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Determinants of Friendly Digital Library Interfaces in Information Retrieval by Persons with Visual Impairments in Kenya

By

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Abstract
The access to and retrieval of information from digital libraries (DL) by persons with visual impairments promotes their inclusion and participation in academic and research activities. This paper sought to evaluate determinants of friendliness of digital library interfaces by persons with visual impairments to inform appropriate interface design to enhance accessibility and functionality and promote pragmatic student preparation for tertiary education levels in Kenya. Data was collected from 117 students with visual impairments from selected public universities in Kenya between September and October 2019. A structured questionnaire with 11 test items adapted from the System Usability Measurement Inventory (SUMI) was used collect the data on friendliness of digital library interface. Principal Component Analysis was used to construct a DL index based on extraction of eigenvalues and factor loadings. Descriptive analysis and logistic regression model were used to model selected demographics such as sex, age, nature or type of visual impairments, year of study and status in prior training in assistive technology (At) as determinants of friendliness of digital libraries (DL) interface. The study shows that the type of visual impairments and prior training in AT and significant predictors of reported friendliness of DL interface. The study concludes that effective and efficient information retrieval from digital libraries (DL) by persons with visual impairments is a product of both system design that enhances accessibility and functionality, and personal attributes such as proficiency in technology which is best achieved in training in AT. The study recommends mainstreaming provision of assistive technology for persons with visual impairments as a requisite for tertiary education in Kenya.

Key words: Digital Libraries interface, Functionality, Accessibility, Assistive Technologies

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1.0 Introduction

Information access, retrieval and utilization plays key roles in the contemporary information age and society and are drivers towards knowledge-based economy (Mallik & Bera, 2021). Digital libraries become crucial in obtaining and utilization of information for academic, research, social and economic purposes among others (Babu & Xie, 2017; Moorthy et al., 2019). This provides evidence that for one to be abreast with the fast-paced contemporary academic lifestyle, one need to be quick at retrieving and utilizing information from available digital platforms. Whilst information retrieval is core to all in this era, persons with visual impairment are susceptible to exclusion from full utilization of digital content due to the limiting interfaces of information retrieval systems (Xie et al., 2020). This paper sought to explore determinants of friendliness of digital library interfaces for students with visual impairments in selected public universities in Kenya. The study was delimited to students with visual impairments who access the digital content by means of screen readers and screen magnifiers.

2.0 Statement of the Problem

Despite advances in educational technology that has led to efficient access to information, persons with visual impairment still experience difficulties when using digital libraries. Whilst there is a lot of empirical research on usability of digital library by persons with visual impairments, there still exist knowledge gaps regarding friendliness of a digital library interface as a core usability attribute that hinders both access and information retrieval by persons with visual impairments. This study sought to establish determinants of friendly digital library interface by persons with visual impairments user experience.

3.0 Review of Related Literature

Significant amount of research demonstrates that the blind and visually impaired (BVI) students experience vulnerabilities in accessing digital library (DL) platforms (Arif & Kanwal, 2009; Matusiak, 2012; Xie et al., 2020). Latest research suggests that such difficulties are largely attributable to limitations in DL's design that prevent BVI from effectively interacting with features and subsequently the content (Xu & Du, 2019; Xie et al., 2020). However, most of this evidence are drawn from outside Sub-Saharan African countries. In this regard, there is need to integrate drivers of friendly digital interface platforms in the African context. One of the reasons why such a research initiative is core is the fact that measurement of visual impairment varies across different regions and countries of the world (Papadopoulou et al., 2020). Despite adoption of the Washington Group of Tools by different countries in measuring disabilities such as visual impairments, there still exists discrepancy in the consistency of disability statistics within and between countries. This situation poses a challenge to domesticate research evidence from other parts of the world in the Kenyan situation.

A Digital Library (DL) that does not allow effective access to information and subsequent retrieval by a person with visual impairment can be described as one with an unfriendly user interface. In this study, we describe a friendly digital interface as one that

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increases access to the content, improves navigability through the system and consequently makes information retrieval successful (Rodriguez & Carver, 2019). When the needs of all users regardless of their disability are met in the design of an information retrieval system such as a digital library, significant steps are achieved towards an inclusive information society in which access to information, its retrieval and use are key. Universal design of digital library interface accounts for all individual differences in the access to content and navigation.

