of potential smartphone consumers. A majority of this cohort are more familiar with the feature phones, which are equipped only with basic functions such as voice calling and text messaging (PC Magazine, n.d.; Technopedia, n.d.), rather than the smartphone user interface. However, the birth of the iPhone in 2007 marked the initiation of the "smartphone era" (Anh, 2016; Pothitos, 2016), and 10 years later, almost no one buys a feature phone anymore (Hern, 2017). As a result, older adults cannot escape migrating into the "silver smartphone users" cohort, also known as the "grey market" (Mack, n.d.). Having said this, older adults generally are perceived as "techno-phobic" in taking up new technology (Essén & Östlund, 2011; Fisk, Rogers, Charness, Czaja, & Sharit, 2009; Haederi, 2011; Hogan, 2006, 2009; Nimrod, 2018).

Although the smartphone is becoming a ubiquitous communication tool for older adults in their daily lives, learning the new interactive mode is neither easy nor straightforward for them, and it takes time for them to adopt fully the overall smartphone user interface. As such, affordance plays an important role for interaction and user interface designers in terms of designing and developing an intuitive smartphone user interface. This implies that the concept of affordance is significant for user interface–user experience (UI–UX) designers and mobile app developers when designing an artifact, device, or system in that the UI–UX provides visual cues for users to understand possible actions. Crucially, in the context of this study, the perceived affordance involves both the action possibility and visual appearance for smartphone user interface. Users interact with a smartphone's capabilities through its user interface components, such as icon design and navigation tabs, and they are exposed to several action possibilities. It is essential that all these elements are visibly clear and make sense to the users.

The research question of this study is "What is the affordance gap on levels of expectation for older adults interacting with smartphone user interface?" As such, we aim in this paper to examine the affordance gap by measuring the various levels of expectation (pre- and posttasks) of older adults interacting with smartphone functions and mobile apps. We also explore the reasons for any identified affordance gap in the smartphone user interface among older adults.

PRIOR RESEARCH AND RELATED WORK

This section provides a review of the literature and related work on the affordance concept and its model. In addition, we analyze previous studies on intuitive user interfaces, smartphones, and mobile apps for older adults.

Affordance

The term "affordance" was first introduced by James J. Gibson (1977, 1979), an ecological psychologist with a focus on the field of visual perception. He explained, "Affordances of the environment are what it *offers* to the animal, what it provides or furnishes, either for good or ill" (Gibson, 1979, p. 127, italics in original). Thus, an affordance is a single attribute of an object that allows the user to carry out an action.

In the 1980s, the term affordance was propagated by Donald Norman—a design psychologist situated among industrial designers and the human–computer interaction and design communities—through his *Design of Everyday Things* book (Norman, 1998). He defined affordance as "the perceived and actual properties of the things, primarily those fundamental properties that determine just how the thing could possibly be used" (p. 9). The concept of affordance is applied to the analysis of everyday objects. If the affordance contradicts a user's expectation and mental model of use, the object or artifact most likely will not be used easily and thus may be discarded. Therefore, the user's perception of an object's affordance fosters or jeopardizes usability.

Norman (1998) highlighted that affordance provides strong clues for the operation of things and suggests the range of possibilities. For instance, a chair affords support and, therefore, it affords sitting. In addition, certain types of chair also afford the ability to be carried or to be stackable. Norman distinguished the concept of affordance into two types: actual affordance and perceived affordance. Actual (or real) affordance refers to physical objects available to humans through sight, touch, sound, or to a certain extent, smell or taste of the artifact. For example, a chair allows a user to touch its hardness via its material, for instance, wood or plastic; to view the color of its surface; and to listen to a sound by hitting its surface. On the other hand, in the virtual world, the graphical user interface of a software application represents a perceived affordance. For instance, the user-interface components of a smartphone comprise icons, a menu, navigation tabs, and clickable buttons. Therefore, as an example, a user presses an icon of a phone on the smartphone user interface to make a call. The tactile sensation of touching the phone icon on a graphical user interface is very different from the tactile sensation of pressing a number on or holding a physical telephone.

A vast literature indicates that the appearance of an object, artifact, or system should allow users to know what to do even at the first look. Thus, for a simple design like a button, the users should be able to know to press the button, provided it is "press-able," from its appearance. As a result, a simple design does not require any extra picture, label, or instructions for users to know what action they need to take. Unless the item is a complex design that requires further information from a user manual or training, the user's first impression—or perceived affordance of an artifact or system—will determine whether the artifact is a good or poor design.

In this study, we intended to examine the perceived affordance of a smartphone user interface. The issue for a graphical user-interface component is that it has no obvious physical or real affordances other than what the actual device provides simply as the host for the intended operations of the virtual environment. This difference sometimes poses challenges for users to comprehend how a familiar item works in a virtual environment. Norman (1998) highlighted that users can only learn the perceived affordances of graphical user interface elements in a virtual world (i.e., software programs or mobile applications) through convention. These could be challenging for first-time users who have no visual clues or prior product experience of how to

interact with a graphical user interface, in this case, a touch screen interface to the virtual world. This is especially true for adults who start to learn how to use the smartphone user interface in their older years. Thus, no matter what age, users need to learn the convention through practices, or trial and error, several times to become familiar with the use of virtual objects or graphical user interface elements. However, no matter what the services or artifacts, older adults find it useful and interesting to access new media (e.g., photos and videos) on their smartphone, but they also generally find it difficult to navigate through the complex design of a smartphone user interface and mobile applications.

Norman's Execution/Evaluation Action Cycle Model

In a human–computer interaction framework, it is important to understand how older adults interact with an artifact, such as a smartphone user interface, as is the focus of this study. When an object is designed for a purpose (function), it affords interaction between a user and the function itself. Norman (1998) explained the interaction as a way of framing the relationship between people and object by way of the execution/evaluation action cycle (EEAC; Figure 1).

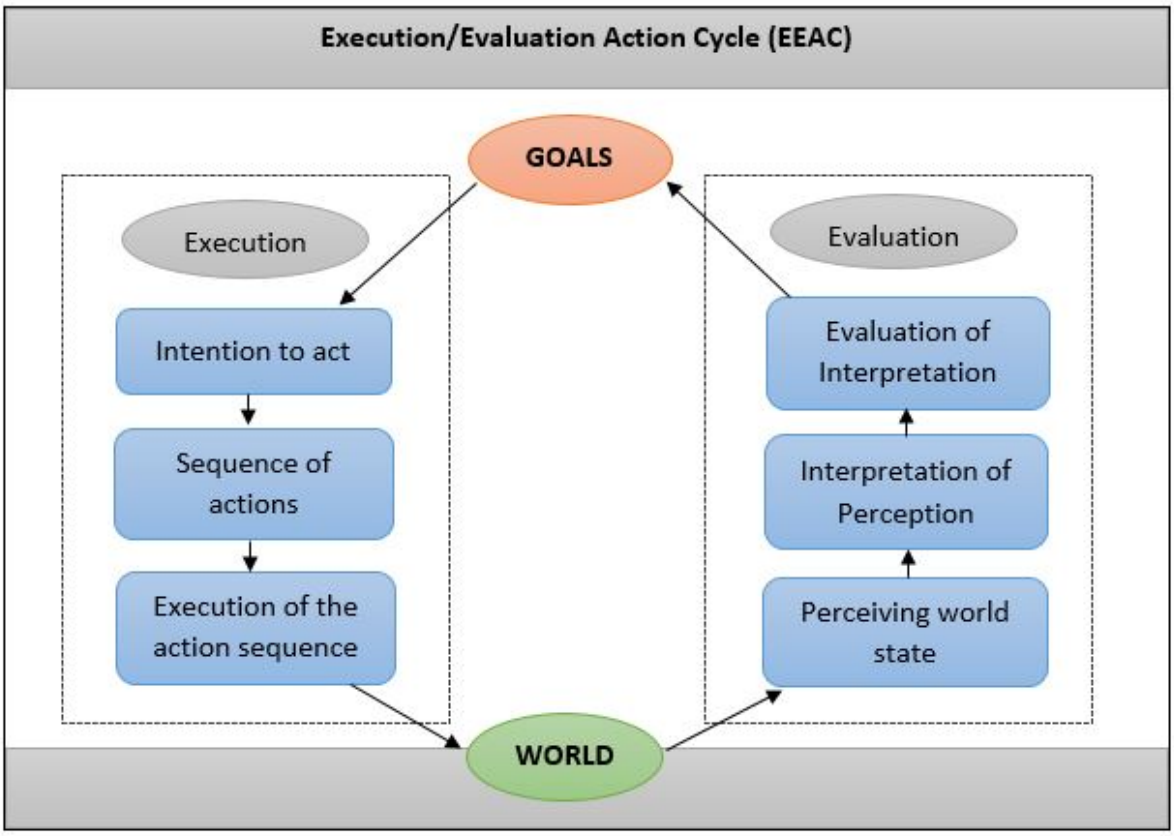

Figure 1. Seven stages of actions under execution and evaluation in the EEAC. The stages of execution begin with the goals, which are then translated into action sequences. This is followed by user's perception of the world that impacts the stages of evaluation (Norman, 1998). The image was adapted by the authors from http://picostart.myweb.hinet.net/

