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Research Article

THE SPECIAL DESIGN AND USE INTENTION EVALUATION OF A BRAIN WAVE MEASURING AND LEARNING SYSTEM FOR PHYSICAL INSTALLATION IN THE MUSEUM

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ABSTRACT

A novel installation is designed to process the people's brain waves in an educational system to help user to understand the characteristics of brain waves. Participants can operate the system by themselves, so they can observe the changes in their own brain wave spectrums as their mind is changing. To further understand user's intention to use this system or not, a questionnaire was designed to analyze the user's acceptance of this system based on theories of Technology Acceptance Model (TAM), social influences and curiosity. 403 valid samples were collected. Based on theories of TAM, curiosity and peer influence, this research did propose a reliable result to predict and explain the user's acceptance of the human brain wave learning system.

Key Words **:** *Brain Wave; Kalman Filter; Museum; Social Influences; Technology Acceptance Model (TAM)*

INTRODUCTION

What is the principal and function of the brain wave? It is interesting and curious issue for most of people. Within this decade, the Education Department in Taiwan has been eagerly promoting general science education to raise people's literacy of science. For instance, understanding oneself is one of the topics in general science education. Usually, curiosity and peer influence will motivate people to learn more about oneself. With the prevalence of computer technology, computers have been pervasively used in education and learning over the past decades (Wood, 2001; Valanides & Angeli, 2008; Uzunboylu, Bican & Cavus, 2010). Many high quality computer-aided learning (CAL) materials have seen the emergence of support both for teachers and learners. CAL not only helps learners' learning, but also advances the learning motivation of learners. With the availability of CAL, students or learners are therefore more likely to have different approaches or methods to support their learning without time or location constraints. The hands-on science with interactive interface (Axelrod & Hone, 2006) is a good method for people learning something from doing experiment. Experiments could be designed as an educational tool and exhibited at many public museums or on the Web.

The main purpose of this paper is to develop a system to help people understand the changes and its normal functioning in their own brain wave. Helping people understand themselves through brain wave with information technology support plays a critical role in the domain of adult education. This system used the bio-electronic and information technologies to develop a brain-wave learning tool for people and attract them to understanding bio-science knowledge. This system uses four metal plates and an AD/DA converter analyzing a series of signals taken from the brow. Computers obtain the wave results of the bio-voltage resolution variation of the brain, which is an easy bio-scientific learning tool.

Further, the newly implemented system's success depends on how people feel about it and whether they intend to use it. Many factors from previous researches affect the acceptance of information technology, such as system playfulness, perceived ease of use, perceived usefulness, system quality, the friendliness of the user interface and so on (Yang & Lay, 2005; Reynolds, Walker & Speight, 2010; Lin, Chang & Chen, 2008). As we know, Davis's Technology Acceptance Model (Davis, Bagozzi & Warshaw, 1989) proposed the acceptance of users with the system determines the success or failure of a newly developed information system. Two salient constructs, perceived ease of use and perceived usefulness, are the primary antecedents to predict the intention of system use, which in turn determines the actual system use. Adult continuing education needs more detailed and effective instructions during the learning process (Cheung, Hui, Zhang & Yiu, 2003). Curiosity is also one of the important factors explaining people's motivations to know the objects or things (Litman, 2005; Litman & Silvia, 2006; Eugene, 2010). People are always curious about unknown objects or things. Education theory holds most people seek to satisfy their curiosity if the opportunity is presented and those who are curious about a product are likely to use it if they perceive the trial is low-cost and low risk (Pierce, Distefan, Kaplan & Gilpin, 2005; Harvey, Novicevic & Breland, 2009). Yet, curiosity has rarely been used in the studies of behavior intention to use a new technology. Social influence, especially peer influence, is also another factor affecting people's behavior. Social influence is a reliable predictor of future system use and intention. Therefore, the second purpose of this study is to conduct an evaluation survey with a questionnaire to understand learners' opinions and acceptance of this brain wave measuring and learning system, after the system was installed at the Science Museum (Lin, Yang, Lay & Yang, 2011). Curiosity and peer influence are also added to system evaluation, with the aim of identifying the relationship among curiosity, peer influence and use intention. Thus, the major constructs are used in the evaluation step include perceived ease of use, perceived usefulness, curiosity, peer influence and use intention (Lin, Lin, Yang, Liou & Lay, 2012). It is our hope the research results can help us understand the effectiveness and usability of this brain wave measuring and learning system, point to the directions for follow-up system improvements, and provide implications for practitioners.