Friendliness is an important attribute of usability. As such friendliness of a digital library interface refers to the degree to which the interface minimizes the efforts employed by the user and at the same time maximizing the results these users get from the digital library in relation to expected results (Matusiak, 2012). According to Arif and Kanwal (2009), digital library users are not experts in using the computers and internet. Therefore, developers of the digital library interface should make it easy to understand for every user, i.e., whether novice or expert users of the digital library interface. Matusiak, (2012) describes a friendly interface as one that is easy to use, one that has well-organized information, clear labelling, attractive visual appearance, and appropriate content.

Persons with visual impairment form part of the digital library users in the quest to meet their information needs. Their inclusion, therefore in the design of user-friendly digital library interfaces is critical. Various studies have been conducted globally emphasizing on the need for user-friendly interface for successful information retrieval venture. Dodamani and Dodamani (2019) conducted a usability study in India that focussed on the friendliness of digital libraries for students with visual impairments. Out of the 20 students who participated in the study only 22.7% perceived the digital library as being friendly. The key indicator of unfriendliness was the fact that they needed guidance every time they wanted to use the digital library.

Persons with visual impairments enjoy studying and learning when technology is usable and friendly to them. This is according to Malaysian research conducted by Bodaghi and Zainab, (2017) regarding user friendliness of digital library. The study focused on perceptions and experiences of students with visual impairments in accessing digital libraries while using computers located in the university library carrels. It was found out that, the friendly library technologies gave students with visual impairments a sense of belonging to the learning community due to increased independence in information seeking without much reliance on external support (Bodaghi & Zainab, 2017; Li & Liu, 2019).

4.0 Research Methodology

4.1 The Data

The data used to analyse determinants of friendly digital library interfaces was extracted from the author's PhD dissertation on "Usability of Digital Libraries in Information Retrieval by Persons with Visual Impairment in Selected Public Universities in Kenya". The data was collected using a questionnaire adapted from the System Usability Measurement Inventory (SUMI) by Kirakowski and Corbett (1993) which is a known standard usability tool. Test items of SUMI were reversed coded on a Five-point scale where 1=Strongly Agree, 2=Agree, 3=Not Sure, 4=Disagree and 5=Strongly Disagree. As such, a high mean score indicate that majority of respondents disagreed with the statement while a small mean score suggest that majority of respondents agreed with the statement (*See Table 2*). The data was collected from 117 students with visual impairments from three public universities in Kenya, 95% were undergraduate and 5% were graduate students.

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4.2 Computation of Digital Library Friendliness Index

We applied Principal Component Analysis (PCA) to generate an indicator of friendliness of digital library interface based on 11 test items on SUMI's standard usability tool (Kirakowski & Corbett, 1993). The indicators of friendliness of digital library according to the questionnaire used include; ability to log in and out of the digital library, using the right function when required, clarity of system instructions, disruption resulting from the use of digital library system, the feeling of being in command of digital library, preference to stick to familiar functions, understanding page layout in digital library, perceived straight forwardness of digital library tasks, logical organization of menus, the ease of navigation in the digital library system, and difficulties in files in digital library.

The PCA is a multivariate statistical method used to reduce the dimensionality of predictor variables in a predictive model without losing critical information. The PCA reduces the number of variables by linearly combining the original variables to create fewer new uncorrelated variables. The first among the variables accounts for most of the variations, while the last among the new variables explains the least variations in the original dataset.

Given the variables $(X_1, \dots, X_p)$ as predictors in the original dataset measured on a sample n, PCA creates p uncorrelated principal components $(Z_1, \dots, Z_p)$which are all linear combination of the original variables in the dataset defined by Fallat and Mojallal (2021) as.