The EEAC model comprises four basic parts: goals, execution, world, and evaluation. A goal is something to be achieved, although often it is stated vaguely. A goal does not specify any particular action. Rather, a goal is an intention for a specific action to be taken to achieve the goal. However, intentions also are not specific enough to control actions. To achieve the goal, then an action in the world must be enacted. Norman (1998) indicated that any action comprises two aspects: execution and evaluation. Execution involves doing something, and evaluation is the comparison of what happened with what was wanted or expected to happen. Yet these are not simple processes. In fact, there are seven stages of actions in the EEAC.

The stages of execution start with a goal, the objective to be achieved. The goal is then translated into an intention to do some action(s). The intention must be translated into a set of internal commands, that is, an action sequence that can be performed to satisfy the intention. The action sequence takes shape as a mental event. Nothing will happen until it is executed, meaning performed upon the world. This is followed by the stages of evaluation, starting with the user's perception of the world. This perception must then be interpreted according to the user's expectations and compared with the intentions and goals. If the system's design and behavior match with the user's expectation and falls within the user's mental model, which is what the user believes about the system at hand (Nielsen, 2010; Norman, 1998), the user will not experience unmet expectations that typically yields frustration and dissatisfaction with the artifact. As such, we intended in this study to examine the level of user expectation before and after a smartphone interaction task. This means we measured how the users perceived an icon design before exposing and interacting with a certain task, and their interpretations of the icon design with its intended function after interacting with the task.

As an example of the EEAC in action, we presented a simple task of how a user interacts with a mobile phone. The goal was to take a phone call; the intention was to answer to an incoming phone call on a smartphone. The action, then, was for the user to react to an incoming phone call on the smartphone user interface. If an older adult is a first-time user of a smartphone, he or she may not understand how to operate a smartphone user interface. For a user whose previous experience was a keypad-enabled feature phone, he or she most likely would attempt to retrieve a phone call by pressing a "phone call" keypad button. However, when migrating to smartphone use, older adults need to relearn the new interaction mode and conventions of how it works. Instead of the former typical interaction mode of pressing, the older adult needs to learn to slide (action) the green colored "receiving call" function in order to pick up the incoming call (intention). Throughout the study observation, we frequently saw first-time users continually pressing the green colored phone icon instead of sliding it, and this led to missed calls and yielded user frustration. As a result, we identified affordance gulfs (gaps) in execution and evaluation, where the perceived function did not match with user expectation. Therefore, in this study, we examined the affordance gaps by measuring the level of expectation of the smartphone user interface by older adults.

Affordance and Its Related Work

The concept of affordance has evolved since its original presentation in the discipline of ecological psychology and, over time, it has been applied across various disciplines, such as design studies, human–computer interaction (HCI) and interaction design fields, media and social media, communication studies, and others. In the HCI discipline, the field in which this study is situated, the concept of affordance has evolved and been developed by various scholars. Gaver (1991) extended

the concept of affordance by proposing the technology affordance model, which is applicable for user interface design in HCI studies. The concept of technology affordance focuses on the interaction between technology and the user of it. According to Gaver, affordances are fundamental objects of perception, where people perceive the environment directly in terms of its potential for action, without involving any significant intermediary, such as memory or inference. Under the concept of technology affordance, Gaver described "perceptible affordance" as the perceptual information available for an existing affordance or user interface. This implies that the term perceptible affordance is considered similar to Norman's (1998) definition of perceived affordance.

In regard to our study, the major scholarship and concepts of the HCI field still are focused on Norman's (1998) EEAC model. Thus, the concept of affordance that undergirds our study is described broadly as the possibilities for actions between an object/technology interface and the user that enables or constrains potential behavioral outcomes in a particular context (Faraj & Azad, 2012). Hence, the understanding of affordance is accepted universally in this field as "action possibilities offered by the environment" (Kaptelinin, 2013, p. 2565). This concept is more applicable to design and HCI studies and relates to the original notion of Norman's (1998) EEAC model. Nonetheless, we see a scarcity of research articles that measure the affordance gap. Thus, this study aims to plug a part of that gap in the literature by focusing on measuring the affordance gap in the older adult users' expectations of the smartphone user interface.

Intuitive User Interface

The design of a user interface refers to the look and feel of software (i.e., mobile apps, software programs) or machines (i.e., mobile devices, computers, home appliances). To ensure the perceived affordance of user interface design is intuitive, Blackler (2006) and O'Brien, Rogers, and Fisk (2007) both highlighted the importance of taking the users' prior experience and knowledge into consideration when designing artifacts. Prior experience or knowledge is defined as information available in the participant's memory that is used during the interaction with the artifact. For instance, an older adult's prior experience using a keypad-enabled mobile phone can help him or her, in some ways, understand some components of a smartphone because of the relatedness between the features of the two phone systems. This is particularly true when compared to someone who has never handled a less complex mobile phone.

To explain further the notion of familiarity, an icon design that depicts a telephone or phone handset is a familiar metaphor suggesting the function of making a phone call in smartphone user interfaces. Norman (1998, p. 62) referred to this information gained from relevant prior experience as "knowledge in the head" (KiH). Meanwhile, other information available to the users—such as instructions, device feedback, mobile-user interface screen controls, and user-interface design components—is considered "knowledge in the world" (KiW). Good design of KiW is important for older adults who prefer to use new technologies with the support of instruction and training. To reduce errors, one design recommendation is to place guidance or external consistency on the display of user interface that links KiW to a user's prior knowledge (KiH; Norman, 1998; O'Brien, 2010).

If the artifact or user interface of a product is intuitive to use, which means with affordance design, users can call upon their previous experience to complete the task easily without referring to user manuals, receiving help from others, or attending trainings. Thus, a user interface is intuitive when it contains the components of affordance, familiarity, and no frustration to users

(Blackler, 2006; McKay, 2010). Intuitiveness also implies that when UI–UX designers and mobile app developers create smartphone user interfaces and mobile apps, their consideration of affordance and consistency in the design is vital.

To ensure the smartphone user interface is usable and intuitive, various usability evaluation methods are employed in studies to measure the usability and design issues, such as heuristic evaluation, usability testing involving users, focus groups, field observations, and the shadowing method (Gómez, Caballero, & Sevillano, 2014). One popular method of performing usability inspection without requiring too much expertise, time, or expense is the heuristic evaluation (Nielsen, 1994). Nielsen and Molich (1990) designed 10 fundamental usability heuristics for user interface design over a range of system user interfaces. However, some researchers found these heuristic guidelines too general and additional heuristics were developed to cater to specific contexts. For instance, a list of heuristics for smartphone apps targeted toward older adults (Silva, Holden, & Jordan, 2015), heuristic evaluation on mobile interfaces (Gómez et al., 2014), smartphone usability heuristics (Inostroza, Rusu, Roncagliolo, Rusu, & Collazos, 2016), design guidelines and checklists for feature phones and smartphones (Petrovčič, Taipale, Rogelj, & Dolničar, 2018) represent some of context-specific evaluative tools.

Smartphone, Mobile Apps, and Older Adults

Some literature mentioned that older adults have been stereotyped as "late comers" or "laggards" regarding the uptake of new technologies or services (Essén & Östlund, 2011; Price, Pak, Müller, & Stronge, 2013; Wong, 2011). On the contrary, burgeoning research, especially in the fields of HCI, aging, and technology (Abascal & Civit, 2001; Plaza, Martin, Martin, & Medrano, 2011), has been conducted on smartphones and older adults due to the rising aging population worldwide. Other studies revealed that older adults are active smartphone users (Colombo, Aroldi, & Carlo, 2018; Rosales & Fernández-Ardèvol, 2016a; Selwyn, Gorard, Furlong, & Madden, 2003). A majority of older adults, especially those in the young-old cohort, aged 60 to 74 (Fisk et al., 2009), are considered still productive and active at their age, having special information and communication technology (ICT)-related needs, and are interested in learning new technology, including smartphone and mobile apps (Berenguer et al., 2017; Carlsson & Walden, 2015; Nikou, 2015; Rosales & Fernández-Ardèvol, 2016a).