Signal Process and Brain Wave

The critical part of actual signal spectrum is usually restricted within a small range of frequency, which is very useful from the view of signal process (Lin, 2002; Li & Xu, 2006; Ruiz, Li, Freeman & Gonzalez, 2009). The signal of a time function $v_a(t)$ is denoted by the summation of sine-waves with the different frequencies and the intensities through the mathematic calculation of Fourier series and Fourier transform. Fourier transformation can process a non-cyclical sound function signal which spectrum includes all possible frequencies (Couperus & Mangun, 2010). However, an actual signal frequency spectrum is usually limited in the small range of frequencies, which are extremely useful in the signal process. The frequency response of the brain wave game system is in the low frequency area which is between 0Hz~60Hz. Hence, a software signal band pass filter is designed to grab the input signal. Two cut off frequencies have been designed. 60Hz is for the high frequency bond ω_H. 0 Hz is for the low frequency bond ω_L. All input signal should between 0 Hz~60 Hz for passing the filter.

In the design stage, we found two protuberance noises are near the band pass filter. One is 0.5Hz and the other is 60Hz. The 60 Hz noise could be filtered by the band pass filter. A notch filer (V filter) has been designed for filtering the background noise.

Brain wave pattern can be displayed by converting them into frequency form. The frequency forms are classified as four types named α、β、θ and δ (Weinberger & Richter, 2002; Robertson, 2002; Halici, 2009).

When the brain wave of a user has been detected closely to the α wave, this means the person's consciousness is sober with the body relaxation condition. The α wave disappears when the user falls asleep. The frequency of the α wave is between 8 to 13Hz. When a user feels stressed or nervous, the α wave becomes a β wave. The frequency of β wave is higher but the amplitude is lower than the α wave. The frequency of the β wave is higher than 13 Hz. Usually, the θ wave can only be measured in children. The θ wave appears in an adult when he falls asleep or fully relaxes. The frequency of the θ wave is between 4 to 8 Hz. The δ wave could occur when the person is in deep sleep and is unconscious. The frequency of δ is between 1 to 4 Hz.

When the user attaches the four metal plates sensor input points to the forehead the brain wave will be captured by the computer for calculating the data in time domain as shown in Figure 1. The calculation must be estimated and quantized by suitable filter to allow for possible noise disturbance in the input data (Lin, Cho, Lay, Lin & Lin, 2006; Stamoulis & Chang, 2009). Here we can assume the input data as the correlation functions r_a of background noise $u_a(t)$ and brain wave signal $f_a(t)$.

This system uses the Fast Fourier transform to analyze the brain wave. From the studies of brain waves, for most people who sit in meditation, after a period of time, the α brain wave oscillation amplitude will become very small. Some people's α brain wave amplitude is naturally very small.

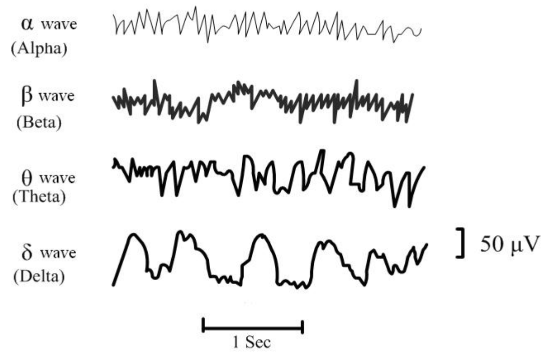

Figure 1: Brain wave types

This kind of person will more often have special abilities as well as the heart electric induction condition. Sometimes, extraordinary physical ability may be seen from some people who have special talents. Therefore, many scientists want to use experiments or scientific theory to measure the quantity of α brain wave amplitude or the bodily acupuncture point resistance value for understanding these mysteries. Can people gain