$$Z_i = a_{ij}X_i + \cdots + a_{ip}X_p, \qquad i = 1, 2, 3, \dots, p$$

The Z_i is a system of equations which can be expressed as a matrix of the form $\boldsymbol{z} = \boldsymbol{Ax}$ where $\boldsymbol{z} = (Z_1, \dots, Z_p)$, $\boldsymbol{x} = (X_1, \dots, X_p)$ and $\boldsymbol{A}$ is a $p \times p$ matrix of coefficients. The coefficients of the first principal component $(a_{11}, \dots, a_{1p})$ are selected by the PCA in such a way that the first component Z_1 is maximum subject to the condition $a_{11}^2 + \cdots + a_{1p}^2 = 1$. The variance of the first component Z_1 is equivalent to the largest eigenvalue of the matrix $\boldsymbol{A}$ denoted as λ_1. The second component Z_2 explains additional but less variations not accounted for by the first component and its variance will be given by the second largest eigenvalue of the matrix $\boldsymbol{A}$ denoted as λ_2. Similar iteration is observed for all the components up to component Z_p which explains the least of the variations in the original dataset. Table 1 presents a summary of PCA summary statistics based on eigenvalues and factor loadings.

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Table 1: Principal Component Score

Component	Total Variance Explained					
	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.22	20.19	20.2	2.2	20.2	20.2
2	1.59	14.44	34.6	1.6	14.4	34.6
3	1.47	13.40	48.0	1.5	13.4	48.0
4	1.04	9.41	57.4	1.0	9.4	57.4
5	0.88	7.98	65.4			
6	0.81	7.34	72.8			
7	0.74	6.76	79.5			
8	0.67	6.13	85.7			
9	0.60	5.41	91.1			
10	0.52	4.72	95.8			
11	0.46	4.21	100.0			

Source: Field Data, 2020

Extraction Method: Principal Component Analysis

The results from PCA presented in Table 1, the first principal component (PC) explains 20.2% of the total variation in the original dataset, the first and second PC cumulatively explain 34.6% of total variation and each subsequent component explains less and less variations. In the creation of the digital library friendliness index, only four factor scores (that is the eigenvalues) of the first principal component were used. The four PC used to model friendliness of digital libraries (DL) was based on 57.4% of the variability of the total variations in the original dataset. The decision to use 4 PC to establish friendliness of a DL was based on the description of index construction by Fallat and Mojallal (2021) who contends that for a graph G, we associate a family of real symmetric matrices, $S(G)$, where for any $A \in S(G)$, the location of the nonzero off-diagonal entries of A are governed by the adjacency structure of G. Let $q(G)$ be the minimum number of distinct eigenvalues over all matrices in $S(G)$ (Fallat & Mojallal, 2021, p.5).

4.3 Logistic Regression Model

To identify key determinants of friendliness (FDL) we first computed a binary variable that indicates whether the respondents perceive the interface of a digital library as friendly or unfriendly. That is.

$$FDL = \begin{cases} 1, & \text{if DL system is perceived as friendly} \\ 0, & \text{if DL system is perceived as unfriendly} \end{cases}$$

such that FDL is the indicator variable of friendliness of digital library interface.

Based on Pearson's Chi-square statistic, we determine whether sex, age, nature of visual impairment (blind or low vision), year of study and prior training in assistive technology were associated with respondent's indication of the level of friendliness of DL system.

4.4 Ethical Considerations

The identifiers of study participants and their affiliate universities were removed from the dataset and replaced with pseudocodes to adhere to confidently standards. Informed consent

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form approved by Kenya's National Commission for Science, Technology, and Innovation (NACOSTI) was signed before commencement of data collection exercise, and respondents were made aware that they could skip any question that they felt uncomfortable to respond to or stop the interview without any consequences. The authors adhered to the highest scientific principles in data collection, processing and remained impartial in reporting the findings of the study.

5.0 Results and Discussions

5.1 Descriptive Analysis of Indicators of DL Friendliness Index

Table 2 shows all descriptive statistics of variables used in the creation of digital library friendliness index with items presented in descending order of magnitude where the highest mean score showing the most disagreed statement at the top and the most agreed statement with the least mean score at the bottom.

