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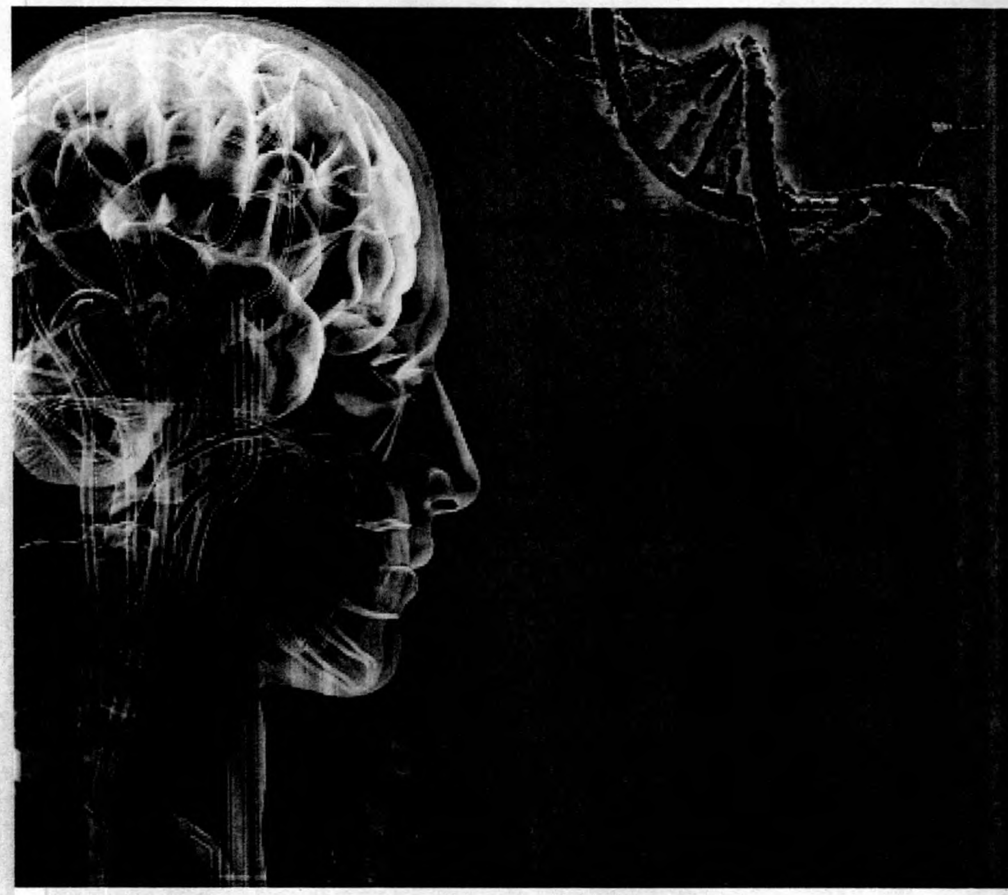

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Research article

Development and validation of a survey instrument to assess attitudes of healthcare professionals on using 2D bar-code technology: an extension of the Technical Acceptance Model

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Abstract

User attitudes can help to identify practical issues related to using a technology. The aim of this study was to develop and validate an instrument to assess attitudes of nursing and pharmacy staff on using 2D bar-code technology in dispensing and drug administration. The Technical Acceptance Model (TAM) was used as the basis for developing the instrument. New items were added to address areas more specific to 2D bar-code technology. All items were measured using a five-point Likert scale. The validity and psychometric properties of the instrument were assessed using responses from 46 health care professionals (30 nursing and 16 pharmacy staff). The resulting instrument contained 26 items. Factor analysis extracted 6 constructs that were not identical but generally conformed to the factors in the TAM. The six constructs measured 'attitudes of output and intention to use', 'perceived usefulness', 'perceived ease of use', 'external influences', 'job relevance' and 'perceived adequacy of training'. The factor structure showed good construct validity. All correlations between hypothesised construct and item were above 0.4 after adjusting for overlap. The instrument showed good reliability with an overall Cronbach's alpha of 0.86 and overall intra-class correlation of 0.89. A valid and reliable instrument to measure attitudes of pharmacy and nursing staff on using 2D bar-code technology was developed as an extension of the TAM. This instrument may be used to assess user attitudes before implementing the 2D bar-coding technology or for continuous improvement of the system.

Key words: 2D bar-code; Questionnaire validation

Introduction

Bar-coding technology helps healthcare professionals to improve patient safety by enabling verification of the five rights; right patient, right drug, right dose, right route and right time.[1,2,3,4] In the West, a patient admitted to hospital is given a bar-code identity which he will wear as a wristband throughout his hospital stay. All his medical records including prescriptions and medicine labels will also bear the same bar-code identity. At prescribing, dispensing and administration of medicines, the respective healthcare professional will cross-match the barcode on the patient's wristband with his medical records/prescription/medicines to ensure correct medicines are administered to the right patient, at the right time and dose.