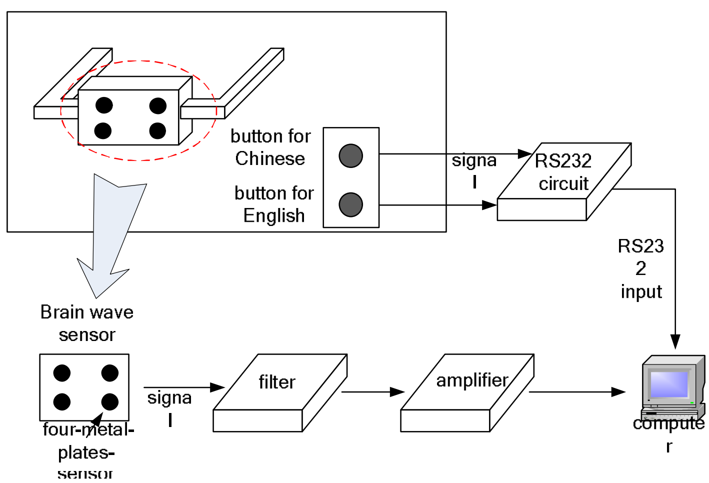

Figure 2: Schematic diagram of the brain wave learning system

extraordinary physical abilities through teaching or practicing by advance technology? This is not a simple question that can be solved in a very short time. The cerebral cortex neuron contains bioelectricity activity; therefore the cerebral cortex frequently has the rhythmic electric potential activity signal, which generates continuous called spontaneous brain electricity activity and this kind of brain electricity forms the brain wave signal. When a person carries on with different activities, the brain wave displays different characteristics. In the clinic, brain wave signals are obtained from the head by pasting four to eight pieces of electrodes on the scalp for measuring. Synthesis of change for the most scalp electric potential, the enlargement percentage is approximately 10000 times.

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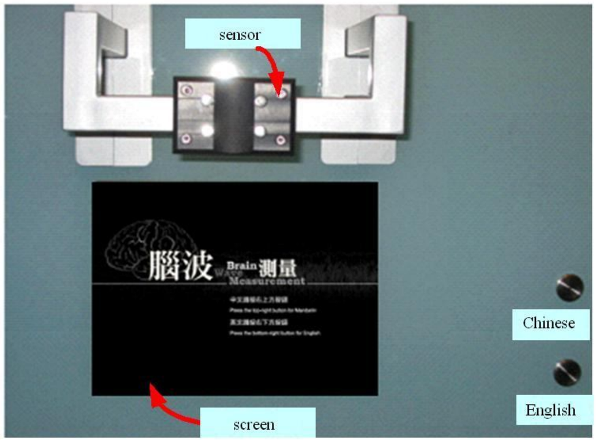

Figure 3: Mechanism design of the brain wave learning system

In the science museum, the brain wave measuring and learning system must be designed as an easy to use tool which the visitor may operate himself or herself and not need any assistance from other people or any assistant materials. Therefore, the electrode plates designed for whole formation construction let the user attach the forehead to four metal plates measuring points. The schematic diagram of the brain wave learning system is shown in Figure 2. Figure 3 is the mechanism design of the brain wave learning system. Assume a high frequency noise occurs from the sensor called $n(t)$. The input data can be represented as the correlation functions of these two intensity distribution function $u_n(t)$ and $f_n(t)$. Kalman filter (Lin, Cho, Lay, Lin & Lin, 2006) can provide effective noise cancellation by using the same derivation steps measure N times by a single estimation method.

System Evaluation

The goal of the system evaluation step is to confirm the visitors' intention in using the brain wave measuring and learning system. Two tasks are to be explored in the system assessment step: (1) The descriptive profiles for user's background information; (2) Regression analyses were used to test the casual-effect among impact factors on the intention to use the brain wave measuring and learning system. Evaluation procedures, theoretical base and testing hypotheses, measurements and pre-testing, samplings, results and discussions are outlined as follows.