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Table 2: Descriptive Analysis of individual Measures of DL friendliness

	N	Mean	Std Error	[95% CI]	
1. I can log in and out of the digital library	117	3.77	0.116	3.54	4.00
2. I sometimes wonder if I am using the right function	117	2.92	0.125	2.68	3.16
3. I do understand the information as presented in the digital library pages	117	2.68	0.118	2.45	2.91
4. The way information is presented is clear and understandable	117	2.66	0.118	2.43	2.89
5. When using the digital library, I get disrupted the way I normally like to arrange my work	117	2.62	0.128	2.37	2.87
6. I feel in command of the digital library when I am using it	117	2.61	0.124	2.37	2.85
7. I can perform tasks in a straightforward manner using the digital library	117	2.60	0.118	2.37	2.83
8. The organization of the menus seem quite logical to me	117	2.59	0.116	2.36	2.82
9. I find easy to move from one part of a task to another in the digital library	117	2.56	0.126	2.31	2.81
10. I find it difficult to get data files in and out of the digital library	117	2.48	0.127	2.23	2.73
11. I prefer to stick to the functions that I know best	117	2.33	0.102	2.13	2.53

Source: Field Data, 2020

The results show that majority of BVI students are not able to log in and out of digital library (*M=3.77, SE=0.116).* This finding suggests that there are significant accessibility challenges of the digital library systems for students with visual impairment. Over 77% of those who reported that they cannot log in and out of the system also reported that they have no difficulties using the right functions (*M=2.92, SE=0.125*). Clearly, this result shows that even students with visual impairments who are proficient in the use of computers (or digital gadgets in general) may be hindered by inaccessible digital interface. As a result of this inaccessibility this study found that majority of BVI students (*M=2.68, SE=0.118; Mean=2.66, SE=0.118*) reported that information and pages are not presented in clear and understandable manner.

About half of study participants reported that when using digital library, they get disrupted the way they normally like to arrange my work (*M=2.62, SE=0.128*), some reported that they felt to have sufficient command of the digital library after successfully logging in

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(*M=2.61, SE=0.124*) and also a significant number reported that they can perform tasks in a straightforward manner using digital library (*M=2.60, SE=0.118*). Clearly, these results show that 1 in 2 BVI students interviewed can use digital library productively for their academic and research work. However, the greatest challenge is experienced at the access level to the level, perhaps suggesting high instances of inaccessible digital library interfaces in most of public university libraries is Kenya.

Further, this study established that a much smaller number of study participants (*less than half*) agreed that the organization of the menus in the digital library seem quite logical to them (*M=2.59, SE=0.116*). This result suggests that BVI often experienced difficulties figuring out the flow of ideas and issues presented in the digital library menus. The study found that almost all of those who reported that menus were not logically arranged also found it difficult moving from one part of a task to another in the digital library (*M=2.56, SE=0.126*). The results reinforce the need for accessible digital layout and content to maximize their usability. It was found that 2 in 3 BVI students find it difficult to get data files in and out of the digital library (*M=2.48, SE=0.127*). As used in this study, obtaining useful information from a digital library is typical information retrieval. As such, it can be concluded that less than 30% of BVI students in public universities in Kenya are able to independently retrieve information from digital libraries. Almost all, BVI students reported that they prefer to stick to the functions that they know best (*M=2.33, SE=0.102*). This suggests that regardless of the level of individual proficiency in using technology, most BVI students could be sceptical in exploring possible alternatives to get around challenges they face in retrieving information from digital libraries.

3.2 Friendliness of DL with Selected Demographic Data

This section presents friendliness of digital library cross-tabulated by; sex, age, nature of visual impairment (*blind or low vision*), year of study and prior training in assistive technology. Table 3 presents a summary of cross-tabulation results between DL friendliness and demographic information.

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Table 3: Cross-Tabulation Analysis of Friendliness of DL with Selected Demographics

Demographic	Not Friendly	Friendly	Total
Sex			
Male	76.1%	22.4%	55.8%
Female	81.1%	15.1%	44.2%
Age (Years)			
18 - 25	81.1%	18.9%	81.2%
26 - 35	80.0%	20.0%	12.8%
36 -45	80.0%	20.0%	4.3%
Above 45	50.0%	50.0%	1.7%
Nature of VI			
Blind	95.8%	4.2%	20.5%
Low Vision	76.3%	23.7%	79.5%
Year of Study			
Year 1	83.3%	16.7%	20.7%
Year 2	81.8%	18.2%	37.9%
Year 3	76.9%	23.1%	22.4%
Year 4	81.3%	18.8%	13.8%
MSc/PhD	66.7%	33.3%	5.2%
Training in Assistive Technology			
No prior training	88.7%	11.3%	45.3%
Has prior training	73.4%	26.6%	54.7%