However, problems can occur when people operate technologies. Users tend to bypass essential steps and find shorter or easier ways to operate, if a technology is difficult to use.[5,6,7,8] Such workarounds are often associated with medication errors.[6,9] Benefits of bar-code technology in medication safety can only be achieved if the technology is used correctly. It has been shown that workarounds

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are minimal among users who have accepted the technology and understood its role in improving patient safety.[10,11] Perceptions of bar-code users on using the technology is a good way to understand their level of acceptance.

There are only a few studies that assess attitudes of bar-code users in the literature. The Medication Administration System – Nurses Assessment of Satisfaction (MAS-NAS) scale developed by Hurley et al. is used to study the satisfaction levels of nurses who use bar-code assisted medication administration systems.[12] It is an 18 item scale covering areas related to team communication, efficient use of time, ease of carrying out five rights of medication administration, support for the application of clinical judgment and straight forward real- time documentation. Although, the MAS- NAS scale is a validated instrument it is highly specific to nurses who use bar-code technology for drug administration. The instrument cannot be used to assess attitudes of healthcare professionals who are engaged in other bar-code related processes such as bar-code aided dispensing, patient identification and blood transfusion. Furthermore, items in the MAS-NAS evaluate nurse satisfaction on more specific, system level attributes rather than general attitudes about the technology. Wang et al used a six itemed questionnaire to evaluate pharmacist attitudes on the use of a 2D bar- coded prescription system but the instrument only focused on efficiency and ease of use.[13] Currently, there is no valid instrument to assess general attitudes of all types of bar-code users.

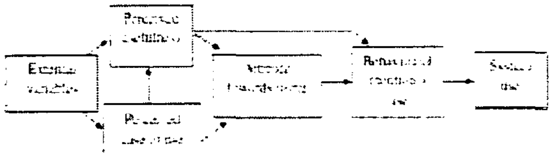

Figure 1: The Technical Acceptance Model

The Technical Acceptance Model (TAM) is a robust and parsimonious instrument widely used to assess the acceptance levels of information technology.[14] The model states that 'perceived usefulness' defined as "extent to which a person believes that using a system will enhance his or her job performance" and 'perceived ease of use' defined as "extent to which a person believes that using a system will be free of effort", of a technology are key factors that determine the behavioural intention to use. The model continues to explain that all other external factors that affect intent to use are mediated through 'perceived usefulness' and 'perceived ease of use'. 'Perceived usefulness' is also influenced by 'perceived ease of use' because a system is more useful if it is easier to use. TAM was later extended as TAM 2 (Technical Acceptance Model 2) where more attributes such as subjective norm, job relevance, voluntariness, quality of output and results demonstrability were shown to directly or indirectly contribute to user acceptance (Figure 1).[15]

The TAM has also been extended to determine acceptance levels in health informatics.[10,16,11] Alper et al used the TAM to test the link between rule violations and the ease of the drug administration process.[17] However, this is the first time that TAM has been used to assess general attitudes of bar- code users. Attitudes of bar-code technology users can help to determine the level of acceptance and possible reasons for workarounds. TAM is a well accepted model that explains the intention to use of information technology and has also been extended to assess the acceptance of other health technologies.[14, 15] This study aims to develop and validate an instrument that is based on the TAM to assess attitudes of healthcare professionals who use 2D bar- code technology for drug administration and dispensing. Specifically, we aim to establish the factor structure, and construct validity and reliability of the instrument.

Methods

Study setting
The studies were conducted in one of the largest government hospitals under the Hospital Authority of Hong Kong which is also the teaching hospital of the University of Hong Kong.

A stand-alone bar-code assisted medication administration system (BCMA system) was planned to be initiated in one medical ward (12 beds; 8-9 nurses) in the study hospital. According to the planned project, prescribing information on hand-written prescriptions will be transferred to the computer, 2D bar- coded dispensing labels will be printed and attached onto each drug item dispensed by the pharmacy. Drugs that are dispensed by an Automated Dispensing Machine (ADM) will be ere directly dispatched, with a 2D bar-code printed on the packaging. At the bedside, the nurse will match the bar-codes on drug containers/packs with that of the patient's bar-coded wristband and the prescription in the computer system, to confirm the accuracy of the drug administration process.

Ethical approval for the study was obtained from the Institutional Review Board of the University of Hong Kong/Hospital Authority of Hong Kong.