Despite the perception of older adults as late comers to smartphone adoption, a majority of seniors received their first smartphone as a gift or as a second-hand device passed down from a family member (Ivan & Fernández-Ardèvol, 2013; Oreglia & Kaye, 2012; Sun, Ding, Lindtner, Lu, & Gu, 2014). This opens a new era in the mobile business landscape for the telecommunication industry, as well as for mobile apps developers and designers. In contrast, the findings of a survey study conducted in Spain by Rosales and Fernández-Ardèvol (2016a) revealed that a majority (79%) of the older adult respondents bought the smartphone themselves because they wanted a new mobile phone rather than a second-hand device. Family encouragement is the primary factor influencing older adults to overcome their psychological barrier to accepting their first smartphone (Pee, Maksom, & Norizan, 2014; Sun et al., 2014).

In terms of mobile apps usage, another study done by Rosales and Fernández-Ardèvol (2016b) revealed that WhatsApp is the most popular and frequently used mobile application across all age cohorts studied, but especially by older adults (aged 55 to 76 years), in Spain. One reason older adults in Spain were adopting a smartphone was because, with a minimal mobile

data plan subscription, it is cheaper to make a WhatsApp phone call rather than using the mobile voice call feature. Interestingly, their findings also revealed that older adults viewed the source of incoming calls differently: Older users felt a sense of urgency in taking calls coming from the voice call function on smartphones whereas a WhatsApp voice call was not deemed an important call. In addition, it seems the older adults were excited to keep themselves active in a WhatsApp group because it allowed them to maintain and reinforce relationship ties with their family members regardless of geographic separation. It also allowed them to share their happenings via media files (photos and videos) with significant others. These findings are supported by research done by Nouwens, Griggio, and Mackay (2017), who found that their respondents used specific mobile apps for specific interactions: WhatsApp to communicate with family members and Facebook Messenger to engage with friends.

Plaza et al. (2011) pointed out that the important reason for older adults to use mobile apps is that they want to live independently in their own homes as long as possible. The needs of older adults using smartphones and mobile apps can be classified into two main domains: "health–wellness–home care" and "safety–security–mobility." The former domain consists of social interaction, hobbies, information gathering, learning and education, working life, health and wellness, home care, and chores and supply with goods. The latter domain involves issues related to safety-security and privacy, peace of mind, and mobility (Plaza et al., 2011). As such, those young-old adults who are conversant with using smartphones and with ICT use during their active work life will continue to use mobile apps and advanced features on their smartphones after they retire. As a result, domains such as working in later life, spirituality, hobbies, and lifelong learning-related mobile apps are worthwhile for researchers, designers, and developers to explore further.

METHODS

This paper presents part of a larger mobile-user interaction study. This full study was conducted using concurrent embedded design mixed methods (Creswell & Clark, 2011), which means qualitative data (interview) was collected concurrently and embedded within a major quantitative data (survey and observation) collection. The purpose of conducting a concurrent embedded design mixed method was to enhance a better understanding of and to supplement the secondary qualitative data within a larger quantitative study. The quantitative data were analyzed to assess the affordance gap in terms of level of expectation. We used the qualitative data to complement the quantitative data by identifying the reasons for an affordance gap, that is, the mismatch between older adults' expectations and a smartphone user interface. The qualitative data also aimed to gain insight into how older adult participants interacted with a smartphone UI.

As this is a cross-sectional observational study, it did not include an intervention component. The intention of the study was to examine the perceived affordance on the level of expectation before and after presented tasks and the possible actions taken among the older adults interacting with smartphones.

Participants and Sampling

Due to the nonexistence of national statistical data on the Malaysian older adult population who own smartphones, this study used nonrandom sampling techniques that involved purposive

sampling and snowballing. In Roscoe's (1975) rule of thumb, a sample size of 30 or more is recommended in most experimental and observational studies.

We recruited the participants from the attendees at the University of the Third Age (U3A) in Kuala Lumpur, Malaysia. Some also were seniors from community centers in the Malaysian state of Selangor. The U3A offers lifelong learning programs for older adults in Kuala Lumpur and Selangor. We selected this association because it is one of the most active senior citizen organizations in the country. It also offers a first-of-its-kind smartphone-for-seniors training course. In this study, we recruited 80 (40 male and 40 female) older adults as participants for the mobile-user interaction study in 2016. They were aged 60 to 74 years (M = 65.63), thus representing the young-old adults cohort.

Two criteria were employed for selecting the participants in this study: the individuals were members of the young-old adults cluster (Fisk et.al. 2009), meaning aged from 60 to 74 years, and each had experience using a smartphone for at least 3 months. This cohort has high potential for actively using online services and mobile apps for the rising "grey market" in the Malaysian mobile industry. Because we focused our study on the operational activities of older adults using smartphones, and not on health-related matters, those who suffered from severe visual, cognitive, motor, and hearing impairment were excluded from participation.

Malaysia is a multiracial society. Thus, all the participants (N = 80) were Malaysians, but comprised three major ethnic groups: Malay (27.5%, n = 22), Chinese (58.8%, n = 47), and Indian/others (13.8%, n = 11). The percentage of Chinese older adults was higher among the three groups due to their high "turn-up" rate and that they represented the higher percentage of U3A membership during the 2016 data collection period.

Apparatus and Settings

A smartphone with an Android mobile operating system (OS) served as the test apparatus for this study. An Android smartphone was chosen because the findings from our previous smartphone usage survey (Wong, Ibrahim, Hamid, & Mansor, 2017) revealed that a majority of older adults owned an Android smartphone, and it also was more affordable and popular than the other types of smartphones, the iPhone in particular. In this study, we used a Samsung S7 Edge due to its large 32GB internal memory, allowing us to capture and store screen interaction videos within the phone itself. This model had launched in the global market (March 2016) just prior to our data collection process. The Android 5.0 Lollipop design was the Android mobile OS software version used when we conducted the user testing from May to July 2016.

We conducted the study in a quiet meeting room at the Malaysian Research Institute of Ageing (or Institute of Gerontology), where the U3A is based and many older adults were available. All the participants were scheduled for user testing at a specific time, and each test was conducted independently at U3A.

Task Design

In this study, the four task scenarios were derived from the results of the second phase of the previously completed smartphone usage survey result (Wong et al., 2017), which allowed us to adhere to ecological validity. In short, the four main tasks for this study were making a phone call, adding a contact to a phone book, installing a mobile app using the Google Play Store,

and using WhatsApp. Each of these main tasks also contained two or three subtasks in line with goal of the main activity. Table 1 provides the details of the four-task design, details on which can be found in Wong, Ibrahim, Hamid, and Mansor (2018).

Procedure

We received approval from the University Putra Malaysia Research Ethic Committee before conducting the mobile-user interaction study. A screening process was conducted during user recruitment based on the criteria for participant selection. During the mobile-user interaction study, all participants signed an informed consent form; we kept their identities anonymous for data analysis purpose. Each participant was given a code name with number; for example, P1 represents Participant 1. Each session took between 45 and 120 minutes for the users to interact with the given tasks, depending on the participant's ability and familiarity with the smartphone user interface.

Firstly, before we presented the test tasks to the older adults, the participants completed the first part of an affordance questionnaire regarding their demographic profiles, smartphone usage, and their perceived affordance on the level of presumed expectation for selected tasks. They also were interviewed to identify their motivations for and barriers to using a smartphone. This served as the pretest. Next, they were presented the four tasks to perform on the Android smartphone platform. After the participants performed the four tasks, they were asked to complete the second part of the affordance questionnaire, which gathered information on the participants' perceived affordance and experience interacting with the smartphone tasks that formed the quantitative element of the study. Lastly, the participants participated in a follow-up interview during the debriefing session.

The questionnaire was written in three languages: English, Bahasa Malaysia (the national language of Malaysia), and Mandarin. The questionnaire underwent backward and forward translations from English to Bahasa Malaysia/Mandarin and vice versa. All the translations were handled collaboratively among the primary researcher (i.e., the first author), an online translation service company, a certified translator in Bahasa Malaysia and English languages, and a qualified translator in Chinese and English languages. After comparing the forward and

Table 1. Tasks and Subtasks Presented to Young-Old Participants of Concurrent Embedded Design Mixed Methods Study of a Smartphone Interface Affordance Gap.