Source: Field Data, 2020

The results show that 55.8% of study participants out of whom 22.4% reported that digital library interfaces are friendly to them compared to 15.1% of their female counterparts. At least 81% of study participants were aged between 18 and 25 years and only 18.9% of them reported that digital library interfaces are friendly to them. The results show that 20.5% of study participants were blind out of whom only 4.2% reported that digital library interfaces are friendly to them compared to 23.7% of those with low vision. This implies that 20.3% of students who are blind perceive DL interface as friendly compared to 29.8% of those who are low vision. This result shows a 9.4% difference in magnitude between those who are blind and those with low vision regarding their perception of a friendly DL interface.

The study shows that 20.7% were first year students only 16.7% reported that DL interface was friendly and 83.3% said it was not friendly. This shows that a higher proportion of first year students found DL interface to be unfriendly. Similar trend is observed for all students in different years of study where majority of the BVI students found DL interface to be less friendly. The study found that 45.3% of participating students had no prior training in assistive technology while more than half at 54.7% had some prior training in assistive technology. From the results, it can be deduced that 3 in 4 (75%) of students who have no prior training in assistive technology reported that DL interface was unfriendly which is significantly higher compared to there counterparts with prior training. For those with prior training in assistive technology, about 2 in 4 (51%) found DL to be less friendly.

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5.3 Logistic Regression Analysis

The final logistic model that was used to fit the data was

$$\text{logit}\ (p) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \varepsilon$$

where p was probability of rating DL interface as friendly [p=1] relative to rating a DL interface as not friendly [p=0], X_1 is sex, X_2 is age, X_3 is nature of visual impairment, X_4 is year of study and X_5 is prior training in assistive technology and results presented in Table 4.

Table 4: Logistic Regression Summary of determinants of friendliness of DL

	Coef.	Std. Err.	z	p>|z|	[95% conf.	Interval]
Sex	-0.38	0.52	-0.73	0.47	-1.39	0.64
Age	0.56	0.49	1.13	0.26	-0.41	1.53
Number of VI	2.44	1.10	2.22	0.03	0.29	4.60
Year of study	-0.02	0.27	-0.09	0.93	-0.56	0.51
Training in assistive technology	1.41	0.56	2.54	0.01	0.32	2.50
Constant	-7.57	2.75	-2.75	0.01	-12.96	-2.18

Source: Field Data, 2020

The distributions of perceived friendliness of digital library interface are significantly explained by individual's nature of visual impairments (*p=0.026*), and prior training in assistive technology (*p=0.011*). These results further support our earlier findings that there were more students with low vision who reported that DL interface was friendly compared to their counterparts who were blind. Similarly, there was a significantly higher proportion of students with prior training in assistive technology who reported that DL interface was friendly compared to their counterparts without such training. On the other hand, perception of a friendly digital library friendliness is independent of individuals' Sex (*p=0.468*), age (*p=0.257*), and year of study (*p=0.929*).

From the above results, we can conclude that provision of training in assistive technology to BVI students as part of early intervention can increase their aptitude in information retrieval, thus making them more productive academic and professionals regardless of their sex, age, and level one is in their academic ladder. In so doing, however, the training ought to be tailored differently to suit the needs of those who are blind and those with low vision. Whilst both the blind and low vision constitute individuals with visual impairments, this study has shown that there are differences in how they access digital content, hence training in assistive technology ought to be designed to suit individual needs. To further examine variations in students' perceptions of a friendly digital library interface, a marginal effects model was conducted, and results presented in Table 5.