Development of questionnaire
A questionnaire was developed to assess the attitudes of pharmacy and nursing staff. A modified version of the Technical Assessment Model (TAM) was used as a basis for developing the instrument. As recommended by Churchill (1979) multiple variables were used to assess each construct.[18] The initial instrument included 44 items, where 9 variables were included to assess demographics and 35 variables to assess attitudes. All demographic variables were developed in-house. Twenty three variables were adopted from Venkatesh et al.[15] after minor modification in wordings to better suit the current context. Twelve new variables, more specific to the use of 2D bar- coding that were not addressed by Venkatash et al were also developed. All variables represented a total of eight pre-specified constructs[15] and two new constructs (Table 1). All items were measured using a five point Likert scale where '1' measured strong agreement and '5' measured strong disagreement.

Psychometric properties of the instrument
The TAM has been previously validated and used in the fields of information and health technology.[10,11,16,19] Since items adopted from Venkatesh et al were slightly modified and new variables were also added,[15] further validation of the current instrument was needed.

Table 1: Pre-specified constructs assigned to variables before factor analysis and validation

Pre- specified construct names	Number of variables in each construct
Intention to use*	2
Perceived usefulness*	5
Perceived ease of use*	4
Subjective norm*	2
Voluntariness*	2
Job relevance*	3
Quality of output*	2
Perceived adequacy of	2
Results demonstrability*	2
Perceived suitability of infrastructure†	2

*Constructs adopted from the Technical Acceptance Model[15]
† Constructs that were newly developed

Face and content validity
The face validity of an instrument will assess if all items are clear, comprehensible and in logical order.[20] The content validity will assess the appropriateness of the content of the instrument.[20] Both face and content validity were assessed by three healthcare professionals in the fields of pharmacy, nursing and clinical pharmacology. All three reviewers were well experienced and experts in

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their respective fields. Three demographic variables on age, education and current employment position were re-worded following their comments.

The face and content validated instrument was administered among the limited potential 2D bar-code users (study participants) in the study hospital. All potential users of the 2D bar-code system in the proposed ward and pharmacy of the study hospital were included. This included 16 pharmacy staff from the pharmacy and 30 nursing staff from the ward proposed for implementing the technology. All study participants had completed training sessions on the use of this technology but most had no prior experience in using the 2D bar-code technology in drug dispensing or drug administration. However, all participants were experienced in using linear bar-codes in patient identification.

Dimension reduction

Although the variables used in the instrument had hypothesised constructs, the factor structure was re-assessed using exploratory factor analysis. The Principal Components method was used for extraction and an orthogonal rotation method (Varimax method) was used for improving the exploratory ability of the constructs.[21] As the Eigen value states the total amount of variance explained by a construct, and Eigen value ≥1 was used to decide the number of meaningful constructs derived from factor analysis.[22] Three criteria, the Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO) value, Bartlett's test of Sphericity and communalities were observed to determine the suitability of data for factor analysis. The KMO value is an "effect size measure to determine the suitability of data for factor analysis and should be at least greater than 0.6".[23] The Bartlet's test of Sphericity, if significant, will suggest that there is at least one statistically significant correlation among the data and that the variables are not entirely independen.[23] The communalities measure the "amount of variance of a variable explained by all the constructs" and should be greater than 0.6 to perform a reliable factor analysis.[24] The factor loadings indicate the "strength of association between variables and constructs".[23] Variables that had factor loadings of greater than 0.5 were used to explain the corresponding construct. Factor analysis was repeated after removing variables that had poor convergence until a satisfactory convergent validity was observed. New constructs were created in the database according to the factor solution. This was done by summing up the mean scores of variables in each construct to obtain composite scores. A mean score for each construct was obtained by dividing the composite score by the number of variables in each construct.

Construct validity

Construct validity is to assess "if variables measure what they are intended to measure" .[25] Construct validity was measured in terms of convergent and discriminant validity.

Convergent validity is defined as "multiple attempts to define that construct are in agreement".[26] That is to identify variables that are correlated and measure a similar construct. Three criteria were used to assess the convergent validity. Firstly, each variable in a given construct should substantially and linearly correlate (at least $r>0.40$) to the composite score of the hypothesised construct which is computed by summating the scores of other variables related to the same construct excluding the variable assessed (that is adjusted for overlap).[21, 27] Spearman's correlation was used to derive correlations. Secondly, all variables grouped in one construct should have similar variable-construct correlation values which indicate that each variable represents approximately the same amount of information about the given construct.[27] Thirdly, a variable should correlate more strongly with the hypothesised construct than with other constructs.[27,28,29] For each variable in a construct, the correlation between variable to hypothesised construct was compared with the correlation of the variable to other constructs. The number of times the correlation of 'variable to

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hypothesised construct' was greater than other correlation values was presented as a percentage of the total number of comparisons within a construct.[27] This proportion was termed as the scaling success of the construct.