Task 1: Voice Calls
Subtask 1: Making a call
Subtask 2: Retrieving calls
Task 2: Phonebook
Subtask 1: Adding a contact to a phonebook
Subtask 2: Making a call from phonebook contact
Task 3: Installing a Mobile App
Subtask 1: Go to the Google Play Store to download a flashlight mobile app
Subtask 2: Start initiating the application
Task 4: Using WhatsApp
Subtask 1: Sending a message using WhatsApp
Subtask 2: Sending a photo using WhatsApp
Subtask 3: Sending an audio file using WhatsApp

backward translations, all the meanings remained the same with some variance in sentence structure and grammar. No major correction was done in the translation.

The complete session (from informed consent to debriefing) was video recorded. This process was most useful in gathering intonation and facial expressions during the mobile-user interaction tasks. Additional observation data were collected with Mobizen screen capture software on the Android phone to record the mobile screen interaction. The primary researcher also recorded the timing and verbal comments from each observation sessions. This researcher (mainly the first author) is conversant in the three main local languages, those used for the questionnaire. Hence, each session was conducted in whichever language was preferred by the participant in response to the researcher's inquiry at the start of the session.

Questionnaire and Measures

In this study, the type of measure is self-report. To examine the perceived affordance and possible actions of smartphone user interface among the older adults, the participants were prompted regarding the level of expectation measures before and after interacting with each task. The expectations were measured using a 7-point Likert scale, where 1 indicated *very difficult* and 7 *very easy*. Before every task, participants were asked, "How difficult or easy do you expect this task to be?" Then, after completing each task, they were asked "How difficult or easy did you find this task to be."

Interviews

An interview was conducted before and after the four tasks process. The purpose of interview before the task interaction was to uncover the motivations and rationales that led to the participants adopting their smartphone. During the posttask debriefing session, the interview aimed to discover the participants' opinions of using smartphone and to obtain feedback on their experiences and perceptions while interacting with the four tasks.

Methods of Analysis

The quantitative data were analyzed using a statistical analysis software (IBM SPSS Version 23). A paired sample *t*-test was conducted to examine the affordance gap for expectation levels (pre- and postmeasurement) of perceived affordance on smartphone user interface. On the other hand, we conducted qualitative analysis using NVivo 12 Plus from the observation field notes and interviews. The interviews were coded and organized into categories using thematic analysis (Bernard & Ryan, 2010; Silverman, 2011; Taylor-Powell & Renner, 2003). The categories or themes were then presented with some verbatim quotes as evidence. The qualitative data complement the quantitative data analysis.

RESULTS

This section illustrates and discusses the results of the study in two parts. First, participants' demographic profiles and smartphone usage are presented, followed by their perceived affordance

on levels of expectation. These primarily quantitative data results are supported by the qualitative data derived from the interviews following completion of each task and the debriefing.

Participants' Demographic Profiles and Smartphone Usage

In this section, we explain the descriptive statistics for the participants' demographic profiles. Eighty older adults, aged 60–74 years (40 males and 40 females, with an average of 65.65 years), were recruited for this mobile-user interaction study. All respondents were Malaysians. Table 2 illustrates the participants' demographic profiles.

The participants were asked the duration of owning their current smartphone and its brand. The responses show that the average duration was nearly 23 months. The data showed that the older adults would consider changing or upgrading to another smartphone either by receiving a used mobile from their children/family or by purchasing a new phone. A majority (82.7%) owned an Android OS phone, as compared to an Apple or Windows smartphone.

Regarding who purchased the smartphones that the informants currently use, respondents indicated that their children (45%) were the primary source, followed by themselves (32.5%), and others (22.5%), such as spouse, son or daughter-in-law, relative, or friend. This suggests that the older adults in this study considered their children as reliable and more techno-savvy resources to choose and purchase smartphones for them. In terms of a mobile subscription plan, two thirds of the participants (75%) opted for a postpaid as compared to a prepaid service. Finally, 68.8% participants had their data plan or Internet service as part of a mobile subscription plan, as compared to those with no Internet subscription (30%) or who had "no idea" (1.3%).

Regarding the problems the participants experienced when using their mobile phones, the data depicted that the older adults thought that the battery discharged very quickly (58.2%) for a smartphone as compared to their prior experience of using a keypad-enabled phone. Another problem was that 43% of the older adults thought that their "fat fingers" caused problems using the small virtual keypad on their smartphones. Other problems (46.8%) that the participants encountered included the phones easily disconnecting a call, especially when using WhatsApp; becoming baffled regarding notifications on the phone without knowing what to do; the fear of getting virus; and the fear of downloading software upgrades/updates. Based on their children's advice, some older adults feared using features and phone icons that were not familiar; other older uses found the phones complicated to use.

Figure 2 illustrates the purposes for which the older adults adopted and use mobile phones. The results justify our decision for investigating three of the main tasks for the mobile-user interaction study, that is, making phone calls, adding a contact to their device's phone book, and using WhatsApp. The difference of a feature phone as compared to a smartphone is the latter allows the user to download a mobile app and use it on the device. Thus, we also incorporated installing an app from the Google Play Store as an important task to determine whether the older adults know how to download a mobile app, a crucial skill in smartphone use, by themselves.

Perceived Affordance on Expectation

To identify the affordance gap in the level of expectation by the older adults regarding their perceiving (pretest) and experiencing (posttest) smartphone use via the four tasks, we conducted a paired sample *t*-test. At first, to check whether the assumptions were met for choosing either a

Table 2. Demographic Profiles and Smartphone Usage of Malaysian Adults, Aged 64–75 (N = 80).

Descriptions	Percent (%)	Number (*n*)
Gender		
Male	50.0	40
Female	50.0	40
Ethnicity		
Malay	27.5	22
Chinese	58.7	47
Indians and others*	13.8	11
Marital Status		
Single	7.5	6
Married	80.0	64
Divorced, Separated, or Widowed	12.5	10
Educational Background		
Primary and lower-secondary education	10.0	8
Upper-secondary education	40.0	32
Tertiary education (college/ university)	50.0	40
Occupation		
Working	11.3	9
Retired	77.5	62
Never worked	11.2	9
Proficiency in Languages**		
Bahasa Malaysia		
Speaking	91.3	73
Writing	85.0	68
Reading	88.8	71
English		
Speaking	96.3	77
Writing	95.0	76
Reading	96.3	77
Mandarin		
Speaking	42.5	34
Writing	23.8	19
Reading	26.3	21
Tamil		
Speaking	12.5	10
Writing	10.0	8
Reading	11.3	9
Others (e.g., Cantonese, Hokkien, etc.)		
Speaking	27.5	22
Writing	11.3	9
Reading	8.8	7
Monthly Income***		
RM5000 (US$1193.22) and above	11.2	9
RM3000 (US$715.95) to RM4999 (US$1192.99)	23.8	19
Less than RM2999 (US$715.70)	26.3	21
Currently no income	38.7	31
Current Smartphone OS		
Android	82.5	66
Apple iPhone	15.0	12
Microsoft Windows	2.5	2
Problems in Using Mobile Phones		
Complicated and difficult	36.7	29
Expensive	27.8	22
Small keypad	43.0	34
Danger to health	32.9	26
Battery loses charge quickly	58.2	46
Other problems	46.8	37
None of the above problems	7.6	6

Note. *Indian/Others means Indian and other minority ethnic groups in Malaysia. **All the participants (100%) are bilingual. ***The currency conversion is Ringgit Malaysia/RM1 = US$0.24 on June 5, 2019.