Evaluation Procedures

The brain wave precision is perhaps not as good as a medical brain wave instrument, but still sufficient for achieving the learning goal through playing. Figure 4 is a user operating the brain wave measuring and learning system inside the museum. Figure 5 is the explanation page of the brain wave measuring and learning system. Figure 6 is the results of brain wave measurement on the monitor. This system could function as a foundation of medical science to enable users who participate in the activity to grasp basic brain wave principles and the correlation utilization. Hopefully, the users who participate in the activity will be able to learn richly without fear and use this system as an interesting game to achieve the universal goal of science.

Figure 4: A user operates the brain wave system inside the museum

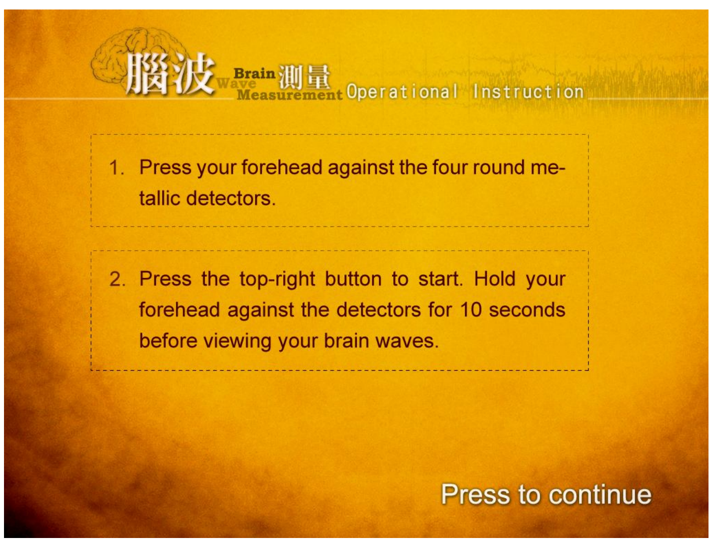

Figure 5: The explanation page of the brain wave system

The developed brain wave measuring and learning system has been installed in the National Science Museum at Taichung since 2006. However, how do people feel about this system, are they curious about this system or will they actually use it remains unknown. The system was developed and tested online, and till now, the system has been modified many times to better fit the users' needs. Currently, the system is well developed and in good condition. Therefore, our research group decided to understand how the users feel about this system and whether people intend to use this system while they are visiting a museum. The assessment procedures involved two steps: (1) A questionnaire was designed and pre-test. (2) One of researcher was on field to distribute the questionnaires to users from January 15, 2008 to February 15, 2008, lasting for one month.

Theoretical Base and Testing Hypotheses

The fundamental question motivating this evaluation experiment (Ashok, 2012) was to deeply explore what factors determine users' acceptance or intention to use this computer-supported brain wave measuring and learning system. The Technology Acceptance Model (TAM) is a well-accepted theory of adoption and intention model in information technology related researches. The Technology Acceptance Model uses the Theory of Reasoned Action as a theoretical basis for specifying the linkages among perceived ease of use, perceived usefulness, intention and actual behavior.

Thus, TAM was then used as a theoretical basis to support this evaluation step. Basically, TAM was implemented to explain the determinants of user acceptance of end-user computing technologies (Davis, 1986). Two salient constructs, perceived ease of use and perceived usefulness, are the primary antecedents to predict the intention of system use, which in turn determines the actual system use. Perceived usefulness means an individual's subjective perception of the positive influences of using an information system. Perceived ease of use refers to the user's perception of the ease of using an information system. Gefen et al. (Gefen, Karahanna & Straub, 2003) found perceived ease of use will affect the intention of on-line shopping. Ahn et al. (Ahn, Ryu & Han, 2004) pointed out perceived usefulness is related to use intention.

Social influence is a determinant of user behavior and is also an antecedent of behavioral intention. Social influence, especially peer influence, is also another factor affecting people's behavior. Users may use a system or product as a result of overt conformity pressures from peer groups, responding to concerns of what others may think of them, or they may react to their product choice and use (Robinson, 2011). As in the theory of reasoned action and other behavioral intentions model, a person with intentions to use some products may be driven by people's attitude towards that behavior, normative influences in the decision context, or a combination of the two. Usually, young people who are very sensitive to the reactions of others in their consumption decisions are more likely to comply with group wishes, regardless of their personal attitudes toward the behavior.