Discriminant validity is defined as the "the degree to which variables differentiate among constructs or measure distinct concepts".[30] That is to measures the degree to which variables in one construct are differentiated from variables in other constructs. To assess discriminant validity, loadings and cross loadings of variables were compared. For good discriminant validity, variables should load (loadings) higher for their associated construct than the variables of other constructs (cross loadings).[19] Variable-construct Spearman's correlations were also compared. The correlations of variables to hypothesised construct should be stronger than correlation with other constructs for satisfactory discriminant validity.[21]

Internal consistency

The Cronbach's alpha was calculated for each construct. Cronbach's alpha is a measure of reliability that will measure the proportion of variability in responses of a survey that is a result of differences in respondents. The value ranges from 0 – 1 and values closer to one indicates better reliability[20,31] High Cronbach's alpha values will indicate that variances in the responses are due to differences in opinions of respondents and not because the questions are confusing or has multiple interpretations.

Intra-rater variability

The intra-rater variability was measured using the Intraclass Correlation Coefficient (ICC).[20,31] This procedure measures the agreement of values within cases. That is to ensure that responses given by respondents are repeatable if assessed again. The ICC values ranges from -1 to +1, and values greater than 0.70 are considered as excellent.[32] A sample of eight pharmacists were given the questionnaire 3-4 days apart. The ICC values were computed using a 'two- way mixed' model which assumes that people effects are random and the item effects are fixed and 'absolute agreement' type.[33] Analysis was done at 95% confidence interval.

Results

Descriptive characteristics

46 participants took part in study which included 30 nursing staff and 16 pharmacy staff. The descriptive characteristics of respondents are shown in Table 2 which includes gender, age category, highest education level, current employment status at study hospital, work experience and years of experience in using a 2D bar-code system. Pharmacy staff had more male representation while nursing staff had more female representation. Age of all respondents ranged from 21 to 50 years and nearly 50% belonged to the 31-40 years age category. Nearly 74% of the participants were graduates or postgraduates and remaining had additional training in their respective fields. The pharmacy staff consisted of pharmacists, senior dispensers and dispensers and the nursing staff consisted of nursing officers, registered nurses and advanced practicing nurses. The work experience in their respective professions ranged from 10.0–30.0 years for pharmacy staff and 0.5-30.0 years for nursing staff. While the pharmacy staff claimed to have no prior experience, 23.3% of the nurses said they had 1-3 years of experience in using 2D bar-coding technology. As stated previously, all participants had training sessions on using the 2D bar-coding technology and all participants used linear bar-coding for patient identification.

Factor structure

The initial factor analysis with 35 variables showed an inadequate KMO value and poor convergent validity for 9 variables (Q17, Q18, Q22, Q27, Q33, Q37, Q42, Q43 and Q44) which were then removed from the instrument. The factor analysis was re-performed with the remaining 26 variables which included 18 variables adopted from

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Venkatesh et al and 8 original variables (Table 3). The KMO value for the data analysed was 0.77, the Bartlett's test for Sphericity was significant and communalities for all variables, except one variable (Q19) was greater than 0.6 (Table 3). These results confirmed that data were suitable to perform a reliable factor analysis.

Table 2: Characteristics of participants who responded to the questionnaire

	Pharmacy staff	Nursing staff
Gender, %		
Men	62.5	10.0
Women	37.5	90.0
Age category, %		
21 – 30	12.5	36.7
31 – 40	56.3	43.3
41 – 50	31.3	16.7
Highest education level, %		
Secondary school	-	3.3
Matriculation/	-	3.3
Additional training	37.5	13.3
Graduate	50.0	46.7
Postgraduate	12.5	33.3
Type of health care professional, %		
Pharmacist	18.8	NA
Senior dispenser	18.8	NA
Dispenser	56.3	NA
Other	6.3	3.3
Nursing officer (NO)	NA	10.0
Registered nurse (RN)	NA	76.7
Advanced practicing	NA	10.0
Number of years of experience at study		
0 – 5 years	12.6	40.0
6 – 10 years	37.5	13.3
11 – 15 years	31.3	19.9
16 – 20 years	18.8	16.6
Above 20 years	-	6.6
Previous years of experience in other		
0 – 5 years	56.3	73.3
6 – 10 years	37.7	19.9
11 – 15 years	-	6.6
16 – 20 years	6.3	-
Experience in using 2D bar-coding		
0 years	100.0	76.7
< 1 year	-	6.6
1-3 years	-	16.6