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Table 5: Marginal Effects Model after logit

Characteristic	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
Sex						
Male	0	*Reference*				
Female	-0.06	0.08	-0.72	0.47	-0.22	0.10
Age (Years)						
18 - 25	0	*Reference*				
26 - 35	0.04	0.13	0.33	0.74	-0.21	0.29
36 -45	0.16	0.24	0.68	0.50	-0.31	0.63
Above 45	0.42	0.37	1.13	0.26	-0.30	1.14
Nature of VI						
Blind	0	*Reference*				
Low Vision	0.25	0.10	2.65	0.01	0.06	0.45
Year of Study						
Year 1	0	*Reference*				
Year 2	-0.01	0.1	-0.07	0.95	-0.21	0.19
Year 3	0.04	0.11	0.32	0.75	-0.17	0.25
Year 4	-0.04	0.15	-0.28	0.78	-0.33	0.25
MSc/PhD	-0.01	0.25	-0.05	0.96	-0.50	0.48
Training in Assistive Technology						
No prior training	0	*Reference*				
Has prior training	0.18	0.08	2.39	0.02	0.02	0.34
Constant	-0.10	0.12	-0.80	0.43	-0.33	0.13

Source: Field Data, 2020

The results show that female students with VI are 0.055 (6%) less likely to find DL interface friendly compared their male counterparts VI. The Pearson's p-value confirms that whilst there is a difference between male and female BVI regarding friendliness of DL, the results suggests that this difference is statistically insignificant (*p>0.47*). This implies that individual sex (male or female) alone is not a determinant of individual perception of friendliness of a DL interface. The findings of our study concur with a recent study conducted by Stecz et al (2021) to determine the characteristics of the variables associated with gaming for adolescents with visual impairments.

The study found that whilst there are many sociodemographic variables that are important in predicting gaming prevalence, sex was not found to be a strong predictor of gaming behaviour among students with visual impairments. The results show that BVI students aged between 26 and 35 years, 36 and 45 years, and above 45 years are 4%, 16% and 42% more likely to report that DL interface are friendly compared to those aged between 18 and 25 years old. These results may give the impression that the likelihood to report a friendly DL interface increases with student age, these results are not statistically significant as shown by the Pearson's P-value (*p=0.74>0.05, p=0.50>0.05* and *p=0.26>0.05*). Our results concur with a recent study by Moon et al (2020) that sought to investigate factors influencing adoption of mobile applications by persons with visual impairments. The study found that accessibility and functionality are the most significant factors influencing adoption of mobile apps by persons with visual impairments compared to age and other demographic factors. The results show that students with low vision are 25% more likely to rate a DL interface as

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friendly compared to their counterparts who are blind. The Pearson's p-value ($p=0.01<0.05$) confirms that this difference is statistically significant. This implies that the type or nature of visual impairment affects significantly how a person determines what a friendly DL interface is. For better intervention, there is need to individually consider determinants of friendly DL interface for the blind and for the low vision to respond to their specific design requirements. There is little evidence from previous empirical research that presents similar or contrary evidence regarding the blind and those with low vision.

The results did not find any significant association between student's year of study and their style of reporting on friendliness of DL interface. A plausible reason for this kind of results could be that given diverse backgrounds of students, it is not necessarily true that the more time an individual spends in school the more they become they find systems friendly. Whilst it may be possible that the longer one stays in schools the more proficient, they become in using technology, the system design difficulties may persist over time. Finally, the results show that students with prior training in assistive technology (AT) were 18% more likely to report that DL interface was friendly compared to their counterparts without prior training in AT. This difference is found to be statistically significant at 95% confidence level based on the Pearson's p-value ($p=0.02<0.05$). This implies that providing prior training in AT can significantly improve BVI's aptitude in overcoming accessibility difficulties that come with the DL interface design.

6.0 Conclusion and Recommendations

The access to and retrieval of information from digital libraries by persons with visual impairments promotes their inclusion and participation in academic and research activities. In the last decade, a lot of research has been ongoing to enable universal design of digital library interface that presents barrier free access to digital content. This study found that with design of digital library interface that enhances accessibility and functionality for all, persons with visual impairments can retrieve digital content independently. Additionally, the study found that the design ought to account for specific needs of users who are blind and those with low vision, clearly demarcating them as persons with distinct usability requirements, rather than assuming that they are all persons with visual impairments. Finally, provision of prior training in assistive technology plays a critical role in lessening the struggle brought about by poorly designed DL interfaces. This study therefore recommends mainstreaming provision of assistive technology for persons with visual impairments as a requisite for tertiary education in Kenya.

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