Malone proposed when individual facing an interesting condition or environment, his or her curious cognition or perception will be evoked for doing the next activity. The environment condition should be neither too complicated nor too simple with respect to the learner's existing knowledge. It should be novel *and* surprising, but not completely incomprehensible. Malone divides curiosity into two variants:

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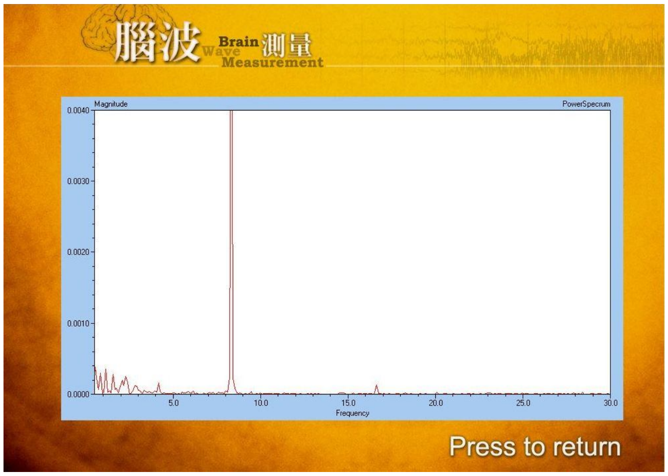
(A)



(B)

(C)

Figure 6: The results of brain wave measurement on the monitor (A) input signal in time domain (B) spectrum of background noise (without filter) (C) spectrum of brain wave with filter

sensory curiosity, which is about maintaining interest in the sense, and cognitive curiosity, which is more about the semantic content of information. The idea of sensory curiosity is not enormously explored in previous studies. This study here focuses on "technical events" –whether the display screen of the brain wave measuring and learning system can catch learner's interest and attention on the level of sensory interest. We believe there is considerably more work to be conducted in exploring sensory curiosity in computer-supportive learning systems. Malone also proposed three of the characteristics of well-formed scientific theories: completeness, consistency *and* parsimony. Based on curiosity theory, the way to engage learners' curiosity is to present just enough information to make their existing knowledge seem incomplete, inconsistent, or parsimonious. This idea strikes us as worthy of further investigation, and even suggests something concerning the intention of system use. So in this study, curiosity includes sensory curiosity and cognitive curiosity. Litman (Litman, 2005; Litman & Silvia, 2006) defined curiosity is the desire to know, to see, or to experience leading to exploratory behavior directed towards gaining new information. This indicated if people were curious about something, they would intend to further investigate or know something. Additionally, previous researches also pointed out curiosity is widely recognized as the antecedent of exploration.

From the aforesaid well-established theoretical basis and empirical studies, the hypotheses in Table 1 were tested in the evaluation step.

Table 1: The hypotheses were tested in the evaluation step

Item	evaluation step
H1:	Perceived ease of use has a positive influence on the intention to use the brain wave system.
H2:	Perceived usefulness has a positive influence on the intention to use the brain wave system.
H3:	Peer influence has a positive influence on the intention to use the brain wave system.
H4:	Curiosity of the system has a positive influence on the intention to use the brain wave system.

Measurements and Pre-testing

The questionnaire consists of two parts. One is demographic information such as gender, age, parental education, and so on; and the other is the constructs of perceived ease of use, perceived usefulness, curiosity, peer influence and use intention.

The measurements of perceived ease of use, perceived usefulness, and use intention are the adaptation of Venkatesh & Davis (Venkatesh & Davis, 1996; Venkatesh & Davis, 2000), and slight modification of the words of measures to fit the current research context. The Seven-Likert Scale was used for measuring

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these variables, and answers ranged from 1"strongly disagree" to 7"strongly agree". Use intention includes three questions modified from the intention scale developed by Venkatesh & Davis. Five items of curiosity are adapted and modified from Pierce et al. (Pierce, Distefan, Kaplan & Gilpin, 2005) and Litman's concept (Litman, 2005; Litman & Silvia, 2006). The respondents are asked to indicate the degree of curiosity while using the automatic human brain wave measuring and learning system.