NA: Not applicable or no available data

Factor analysis extracted six constructs with an Eigen value greater ≥ 1 that explained 77.5% of variance in the original data. Factor loadings showed that variables strongly loaded to only one of the 6 constructs (Table 4). However, these constructs were not entirely similar to the pre-specified constructs. Variables that were intended to measure 'intention to use', 'quality of output' and 'results demonstrability' converged together and was renamed as 'attitude of output and intention to use' (AOIU) in this study. The construct AOIU was the most important construct as it explained a largest portion of the total variance (18.2%). The five variables that intended to assess 'perceived usefulness' (PU) strongly converged together representing the second construct and explained 15.5% of the total variance. Items that intended measure 'perceived ease of use' and 'perceived suitability of infrastructure' converged together and formed the third construct. As it was decided that the variables for 'perceived suitability of infrastructure' also assessed the ease of use, the third construct continued to be named as 'perceived ease of use' (PEOU) and explained 13.4% of the total variance. Variables that intended to assess 'subjective norm' and 'voluntariness' strongly loaded to make the fourth construct and was renamed as 'external influences' (EI). Variables that were intended to measure 'job relevance' (JR) loaded strongly to the 5th construct and variables intended to measure 'perceived adequacy of training' (PAT) loaded to the 6th factor. Constructs, 'external influences', 'job relevance' and 'perceived adequacy of training' explained 11.3%, 9.9% and 9.0% of the total variance, respectively.

Construct validity

Table 5 shows the range of variable correlations with their hypothesised construct and the scaling success of each construct after adjusting for overlap. All correlations were greater than 0.4 and only varied slightly within a construct. The largest variance was only 0.004 and was seen in the construct 'perceived usefulness'.

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Table 3: Variables used in the final instrument and their communalities after factor analysis

No	Variable name	Initial	Extraction
Q10	Assuming that I have access to the 2D bar-coding system, I intend to use it †	1.00	0.85
Q11	Given that I have access to the 2D bar-coding system, I predict that I would use it †	1.00	0.86
Q12	Using the 2D bar-coding system improves my performance in my job	1.00	0.78
Q13	Using the 2D bar-code system in my job increases my productivity †	1.00	0.80
Q14	Using the 2D bar-coding system enhances my effectiveness in my	1.00	0.79
Q15	I find the 2D bar-coding system to be useful in my job †	1.00	0.80
Q16	The 2D bar-coding system makes it easier to do my job*	1.00	0.76
Q19	My interaction (communication) with the 2D bar-coding system is clear and understandable †	1.00	0.52
Q20	Interacting with the 2D bar-coding system does not require a lot of my mental effort †	1.00	0.87
Q21	I feel that the 2D bar-coding system is easy to use †	1.00	0.65
Q23	It is easy to become skillful at using the 2D bar-coding system *	1.00	0.75
Q24	The infrastructure is suitable for the use of the 2D bar-coding system	1.00	0.74
Q25	The 2D bar-coding system does not interfere with other systems in my organisation*	1.00	0.73
Q26	The training I obtained on using the 2D bar-coding system is	1.00	0.73
Q28	I will/do not encounter technical problems when using the 2D bar- coding system*	1.00	0.75
Q29	People who influence my behavior think that I should use the 2D bar- coding system †	1.00	0.79
Q30	People who are important to me think that I should use the system †	1.00	0.79
Q31	My use of the 2D bar-coding system is compulsory †	1.00	0.72
Q32	My supervisor requires me to use the 2D bar-coding system †	1.00	0.70
Q34	In my job, usage of the 2D bar-coding system is important †	1.00	0.88
Q35	In my job, usage of the 2D bar-coding system is relevant †	1.00	0.83
Q36	Patient safety in enhanced by the 2D bar-coding system*	1.00	0.66
Q38	The output I get from the 2D bar-coding system is always relevant *	1.00	0.85
Q39	The output I get from the 2D bar-coding system is always useful *	1.00	0.85
Q40	I believe I could communicate to others the consequences of using the system †	1.00	0.82
Q41	The results of using the system are apparent to me †	1.00	0.86

*New variables;† Variables adopted from the Technical Acceptance Model (TAM) after slight modification[15]

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All correlations were significant. The scaling success was 100% for all constructs except two. The correlation of one variable (Q25) with the hypothesised construct ('perceived ease of use'), was not greater but equal to the correlation with another construct ('perceived usefulness'). Therefore, the scaling success for the construct 'perceived ease of use' was 96.7%. The correlation of the variable Q29 with its hypothesised construct (EI) was lower than the correlation with another construct ('job relevance') resulting in a drop in the scaling success of the construct, 'external influences' below 100%. However, all scaling rates were not less than 95%. These results confirm satisfactory convergent validity among the variables in each construct.