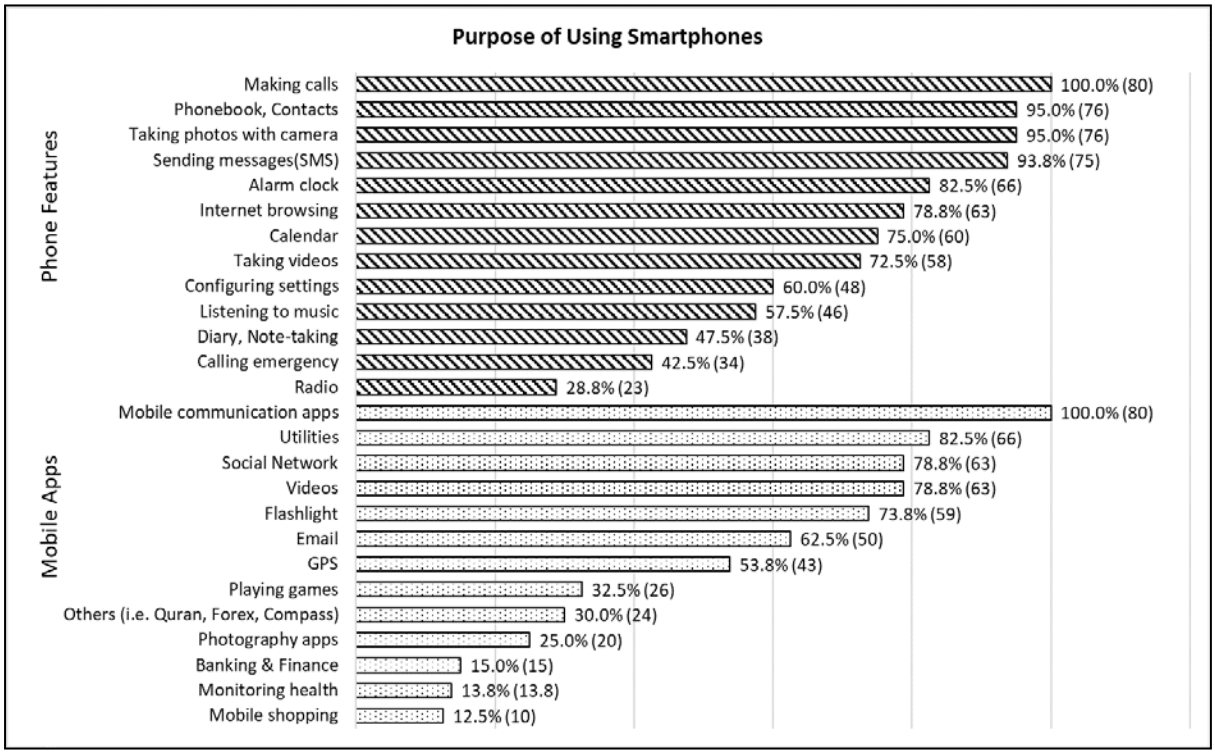

Figure 2. Older adult-identified purposes for using smartphones. Responses are grouped as either phone features or mobile apps.

parametric or nonparametric test, we conducted a normality test, and the results show that all data were normally distributed based on the histogram. Figure 3 depicts the average scores for pre- and posttests of all four tasks. All the tasks showed the average scores above 5.0 except Task 3, installing an app from the Google Play Store.

Table 3 shows the paired sample *t*-test statistical result for perceived affordance on different levels of expectation for the four tasks. The table reveals the mean difference, standard deviation, standard error mean, 95% confidence interval, *t*-score, degree of freedom (*df*) and its significance (2-tailed).

The mean result in Table 3 shows the difference between the two sets of perceived affordance on the level of expectation scores, which was unlikely to occur by chance. However, it does not inform the magnitude of the task effect. As such, we calculated the effect size based on the eta-squared value. To further analyze the magnitude of the effect size for Pair 1, 2, and 4, we referred to Cohen's guideline (Cohen, 1988) for interpreting the Cohen's *d* values, where less than 0.2 = small effect, 0.3 – 0.7 = medium effect, 0.8 and above = large effect.

For Task 1 (making a phone call), the result shows that there is a statistically significant decrease for the older adults making phone call scores from premeasurement (M = 6.26, SD = 1.028) to postmeasurement (M = 5.44, SD = 1.533), $t(79)$=3.764, $p < 0.001$ (two-tailed), d = 0.62. The mean decrease in using a phone call score was 0.825, with a 95% confidence interval ranging from 0.389–1.261. The effect size is medium. For Task 2 (adding a contact), the result shows that there is a statistically significant decrease for the older adults adding contact scores from premeasurement (M = 5.85, SD = 1.370) to postmeasurement (M = 5.06, SD = 1.781), $t(79)$ =3.693, $p < 0.001$ (two-tailed), d = 0.50. The mean decrease in adding contact scores was 0.788, with a 95% confidence interval ranging from 0.363–1.212. The effect size is medium.

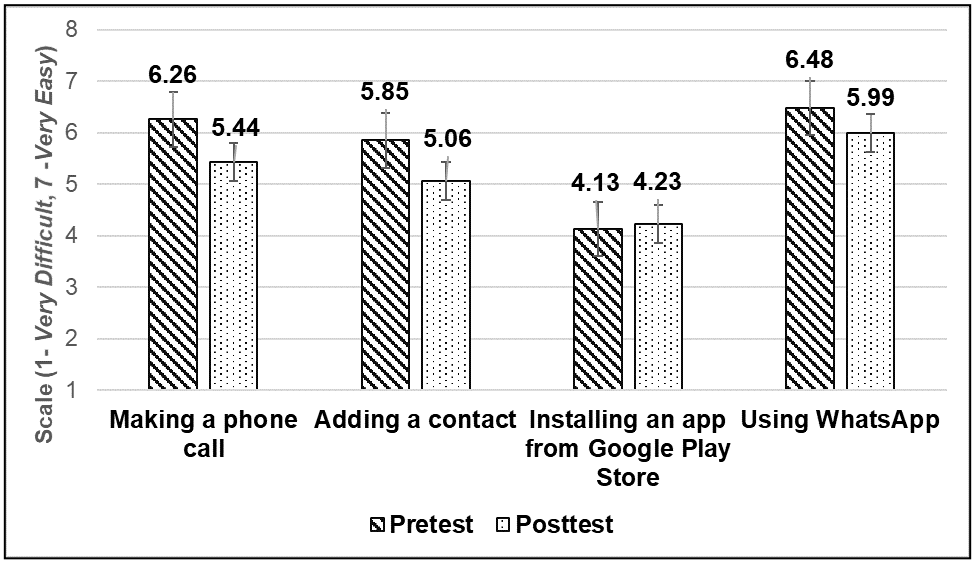

Figure 3. Comparison of pre- and posttest perceived affordance regarding expectations about the four smartphone interaction tasks studied.

Table 3. Paired Sample *t*-test for Perceived Affordance on Levels of Expectation for Tasks via a Smartphone Interface.

	Mean Difference	Standard Deviation	Standard Error Mean	95% Confidence Interval of the Difference		*t*	*df*	Significance (2-tail)	Cohen's *d*
				Lower	Upper				
Pair 1: Level of expectation on making a phone call	0.83	1.96	.22	.39	1.26	3.76	79	.00	0.62
Pair 2: Level of expectation on adding a contact	0.79	1.91	.21	.36	1.21	3.69	79	.00	0.50
Pair 3: Level of expectation on installing an app from the Google Play Store	0.10	1.72	.19	-.48	.28	-.52	79	.60	--
Pair 4: Level of expectation on using WhatsApp	0.49	1.29	.14	.20	.78	3.37	79	.00	0.60

For Task 3 (installing an app from the Google Play Store), the result shows that there is no statistically significant increase for the older adults installing mobile apps scores from premeasurement (M = 4.13, SD = 1.656) to postmeasurement (M = .23, SD = 1.835), $t(79) = -0.52$, $p = 0.60$ (two-tailed). The mean increase in using installing mobile apps scores was 0.100, with a 95% confidence interval ranging from -0.482–0.282. No effect size was required for further analysis. For Task 4 (using WhatsApp), the result shows a statistically significant decrease in the older adults using WhatsApp scores from premeasurement (M = 6.48, SD = 0.993) to postmeasurement (M = 5.99, SD = 1.317), $t(79) = 3.373$, $p < 0.001$ (two-tailed), $d = 0.66$. The mean

decrease in using a phone call score was 0.488, with a 95% confidence interval ranging from 0.200–0.775. The effect size is medium.

To interpret the statistical result of perceived affordance on levels of expectation, Table 3 indicates a decrease in the pre/post measurements for Tasks 1 (making a phone call), 2 (adding contact), and 4 (using WhatsApp). This means the older adults perceived those tasks as more difficult after completion. Several reasons yield the decreasing score for those three tasks. For Task 1, making a phone call, some older adults had problems identifying and locating the keypad phone icon (explained more fully below) due to the not-easily-comprehensible icon design. For Task 2, the older adult participants were not familiar with the menu structure of Samsung S7 phone, and thus some had difficulties in completing properly the task of adding a new contact. In Task 4, using WhatsApp, the majority of participants had no problems in sending a message. However, most experienced difficulty in recording and sending an audio file using WhatsApp (detailed below). Therefore, these challenges resulted in a negative experience for the older adults and reduced their favorable impressions of performing those three tasks. In another words, the participants struggled to complete certain subtasks on a smartphone user interface with features unfamiliar to them or because of the inappropriateness of icon location, both of which yielded an affordance gap.