Before the final version of the questionnaire was distributed, a pretest was conducted with 10 primary school students. Five scales had reliabilities levels of 0.80 or better for all. Based on this pretest, slight refinements and minor adjustments of the wording and sequence of the items were revised to prevent any vagueness and misunderstanding.

Samplings

The questionnaire survey was conducted to validate the intention to use the automatic human brain wave measuring and learning system. One of researcher was on field to distribute the questionnaires to users. The target samples of this study are children, but they should have some degree of Mandarin reading ability. The reason we choose children as testing sample is matching the government's policy to promote children general science education. Hence, only the primary school students are included in this study. After the student uses the system, the researcher will request the student whether he or she is willing to fill in the questionnaires. The collecting period lasted four weeks. Finally, 421 questionnaires were collected. After excluding those with too many missing values and inconsistent responses, 403 valid questionnaires were found to be completed and usable in the analysis.

Demographics of Respondents

Table 2: The database of questionnaires

Item	Detail category of respondents					
Valid questionnaires	403					
	Males		217	Females		186
Respondent age	7 ~ 47					
	7~18	6 %	19~25	82 %	26~47	12%
education background	From elementary school to Ph.D.					
	graduate	18.7%	university	65.9%	others	15.4%

To offer more insight into the respondents, a brief profile was described covering the demographic attributes of the participants. The number of questionnaires collected was not large, only 421 questionnaires were collected in this study, among which 403 were valid samples and 18 were invalid. Among the valid samples, the elementary database is presented as Table 2. From the analysis, it shows students with higher parental education were more willing to use this system. The reason for using this system was in the form of multiple-choice questions. The respondents can choose many reasons listed in the questionnaire. The results show most people were curious about this system, accounting for 62.7%, 39.8% of respondents thought the system were novel, and 38.9% of respondents thought they could know the testing result immediately. Survey results show about 73.6% respondents hadn't used similar systems in the past.

RESULTS AND DISCUSSION

Reliability and Validity of the Measurement

Reliability analysis is a major method for assessing the stability of a measuring tool. Cronbach's α is frequently used for measuring internal consistency. In normal, Cronbach's α should be no less than 0.7. In this study, the threshold value for each variable's α was over 0.7. The use intention was 0.85, perceived ease of use was 0.92, perceived usefulness was 0.84, peer influence was 0.88, and curiosity was 0.87. The above data proved these reliability values are above the value of 0.7. This result indicates a high internal reliability of the data exists and the measurement is reliable.

In this study, items for each construct about use intention, perceived ease of use, perceived usefulness, curiosity and peer influence are modified from foreign measuring scales, and therefore, the accuracy of the translation will be considered. Further, the principal component analysis using orthogonal rotation to ensure the loadings on hypothesized factors was used for assessing the convergent validity of variables. If an item with factor loading values is not greater than 0.5, then the item should be deleted and abandoned from further hypotheses analysis. The threshold values for each factor loading value are all over 0.5 and all items are convergent into their own construct. Therefore, no items were deleted from each construct.

Table 3: Regression of hypotheses

Dependent variable	Independent variables	Beta	t	Sig.
Use intention	Perceived usefulness	0.406	5.589	0.000***
	Curiosity	0.530	7.585	0.000***
	Peer influence	0.313	3.016	0.003**
	Perceived ease of use	0.246	2.372	0.020*

*Use intention: F=98.562 (P<0.001) R2=0.738 ***P<0.001 **P<0.01 *P<0.05*

Regression Analysis

A regression analysis was performed to understand the causal-effect of each hypothesis. Regression analysis was conducted for curiosity, peer influence, perceived ease of use and perceived usefulness as independent variables, and use intention as a dependent variable, shown in Table 3. The overall ANOVA model was significant (P<0.001). The R^2 for this analysis was 0.738 at F=98.562 (P<0.001) in the use intention of brain wave measuring and learning system is accounted for by curiosity, peer influence, perceived ease of use and perceived usefulness. As expected, curiosity (p=.000), perceived usefulness (p=.000), peer influence (p=.003), and perceived ease of use (p=.020) turned out to have a significant effect on the use intention of the brain wave measuring and learning system. All independent variables had a positive effect on use intention of brain wave measuring and learning system. Curiosity (Beta=0.530, t=7.585) had the most significant predictive power, followed by perceived usefulness (Beta=0.406, t=5.589) and peer influence (Beta=0.313, t=3.016). The perceived ease of use had the least predictive power in use intention of the brain wave measuring and learning system (Beta=0.246, t=2.372). These results are consistent with researches, which predicted curiosity, peer influence, perceived ease of use and perceived usefulness have a significant impact on use intention, respectively.