The loadings and cross loading of all variables are shown in Table 4. All variables loaded strongly to the hypothesised construct than other variables did to the same construct (cross loadings). Further, Spearman correlations of variables were stronger for the hypothesised construct (not adjusted for overlap) than with other constructs and were all greater than 0.70 (Table 6). Hence, results show satisfactory discriminant validity for the given factor structure.

Internal consistency

A Cronbach's alpha of greater than 0.7 is known to reflect good internal consistency.[31] The Cronbach's alpha for all constructs were 0.7 or above (Table 7) indicating good internal consistency of the instrument.

Intra-rater variability

Table 8 shows the results of the test-retest reliability of a sample of 8 participants who responded 3-4 days apart. The overall Intra-Class Correlation (ICC) was 0.89. The ICC for each construct ranged from 0.77 to 0.99, excluding the construct 'Job relevance' which showed poor intra-rater variability (ICC=0.192).

Discussion

The instrument

Bar-code technology can reduce dispensing and drug administration errors[1,2,3] but sometimes users may violate procedures that result in unintended or unanticipated errors.[5,6] Understanding the reasons behind rule violations is useful for system improvement. A validated instrument for assessing the attitudes of 2D bar-code users which may be used commonly on nursing and pharmacy staff was developed. The instrument is an extension of the TAM[14,15] and assesses six dimensions; attitudes of output and intention to use, perceived usefulness, perceived ease of use, job relevance, external influences and perceived adequacy of training.

The factor structure, validity and reliability

Most of the variables in the current instrument were adopted from the TAM with only slight modifications to suit the current context. The TAM and the extended version, TAM 2, have previously been thoroughly validated and used in many parts of the world in the field of information technology. Thus, the developed instrument was already based on a valid and reliable instrument. The reliability and validity of the current instrument was further strengthened in this study. The instrument included multiple variables to measure each constructs and demonstrated good internal consistency and satisfactory test-retest reliability. The dimensions extracted from factor analysis were not identical, but generally conformed to the factors in the TAM. Variables that demonstrated 'intention to use', 'results demonstrability' and 'quality of output' converged as expected but could not be discriminated into three factors as in the TAM. It is not surprising as all three dimensions address user's clarity about the overall outcome of using the technology and hence, their intention to use. 'Perceived ease of use' was merged with 'perceived suitability of infrastructure', as the two may be linked to infrastructural limitations and technical-noise which makes the 2D bar- coding system difficult to use. 'Subjective norm' and

Table 4: Factor loadings and cross loadings of variables in the 6 constructs extracted by factor analysis

	Construct loadings					
	AOIU	PU	PEOU	EI	JR	PAT
AOIU 1 (Q11)	**0.64**	0.58	-0.06	0.18	0.23	0.15
AOIU 2 (Q10)	**0.63**	0.59	-0.05	0.06	0.28	0.11
AOIU 3 (Q38)	**0.74**	0.02	0.31	0.21	0.33	0.23
AOIU 4 (Q39)	**0.73**	0.19	0.23	0.12	0.37	0.28
AOIU 5 (Q41)	**0.86**	0.11	0.30	0.07	0.06	0.08
AOIU 6 (Q40)	**0.83**	0.29	0.16	0.13	0.01	-0.09
PU 1 (Q12)	0.46	**0.62**	0.24	0.19	0.09	0.29
PU 2 (Q13)	0.02	**0.72**	0.48	-0.02	0.22	0.03
PU 3 (Q14)	0.21	**0.74**	0.27	0.21	0.14	0.24
PU 4 (Q15)	0.40	**0.62**	0.30	0.15	0.21	0.31
PU 5 (Q16)	0.26	**0.63**	0.44	0.09	0.26	0.16
PEOU 1 (Q19)	0.38	0.33	**0.50**	0.02	0.07	0.11
PEOU 2 (Q20)	0.08	0.38	**0.80**	-0.28	-0.03	-0.06
PEOU 3 (Q21)	0.21	0.10	**0.69**	00.16	0.29	0.09
PEOU 4 (Q23)	0.30	0.13	**0.58**	0.29	0.31	0.34
PEOU 5 (Q24)	0.24	0.35	**0.50**	0.17	0.10	0.52
PEOU 6 (Q25)	0.39	0.21	**0.58**	0.12	0.10	0.43
EI 1 (Q29)	0.34	0.30	0.20	**0.69**	0.06	0.23
EI 2 (Q30)	0.05	0.26	0.15	**0.83**	-0.02	0.03
EI 3 (Q32)	-0.001	-0.17	-0.03	**0.76**	0.30	-0.05
EI 4 (Q31)	0.25	0.10	-0.17	**0.70**	0.35	0.05
JR 1 (Q34)	0.16	0.42	0.15	0.24	**0.76**	0.15
JR 2 (Q35)	0.24	0.21	0.30	0.31	**0.73**	0.08
JR 3 (Q36)	0.39	0.19	0.24	0.29	**0.53**	0.22
PAT 1(Q26)	0.15	0.18	0.08	0.02	0.43	**0.70**
PAT 2 (Q28)	0.03	0.14	0.08	0.02	-0.01	**0.85**