Result of Qualitative Data

Following the posttest and debriefing, we conducted qualitative analysis using NVivo 12 Plus from the observation field notes and interviews. The themes emerging from the analysis reveal how the older adults perceived their expectations regarding the interaction tasks. We identified five themes: (a) a mismatch between user–task interaction and user expectation, (b) prior knowledge or product experience, (c) visual appearance of the smartphone user interface, (d) the visibility of icon location, and (e) participants' seeking help and guidance. Each of these themes are addressed more fully below.

Mismatch Between User Expectation and User-task Interaction

Based on our observation, a majority of the participants expressed disappointment and/or a negative experience in dealing with Tasks 2, 3, and 4. They identified the most problematic subtask as the recording and sending an audio file using WhatsApp. As mentioned earlier, most of the older adults were using smartphones given to them by their children or relatives as gifts or hand-me-down devices. Moreover, the respondents indicated that the main motivation for them to adopt a smartphone was to use WhatsApp to send and receive media files (messages, photos, and videos) to stay connected with their family members and friends. However, for this subgroup of smartphone users, almost all the mobile applications on their smartphones other than WhatsApp were installed already when they received it. Further, they typically were not given proper guidance on how to use and operate their smartphones. As a result, Task 3 was considerably challenging and the first time most of the participants used the Google Play Store to download and install a mobile app. The following quotations from the data indicate their struggle.

> *This is my first time trying to download a mobile app. I really have no clue how to do it. I expect the Play Store is like a game store because the name is "play" store.* (P13, Female, aged 69)[1]

> *I really have no idea of the function and what is it of the Play Store.* (P38, Male, aged 66)

> *It is so difficult* [to download the flashlight app]. *That's the biggest problem for me. Very difficult.* (P40, Male, aged 72)
>
> [Researcher: Did the Play Store feature have the function as you expected it to be?] *That one I am doubtful…* [Researcher: What do you expect the function to be?] *More precise, you know? Instead of searching, you touch* [on the screen] *and you should get all the features here. I don't know what to do. Instead, I have to roll, roll, and roll* [i.e., scroll, scroll, and scroll], *and nothing appeared* [frustrated sigh]. (P40, Male, aged 72)
>
> [For the Play Store] *Hmm, for my age, I don't need the games. For kids, it is ok, like games or entertainment or whatever. But for adults like me, maybe more serious stuff like Bloomberg, the* Star News, National Geographic. *For Muslims, maybe prayer time. The other applications are not required.* (P8, Male, aged 72)

In terms of sending an audio file using WhatsApp, a majority of participants failed to record and send the audio file. The task completion rate for this subtask was 36.25%, considerably low, as compared to other subtasks using WhatsApp (i.e., sending a message, 81.88%, and sending a photo, 63.13%). Based on observation data, the challenge revealed usability issues and technical difficulties regarding the audio record function. After several attempts, the audio record files did not go through for quite a number of participants. It could have been due to the participants just pressing the audio record icon one time and then releasing rather than pressing and holding the icon for the entire time to voice record the message (see Figures 4 and 5). The participants were expected to press and hold the button to speak into the phone to activate the audio recording function. Therefore, we found a mismatch between the expectation of the user's mental model and the technical design of WhatsApp audio function, as clearly noted by the participants' comments on sending an audio file using WhatsApp.

> *I expect after pressing the mic button, I can speak and send. Ah! But, it does not work for me. I have to record first, then I can only send. It does not send. I really don't know how to send. Must be different… I have to get used to this new gadget.* (P40, Male, aged 72)
>
> *This is new to me. I really don't know what to do. I give up!* (P52, Male, aged 71)
>
> *It is frustrating using this audio feature. I had sent the audio files so many times already. How come I cannot hear?* (P36, Female, aged 69)

Prior Knowledge or Product Experience

To find out whether it was intuitive for the older adult informants to perform the four tasks, they were asked during the debriefing whether they drew on any prior knowledge (e.g., experience from using their previous phone or any other information) to complete the test activities. The results revealed that a majority of the respondents did not consciously draw on their prior knowledge to use phone/voice call feature and WhatsApp phone call function, even though previous experience had prepared them for using the new technology that mirrored their prior knowledge. A male participant (P9, aged 73) commented, *"I don't need any prior knowledge to learn how to make a phone call. This is easy."*

On the other hand, we received mixed comments regarding the need for prior knowledge or product experience in using the contacts feature. For instance, when a researcher asked how easy or difficult it was to add a contact onto the testing phone, a respondent replied, *"To my phone is easy, but to your phone is so difficult. I have no idea how to do it"* (P57, Female, aged 66).

Figure 4. The users were supposed to press and hold the audio record icon (bottom right) while recording on WhatsApp and release it when recording was complete to send. Although the instruction appeared above the audio record button, a majority did not understand the instruction well, resulted in failure to complete the task.

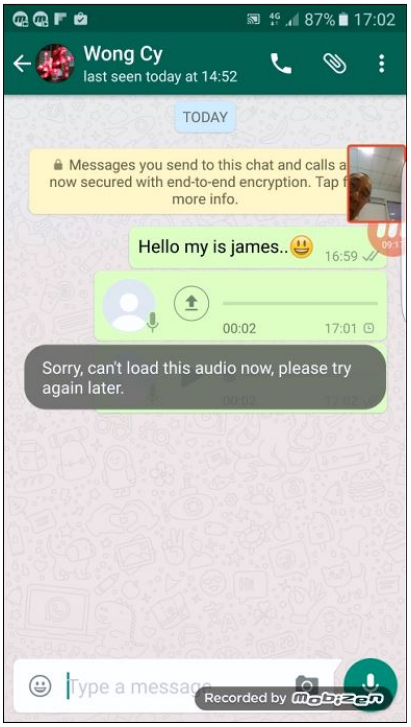

Figure 5. The system response following the failed attempts to create and send an audio file to the recipient demonstrated the technical difficulties experienced by the users in completing the task.

Almost every participant expressed his or her need to learn how to use the WhatsApp audio recording function and the Play Store feature to download and install a mobile app. For example, when the researcher asked, "Do you need any prior knowledge to learn to use WhatsApp?" a female informant (P2), aged 69, responded, "*If for receiving messages, I think it is easy and not complicated. But, if I want to send documents, pictures, this one I need practice.*" A similar question regarding using the Play Store resulted in the response, "*Yes, it needs prior knowledge a lot and I don't know how to use because they* [the functions] *have not been taught*" (P74, Male, aged 73).

The Visual Appearance of the Smartphone User Interface

The visual design of an icon plays an important role on the smartphone user interface. Often it determines the intuitiveness and perceived affordance for users in taking an action via the icon. Generally, the older adult participants had no problems identifying the phone/voice call icon. However, when the participants had to make a phone call on the Samsung S7 Edge, quite a number of them could not find the phone keypad icon for dialing. On this interface, the phone keypad icon was not visible, and the clues on where to find it (at the bottom right, under the Phone page, see Figure 6), were not evident. Some participants applied trial-and-error tactics

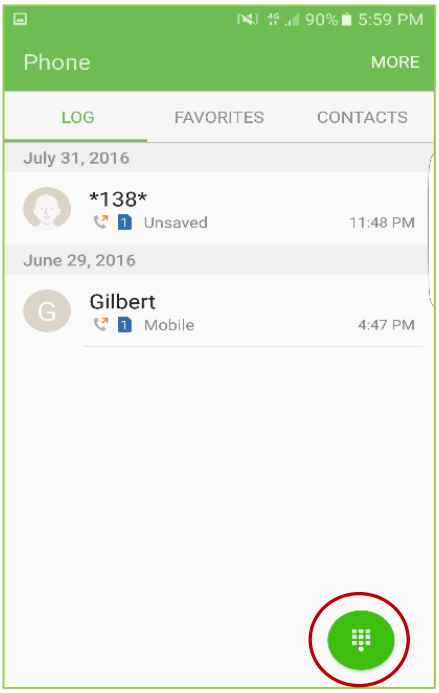

Figure 6. The phone keypad icon located at the bottom right of the phone page on Samsung S7 Edge (circle).

with few attempts, but some eventually gave up of making a call. In general, the older adults expressed their preference for a direct dialing page rather than finding the hidden and not-so-intuitive keypad design. They also lamented that the perceived phone keypad design was neither directly displayed nor intuitive to them, and it did not afford for direct dialing.