DISCUSSIONS

As predicted and consistent with the theoretical perspective, perceived ease of use and perceived usefulness have a positive effect on use intention of brain wave measuring and learning system, respectively. The results pointed out if users feel the system is easy to use and is helpful to them, they would have a high intention to use the system. The result imply when the system designers designed an automatic learning system or measurement system, the user's interface must be very friendly to attract people's attention and the content of the system must be rich and knowledgeable.

There is also a consensus in the literature on the effects of curiosity. The curiosity literature suggests if users show curiosity with an interesting condition or environment, then their curious cognition or perception will be evoked for doing the next activity. Curiosity has a positive effect on the intention to use the brain wave measuring and learning system. These findings are consistent with the theory of curiosity. Respondents with higher curiosity have a higher intention to use the brain wave measuring and learning system. This result implies if the subject or contents of the system are novice or mysterious to the users, they would have a higher intention to learn or use that kind of system. Even if the subject is new to them, they will still have curiosity to use the implemented system.

Also, peer influence, as predicted, has a positive effect on intention to use the brain wave measuring and learning system. From a theoretical perspective, it seemed logical to hypothesize more peer influence would result in a higher effect on intention to use the system because conformity would give pressure to influence one's judgment. Young people, who are very sensitive the reactions of others in their consumption decisions are more likely to comply with group wishes, regardless of their personal attitudes toward the behavior. Thus, in this study we did find peer influence, especially for children, played a critical role in the intention to use the system. This result implies competition and conformity factors should be considered when designing an information system.

Limitations and Future Research

Three limitations should be addressed in this study. First, a limited primary school student's sampling sizes were analyzed in this study, so the result may not be generalized to all users with different ages and will cause sampling bias. Further research should try to enlarge the sampling sizes with different age to know how the users feel about this system. Adults and children maybe have different perception of this system. Second, the evaluation of this study is a kind of snapshot research. This study uses a cross-section study to examine the impact of perceived ease of use, perceived usefulness, curiosity and peer influence on intention to use the system. However, these independent variables will change over time once users are familiar with this system. So, a longitudinal study is necessary for advanced study. Further study should focus on a longitudinal study over time to understand the change of intention to use the system. Third, more factors should be considered in the system implementation evaluation. In this study, only the TAM model, curiosity and peer influence were tested in the evaluation step. Further study should enlarge the theoretical scopes, such as media richness theory, innovation diffusion theory and so on, to make the system evaluation more comprehensive.

Conclusions

The main purpose of the automatic human brain wave measuring and learning system is to display the wave changes of human and help people understand the change and activity of their brain. It can speed up people's knowledge of their own body. Learners do not need to go to the hospital to obtain their own brain wave data. The system evaluation is only a preliminary study to test the use intention of the system with TAM, curiosity and peer influence. Based on theories of TAM, curiosity and peer influence, this research did propose a reliable result to predict and explain the user's acceptance of the human brain wave measuring and learning system. This indicated a successful information system should have users actually use it. If not, the system is useless. Therefore, usability evaluation is important for a newly developed learning system. In this study TAM did provide a robust theory background to explore the adoption behavior of individuals. The findings from this system evaluation indicated curiosity, peer influence, perceived ease of use and perceived usefulness can be viewed as related to use intention of a new technology. Users adopt this system because they are curious about the brain, and the system is useful and easy to use. Also, peer or friend influence plays an important role in affecting their intention to use this system. This result recommends any system implementation needs to evoke user's curiosity and usability test to increase the system acceptance rate. It is a mistake to only focus on the technical side and ignore the user side.

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