AOIU, attitude of output and intention to use; PU, perceived usefulness; PEOU, perceived ease of use; EI, external influences; JR, job relevance; PAT, perceived adequacy of training

Table 5: Spearman variable-construct correlations

Construct	# of variables in each construct	Correlations*	Variance	Scaling success rate¥
AOIU	6	0.83 – 0.76	0.001	100.0%
PU	5	0.80 – 0.64	0.004	100.0%
PEOU	6	0.69 – 0.60	0.001	96.7%
EI	4	0.64 – 0.54	0.002	95.0%
JR	3	0.82 – 0.71	0.003	100.0%
PAT	2	0.50	-	100.0%

* Spearman correlations between variable and hypothesised construct after adjusting for overlap; ¥ Scaling success is achieved when the correlation between variable-hypothesised construct is greater than the correlation between the variable and other competing constructs. The scaling success rate is the percentage of total number 0f comparisons for all the variables in each construct that were successful AOIU, attitude of output and intention to use; PU, perceived usefulness; PEOU, perceived ease of use; EI, external influences; JR, job relevance; PAT, perceived adequacy of training

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Table 6: Comparison of Spearman correlation between variable and hypothesised construct with correlation between variable and competing construct (not adjusted for overlap)

	Spearman correlations					
	AOIU	**PU**	**PEOU**	**EI**	**JR**	**PAT**
AOIU 1 (Q11)	**0.85***	0.60*	0.38*	0.36*	0.57*	0.23
AOIU 2 (Q10)	**0.85***	0.64*	0.45*	0.38*	0.63*	0.28
AOIU 3 (Q38)	**0.81***	0.43*	0.52*	0.39*	0.59*	0.24
AOIU 4 (Q39)	**0.87***	0.54*	0.50*	0.34*	0.65*	0.36*
AOIU 5 (Q41)	**0.85***	0.44*	0.54*	0.26	0.50*	0.22
AOIU 6 (Q40)	**0.84***	0.49*	0.44*	0.32*	0.53*	0.19
PU 1 (Q12)	0.65*	**0.86***	0.58*	0.29	0.55*	0.38*
PU 2 (Q13)	0.35*	**0.77***	0.59*	0.13	0.42*	0.28
PU 3 (Q14)	0.48*	**0.86***	0.55*	0.25	0.50*	0.30*
PU 4 (Q15)	0.65*	**0.87***	0.65*	0.26	0.65*	0.45*
PU 5 (Q16)	0.52*	**0.82***	0.65*	0.19	0.54*	0.36*
PEOU 1 (Q19)	0.58*	0.59*	**0.78***	0.22	0.37*	0.27
PEOU 2 (Q20)	0.27	0.54*	**0.77***	-0.18	0.18	0.14
PEOU 3 (Q21)	0.46*	0.52*	**0.83***	0.32*	0.47*	0.26
PEOU 4 (Q23)	0.44*	0.49*	**0.76***	0.40*	0.56*	0.30*
PEOU 5 (Q24)	0.43*	0.62*	**0.74***	0.22	0.43*	0.53*
PEOU 6 (Q25)	0.51*	0.63*	**0.72***	0.22	0.49*	0.41*
EI 1 (Q29)	0.50*	0.49*	0.41*	**0.71***	0.55*	0.27
EI 2 (Q30)	0.30*	0.33*	0.29	**0.76***	0.43*	0.14
EI 3 (Q32)	0.14	-0.01	0.06	**0.83***	0.32*	0.06
EI 4 (Q31)	0.29	0.13	0.05	**0.75***	0.44*	0.04
JR 1 (Q34)	0.64*	0.59*	0.43*	0.52*	**0.90***	0.40
JR 2 (Q35)	0.57*	0.57*	0.50*	0.55*	**0.90***	0.31*
JR 3 (Q36)	0.56*	0.51*	0.43*	0.37*	**0.88***	0.23
PAT 1(Q26)	0.43*	0.40*	0.41*	0.24	0.46*	**0.89***
PAT 2 (Q28)	0.12	0.28	0.24	0.02	0.09	**0.81***

* Significant at least $P<0.05$

AOIU, attitude of output and intention to use; PU, perceived usefulness; PEOU, perceived ease of use; EI, external influences; JR, job relevance; PAT, perceived adequacy of training