Basically, the older adults had no issues in recognizing the phone/voice call icon, as it was quite similar to their previous keypad phone or smartphone. However, quite a number of them were confused between the phone/voice call icon and the WhatsApp icon due to the similar color (white and green) and nearly identical icon design (Figure 7). A female older adult commented,

> *Well, WhatsApp and the phone icons look the same. It is so confusing to me…* [When prompted by the researcher for a suggestion] *Maybe it can be someone holding the phone for phone icon and for WhatsApp icon, it can be someone on the phone and writing.* (P36, Female, aged 69)

Many older adults also were confused and dissatisfied with the Google Play Store icon and its function. The Play Store nomenclature (see icon on Figure 7) seemed misleading to many of the older adult participants. From the comments expressed during the interviews, many perceived it as "playing games," "shopping bags," "luggage for traveling," and a site presenting fun and entertainment for kids. They did not think the icon suggested a place to download mobile applications.

> *No wonder I don't recognize it* [the Play Store icon]. *To me, I thought the* [Play Store] *was a traveling thing, TripAdvisor. It is like a suitcase or luggage for traveling.* [When asked for a suggestion for the Play Store icon design] *Maybe best to use an image of a video game, something fun or a toy. So game, ah… rather than luggage.* (P45, Female, aged 68)

Figure 7. The default first page of smartphone screen user interface for Samsung S7 Edge. It shows the WhatsApp icon (top row, second from the right), the Play Store icon (top row right and Phone/voice call icon (bottom row left).

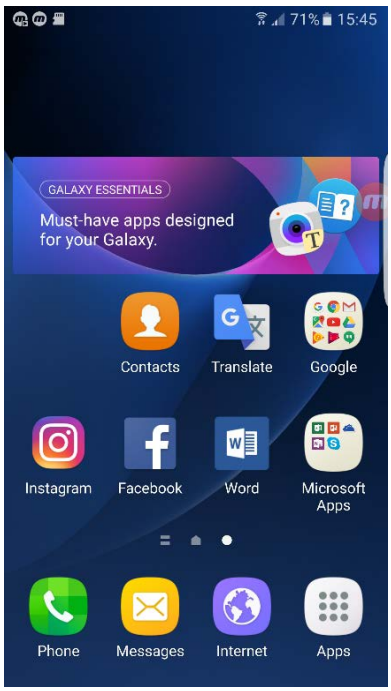

Figure 8. The first row of the default second page of the Samsung S7 Edge interface shows the Contacts icon. Some participants were frustrated at the location of the Contacts icon, feeling it should be placed on the first page, next to the Phone icon.

> *I thought it is for playing game; I expect it to be a chess symbol* [for the Play Store], *like games.* (P6, Female, aged 66)
>
> *I expect the function* [of the Play Store] *to be a play station. Is it for games only? This one I am not so sure.* (P9, Male, aged 73)

This highlights the affordance gap of user expectation (perceived from the visual design) and the external material world (the icon design of the Play Store). For example, a female user (aged 68) was an iPhone user and claimed herself not familiar with Android phone. She commented that she could not recognize the Play Store icon because she had no idea the icon was similar to the App Store icon on her iPhone.

Some of the participants also were not familiar with the use of the Contacts icon. For instance, a female participant (P45, aged 68) commented, "*We* [Apple iPhone users] *don't also have contact icon. The contact icon now looks like a clip art. I expect it to be more like a proper image. This one looks more feminine and mine looks more 'male'-like....*"

Visibility of Icon Location

Some older adult participants were lost in the navigation process for entering contact information on the Samsung S7 Edge smartphone. The study found that the location or position of apps icons

on the smartphone user interface indicated the visibility of the icon appearance to the users. For example, the Contacts icon was positioned on the second page by default on the Samsung S7 Edge. As a result, some participants, who expected it to be placed next to the phone/voice call icon on the first page and not on the second page (Figures 7 and 8), were frustrated in their search for access.

Seeking Help and Guidance

Many older adult participants acknowledged that they are beginner or intermediate users of smartphones. In normal usage, when they faced problems in dealing with technical issues on their smartphones, they would contact their children, younger relatives (e.g., niece, nephew), or the mobile phone shop for help and technical support. For instance, one study participant told of resorting to asking help from a child younger than 10 years to solve quickly his technical problem.

> [Researcher: Do you get any support when you face any difficulties using the smartphones?] *Sometimes, small children, 7, 8 years old. They can handle it. That fella, a 10 years old boy, came to help me. I met him in the Sikh yard boy when I went to Melaka. The father was asking the son to handle my phone. The color* [of my phone is faded] *out. The boy repaired; then the color came back again. Fantastic boys nowadays… children, my golly! So I don't care. I don't feel shy.* [A] *9-year-old girl also taught me how to save to my Contact.* (P40, Male, aged 72)

Because mobile technology advances very quickly, quite a number of the older participants in this study expressed interest in attending smartphone trainings in their areas. Trainings of this nature are rarely available in Malaysia. However, the U3A has organized a series of Smartphone courses for seniors, taught by the first author, since 2011. The thinking behind initiating these trainings is that the older users' children or family members were not always available to assist the users in addressing a problem with their smart phone or may not have been patient in teaching their older family members some aspects of smartphone use. Thus, through guided learning, the smartphone courses help the older adult users deal with typical smartphone technical issues, such as media transfer and downloading apps from the Play Store, and expose them to useful apps.

DISCUSSION

In the first part of this section, we discuss the descriptive results from the participants' demographic profile and the smartphone usage. We then discuss the results derived from the statistical analysis of perceived affordance of level of expectation on the four tasks and present our interpretation of the qualitative data.

The phenomenon of older adults in Malaysia adopting smartphones is similar to that described in a study conducted in Spain (Rosales & Fernández-Ardèvol, 2016a, 2016b). Our interview results showed that the motivation of older adults for using smartphones parallel the reasons for using the feature phones: to communicate and staying in touch with their family and friends. Overall, the respondents cited WhatsApp as their favorite communication mobile app because they can access the service at no cost, as compared to using SMS (short messaging system) that has a per-use fee. Our interviews highlighted that the access to WhatsApp was highly motivating for the older users in adopting a smartphone, even if they found using it challenging, at least at first. They reported that using WhatsApp offers them the fun and fulfillment of

knowing what is happening among their family and friends by sending messages and sharing photos and videos among themselves, something a feature phone could not provide. In addition, for those who had family members and relatives staying overseas, WhatsApp's ability in allowing them to make free calls, and more recently video calls, was the primary motivation for them to adopt the smartphone. In addition, despite any initial reluctance of and resistance to adopting a smartphone, peer pressure was another push factor that motivated the older adult participants to join their peers as senior smartphone users. That said, the older adult users in this study frequently did not explore the features and capabilities of smartphones beyond phone calls and WhatsApp, primarily due to the complexity of the smartphone user interface.

Many of our informants needed help to learn how to use the smartphone, and they always were perplexed on why their smartphones stopped responding to the task they are doing and, at the same time, the screen was frozen and slow in performance. Moreover, they often were afraid to access notifications on their phones because their children warned them that their phone could be infected with a virus if they simply clicked Accept. The older adult users also expressed a need for technical assistance because their children often were too busy or were not patient enough in guiding them in using their smartphones. When they faced a technical problem, they either had to wait for their children to become free to help solve the problem or contact a phone sales shop for help. However, what the respondents really wanted was to become empowered, to be able to solve their own problems, by gaining smartphone knowledge through attending training.

It was clear that when the older adults' needs are met—even if challenging at first—they are more likely to use their smartphones frequently. In some crucial ways, our data also revealed that smartphone user interfaces have not been designed to meet various specific needs of many older adult populations; the complexity of user interface features and overall usage are not intuitive to them, and thus smartphone use remains quite challenging for this segment of users.

The process of meeting user needs and expectations toward user adoption (taking action) is linked to Norman's (1998) EEAC model. For instance, when older adults are motivated by the clear goals of using a smartphone for communicating with their family and for media browsing and sharing, they are exposed regularly to the perceived affordance of a smartphone user interface (evaluation) and taking the action of sending or retrieving, for instance, a WhatsApp message (execution). During the Evaluation Stage (see Figure 1), it is crucial for the smartphone user interface (e.g., matching an easily identifiable phone icon design with its actual function) to meet the user's expectation (e.g., making a phone call). Successfully pairing the icon design with the expected process will lead the user to act appropriately by pressing the phone icon to make a phone call at the Execution stage.