Table 7: Internal consistency of the constructs

Construct	Cronbach's alpha	Variable	Corrected variable – Total correlation	Cronbach's alpha if variable deleted
AOIU	0.9	AOIU 1	0.81	0.91
		AOIU 2	0.78	0.92
		AOIU 3	0.79	0.92
		AOIU 4	0.85	0.91
		AOIU 5	0.76	0.92
		AOIU 6	0.79	0.92
PU	0.9	PU 1	0.80	0.90
		PU 2	0.72	0.91
		PU 3	0.80	0.90
		PU 4	0.81	0.89
		PU 5	0.81	0.89
PEOU	0.9	PEOU 1	0.65	0.84
		PEOU 1	0.58	0.86
		PEOU 2	0.64	0.85
		PEOU 3	0.72	0.83
		PEOU 4	0.71	0.84
		PEOU 5	0.70	0.83
EI	0.8	EI 1	0.62	0.77
		EI 2	0.66	0.75
		EI 3	0.61	0.77
		EI 4	0.65	0.76
JR	0.9	JR 1	0.79	0.80
		JR 2	0.81	0.80
		JR 3	0.71	0.88
PAT	0.7	PAT 1	0.52	-
		PAT 2	0.52	-

AOIU, attitude of output and intention to use; PU, perceived usefulness; PEOU, perceived ease of use; EI, external influences; JR, job relevance; PAT, perceived adequacy of training

(240.)

Table 8: Intra-class correlations of constructs

Construct	Interclass correlation	95% confidence Interval	
		Lower	Upper
AOIU	0.954	0.768	0.991
PU	0.937	0.674	0.987
PEOU	0.774	-0.090	0.955
EI	0.991	0.995	0.998
JR	0.192	-6.219	0.851
PAT	0.753	-0.386	0.952
Total	0.894	0.470	0.979

AOIU, attitude of output and intention to use; PU, perceived usefulness; PEOU, perceived ease of use; EI, external influences; JR, job relevance; PAT, perceived adequacy of training

'voluntariness' also combined together as all relevant variables reflected external influences on using the 2D bar- coding system. The variables that assessed 'perceived usefulness', 'job relevance' and 'perceived adequacy of training' were extracted with excellent convergent and discriminant validity as in the TAM. For 2D bar-code users, 'perceived usefulness' explained the usefulness of the technology in enhancing user performance.

Applications of the instrument

Establishing a 2D bar-code system in a hospital is costly but a good investment[34] if accepted by users and correctly used. The developed instrument may be used to gain a general understanding of user attitudes towards thebar-code system before implementation, so that systems may be designed in a user-friendly way. The instrument may also be used as a tool for continuous improvement. For example, decreased perceived usefulness would indicate that users do not benefit from using the system in their daily work or decreased perceived ease of use could indicate difficulties in using the system. If such issues are identified and corrected, users will not look for workarounds. However, the current instrument does not assess specific areas of using the technology and therefore it lacks the ability to identify the causes for changes in attitudes. In contrast, the MAS-NAS focus on specific details related to using bar-codes in drug administration but it cannot be used among other types of bar-code technology users.[12,35]

Limitations of the study

There are some limitations to this study. The instrument was only validated in one setting as opposed to multiple settings which would have improved the generalisablity of the instrument. Secondly, the sample of responses used in factor analysis is smaller than the commonly accepted norm in factor analysis. However, experts argue that common rules of thumb regarding sample size per-se is not valid or useful in determining the suitability of a data set for factor analysis.[25] They argue that, if all variables have high communalities (>0.6) and factors are well determined, the effect of small sample size and other aspects of design are greatly reduced and a good recovery of population factors can be achieved.[25] In this study, all except one variable had communalities greater than 0.6 with a valid and reliable factor structure suggesting that the small sample size would have had minimum effects on our findings. The validity and reliability of this instrument is further strengthened because most of the variables are adapted from a previously validated and widely used instrument (TAM).[14,15] A limited number of participants stated that they had prior experience in using the 2D bar-code system while the majority stated that they had no previous experience in using this technology. As responses from both groups were anlysed together a cetain degree of bias may be expected. However, given the small sample size, separate analysis of the two groups were not done. Besides as stated in the methods section, all participants had prior experience in using linear bar codes and all of them underwent a training on using the 2D bar code system prior to administering the tool.

Another limitation is that correlation of the constructs and actual usage of the system was not observed nor obtained as self-reported estimates after implementing the technology. Thus we could not establish the correlation between the constructs of the instrument and actual usage of the system.

Conclusion

A valid and reliable instrument to measure attitudes of pharmacy and nursing staff on using 2D bar-code technology was developed as an extension of the TAM. This instrument may be used to assess user attitudes before implementing the 2D bar-coding technology or for continuous improvement of the system.

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