Apparently, the mismatch between the participants' user perception and the smartphone user-interface design violated the usability heuristic of interface design (Inostroza et al., 2016; Nielsen, 1994; Silva et al., 2015). This led to a serious affordance gap between user perception and expectation. This means what the older adults perceived and intended to execute an action was not necessarily met, which led to the affordance gap. This is shown clearly in the result of paired sample *t*-test. It was not surprising that the commonly used phone tasks (i.e., making a call in Task 1, adding contacts in Task 2, and using WhatsApp in Task 4) are statistically significant in the level of expectation scores as compared to installing a mobile app. Having said this, the qualitative results served to complement and support the statistical results of perceived affordance. Thus, the results of Task 3 are unsurprising when considering that a majority of older adults, as supported by the results from our older informants, have little immediate interest in downloading a mobile app, and therefore

would have no knowledge or experience regarding where to find apps or how to download them. In addition, our older users were afraid of downloading an incorrect mobile app, installing incorrectly, and/or inadvertently exposing their device to a virus. Therefore, they had little or no confidence in completing this task and preferred to leave installing apps to their children, who are more technically savvy.

The importance of icon design also surfaced as an important aspect of mobile app access. During the interview session, the older adults commented that the Google Play Store icon and label did not communicate its purpose as a site for mobile apps download. To many of them, the Play Store icon looked like a shopping bag; the name attached to the icon appeared more related to playing games. As a result, most of our informants did not discern that the Play Store icon had anything to do with downloading nongame apps. This indicates an affordance gap between what an older adult expects from function names and icons as compared to what they actually are. This gives rise to a recommendation to the Google Android phone designers that they need to critically reconsider icon design and appropriate labeling for mobile apps download and, in fact, any feature or function available to a diversity of users.

Although Task 3 (installing an app from the Google Play Store) showed an improved score at the posttask measurement, the overall score was still below 5 points and considerably lower when compared to the other three tasks, which all rated above 5 points regardless of their decreasing scores. This indicates that the older adults' participants in general still found difficult the process of installing a mobile app from the Play Store. This conclusion is supported by the qualitative analysis of the observation data and the interviews: The older adults were confused with the icon design and nomenclature of the Play Store and its perceived function.

Apart from visual appearance of icon design, the developers and designers also need to take into account various users' prior experience and/or product knowledge and how that impacts their perceiving an icon and its function. This was reflected in our findings that the older adults generally had no issue with identifying the phone/voice call feature due to the intuitive design and their prior experience of using the similar feature in their feature phone or previous smartphone device.

Language comprehension related to the smartphone interface and the research process in this study could have had an impact. However, although the Chinese comprised of 58.7% compared to other participants (27.5% Malay, 13.8% Indian and other ethnics), it was expected they could comprehend Mandarin well. Instead, some of them spoke Chinese dialects such as Cantonese, Hokkien, Teochew, and the like as their mother tongue. Overall, a majority of participants could speak, read, and write English and Bahasa Malaysia (the national language for Malaysia) very well as compared to Mandarin. This could be due to a few reasons. Firstly, the educational background of the old generation in Malaysia: They spoke well in English because Malaysia was a former British colony. Secondly, those who signed up to join the lifelong learning courses in the University of the Third Age (U3A) somehow were considered quite literate and fortunate to have received a better education during their younger days. This is evident in that 40% of our participants had received an upper secondary education and 50% of the participants had tertiary education. This implies that the participants recruited for this study were considered having high education backgrounds. The result showed that a majority have no problems of understanding the English language displayed on the smartphone user interface; only a few had to change to the Mandarin language on the testing device during the mobile-user interaction session. However,

this result cannot be generalized to all older adults in Malaysia, based on their language proficiency in languages other than their own mother tongues.

Fundamentally, amid the burgeoning interest of older adults joining the legion of smartphone users, our data reinforce findings from studies in other contexts and user groups (Allen et al., 1993; de la Fuente, Gustafson, Twomey, & Bix, 2015; van de Kar & den Hengst, 2009) that mobile apps developers and designers must improve in incorporating the needs, interests, and consideration of perceived affordance into the design process. In terms of design recommendations, we suggest the design of smartphones or new technological designs needs to cater to the critical biological, psychological, and social needs of older adults. We also recommend that the mobile operator and telecommunication industries consider repackaging their marketing strategies and mobile subscription packages to account for older adults' socioeconomic requirements. For instance, a family subscription plan is a popular package introduced by the local mobile operators in Malaysia. The package accommodates not only the proliferation of extra share lines, but it also allows for broadband data plan extension.

CONCLUSIONS

With the increasing aging population worldwide adopting smartphones, much research has underscored how crucial it is to incorporate older adults' needs and to meet their expectations by reducing the affordance gap between smartphone UIs and user expectations. Older adults no longer want to be perceived as laggards (Rogers, 2003; Wong et al., 2017) or late adopters of smartphones. Although many previous smartphone studies have focused on the interests of young adults, the needs of older adults, who represent a growing market for smartphone use, are still not being met in the design of new technologies and mobile apps development. As our study found, many older adults find overall smartphone use complicated, and they require further technical assistance and/or training so that they no longer are forced to rely on their children or relatives for help.

The popularity of smartphones, and in particular WhatsApp as a favored communication app amid preferred health-care and utility mobile apps, have motivated older adults to adopt or trade up to smartphone capabilities. The results of this study provide useful information for mobile operators and the mobile development community (i.e., developers and designers) for capitalizing on untapped or underused opportunities within the growing aged 60+ smartphone user group. Commercial entities can draw on user experience and design strategies, marketing strategies, and mobile development strategies, supported by ongoing research, in meeting the specific needs of older smartphone users. The needs and interests of this older-adult cohort can be sidelined no longer; rather, they warrant important attention.

In terms of the limitations of this study, the participants selected represent a convenience sample and they were mainly from the Malaysian U3A (in Kuala Lumpur and Selangor), which are located in urban and suburban areas. Thus, the respondents are typically better educated and have access to more resources and services. Therefore, these findings cannot be generalized for the entire elder-aged population in Malaysia, particularly those from rural areas. Nevertheless, our findings reveal the needs and concerns of this so-called intellectual seniors cluster in how they use and perceive the smartphone. We also believe this subcluster group usually represents the early adopters among the older adult clusters. However, this study did not intend to explore whether the sociodemographic information—such as educational background, income, or language

proficiency—influenced the older adult participants in adopting a smartphone. Yet these are worthy topics for future study. The same is true for continued investigation of our research concern: examining the affordance of perception and actions of smartphone use, particularly in older adults.

The four tasks selected for this study do not represent the entire smartphone user interface or mobile apps. The reason for choosing these tasks was to investigate the frequently used basic smartphone user interface features and mobile apps interests of older users. Again, although the result cannot be generalized to all aging populations in Malaysia or elsewhere, our findings reveal some behavioral interactions and perceptions toward smartphone user interfaces among the older adults. These topics remain useful topics for future study.

In conclusion, this paper has provided findings of and offered insight into the affordance gap in terms of levels of expectation. This study is part of a larger study that addresses smartphone user interface components, including visual design, icon location, and UI functionality that determine the perceived perception and possibility of actions (Blackler; 2006; O'Brien et al., 2007). That study, still in process, will present and discuss other affordance metrics (i.e., first-click accuracy and task accuracy measures) in association with smartphone user interface components and how prior product experience influences the perceived affordance stipulated in the affordance matrix based on Gaver's (1991) technological affordance framework in the future studies.

IMPLICATIONS FOR RESEARCH AND APPLICATION

This study lays the foundation for a nascent understanding of measuring expectation levels of perceived affordance on smartphone user interfaces for older adults. Our research presented a quantifying means for measuring the affordance gap via examining the levels of expectation. Our approach can be considered a novel approach for formulating Norman's (1998) execution/evaluation action cycle. The qualitative findings provide the insight into and valid reasons for Android developers and the mobile design community to improve their icon design, the phones' functionality, and the information architecture to accommodate older adults. By addressing the concerns and challenges surfaced about older and inexperienced users, smartphone and mobile app suppliers/designers can facilitate improved use across the larger users' base. Thus, this study underscores the importance of mobile apps designers, smartphone developers, and user-interface design researchers investigating or employing independent research regarding the older adults' needs and expectation for the smartphone user interface, and then incorporating recommendations to reduce user frustration and problematic action as early as possible.

ENDNOTE

1. All data quotes that were not spoken in English have been translated by the primary researcher and four qualified lecturers who are conversant in English and Bahasa Malaysia languages.

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