

## Investigating the Impact of Interface Metaphors on Mobile Cognitive Load and Satisfaction in Elderly Chinese Users

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**Abstract:** This empirical study investigates the impact of interface metaphorical factors on the cognitive load and satisfaction of 506 elderly mobile interface users in Shanxi, China. Direct, indirect, and abstract metaphors were examined through a specialized scale-based survey and statistically analysed. The results revealed pronounced effects of direct metaphors in mitigating cognitive load. Moreover, abstract metaphors increase cognitive effort for most seniors.

**Keywords:** elderly people in Shanxi, China; interface metaphor; cognitive load; satisfaction; user experience; technology experience

## 1. Introduction

With the increasing integration of technology into the lives of elderly people, examining age-specific usage barriers has become imperative. Notably, cognitive load poses a significant challenge, necessitating a focused exploration of its impact on older adults' technology experience. Our study centres on the unique needs of older adults in Shanxi, China, to fill critical gaps in our understanding of these challenges by examining the impact of interface metaphors on cognitive load, satisfaction, and user experiences.

With our innovative metaphor design approach, we recognize enduring issues in human-computer interactions for older adults. By leveraging real-world concepts, we provide a novel perspective on mitigating cognitive load and enhancing overall satisfaction with mobile interfaces. We pose the following key research questions:

How do different types of interface metaphors impact the cognitive load of older adults in Shanxi, China?

What variations in satisfaction and user experiences emerge based on these metaphors?

Are there discernible differences in the effects of interface metaphors on cognitive load and satisfaction considering the varying levels of technical experience among older adults in this region?

In addition to building upon established literature, we draw insights from recent studies, including recent research by Li and Luximon (2023), investigating the impact of interface metaphors on older adults' mental models during mobile navigation. Their findings suggest that metaphors enhance navigation, particularly for individuals with faster perceptual speed, considering factors such as task complexity and technology experience.

Insights from a study by Zhou et al. (2017) on metaphors for elderly interfaces, specifically concrete metaphors, reveal their effectiveness in enhancing user experiences. In a 9-day experiment, a communication application with concrete metaphors demonstrated superiority over abstract metaphors, leading to fewer errors, greater usage intention, increased satisfaction, and lasting advantages.

These research questions serve as critical probes for unexplored territories, addressing the specific gaps in current knowledge regarding the nuanced relationship between interface metaphors and the technology experiences of older adults. By delving into these questions, our study aspires to provide new insights that directly contribute to the refinement of interface design strategies tailored to the elderly population in Shanxi, China.

## 2. Literature Review

People's cognitive load is influenced by a variety of factors, including physical and cognitive level, experience and knowledge level, technology acceptance, and digital rejection. (Minkley, N., et al.,2021). These factors are interrelated, and their impact may depend on each other. The aim of this study was to explore the responses and preferences of older adults when confronted with a mobile interface with a metaphorical design. By using a questionnaire as a data collection tool, the views, attitudes and experiences of older adults were collected to understand their perceptions and acceptance of interfaces with metaphorical design. The following section discusses the relevant rationale and hypothesis development, as shown in Figure 1.

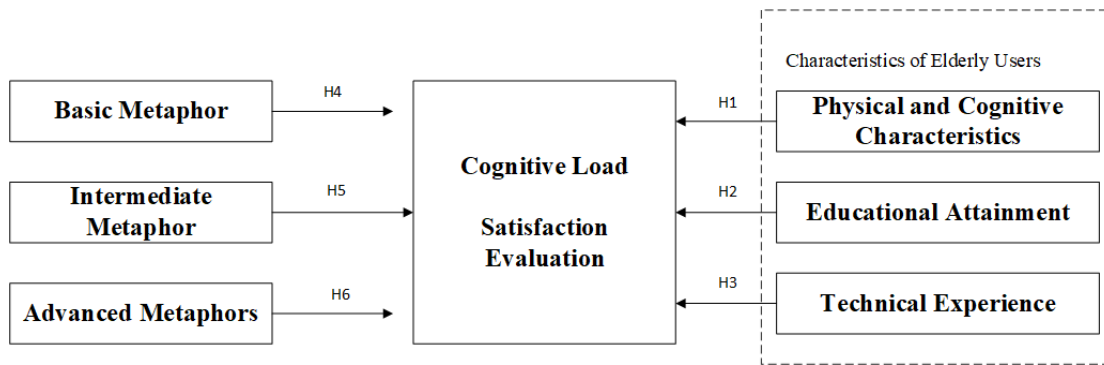


Fig.1: Hypothesis development for this study

## 2.1. Overview of Cognitive Load Research on Older Adults

Older adults face multiple challenges in smartphone interaction interface design, including visual, cognitive, and manual dexterity issues. These challenges affect their willingness and ability to use smartphones; thus, special attention needs to be paid to considering their specific needs in design (Petrovčič et al., 2018).

(1) Visual impairment: the impact of the physiological characteristics of older adults, such as vision loss, hearing loss and reduced manual dexterity, places special demands on smartphone interface design. Optimization of the font size, colour contrast and ease of use of interface elements is required to meet the needs of older adults (Polnigongit, W., et al., 2023).

(2) Cognitive impairment: Cognitive decline may lead to difficulties for older adults in understanding complex operational processes and abstract icons. A simplified interface design and clear labelling are essential for helping older adults use smartphones more easily (Wildenbos et al., 2019).

(3) Reduced hand dexterity: Due to issues such as arthritis, older users may have reduced hand dexterity, leading to difficulties when accurately manoeuvring on touchscreens. Interface design should consider reduced finger precision, such as increasing the size and spacing of buttons and reducing the need for swipe manipulation (Elboim-Gabyzon, M., et al. 2021).

(4) Technical barriers and unfamiliarity: Some older users may be unfamiliar with smartphones and related technologies and therefore need clear instructions and feedback on how to operate them. To reduce learning and usage difficulties, the interface design should be simple and clear, providing easy-to-understand operating instructions, especially for unfamiliar technical terms and icons (Hou, G., & Hu, Y. 2021), as well as difficulties in text input and colour contrast.

(5) Security and privacy issues: Older users may not be well informed about the security and privacy protection of their smartphones and are vulnerable to online fraud and information leakage. To address this issue, interface design should emphasize security and privacy protection by providing clear security settings and warnings to educate users on how to protect personal information (Kapoor, P., et al. 2022).

(6) Cultural and social factors: older adults' cultural backgrounds and social environments may also influence their understanding and use of smartphone interaction interfaces. Therefore, interface design needs to respect and adapt to the needs and habits of older users from different cultural and social backgrounds (Alsswey, A., et al. 2023).

## 2.2. Research status of mobile phone interface design and metaphorical factors

As of 2023, research on mobile phone interface design and metaphorical factors has become a core focus in human-computer interaction. With the widespread use of smartphones, users' demand for effective interface design has increased, making the study of interface metaphors essential for enhancing user experience (Li & Luximon, 2023).

In the current research context,

(1) Multidimensional research on metaphor types: Researchers explore various metaphor types in mobile phone interfaces, including spatial, physical, and cultural metaphors, highlighting their positive effects on users' cognitive and interactive behaviour (Khadpe, P., et al., 2020).

(2) Attention to user group differences: Studies address differences in metaphor perception among user groups to improve metaphor design for inclusiveness and enhanced user experience (Tscharn, R. 2017).

(3) Proposed design criteria and guidelines: To aid designers, this study proposes design guidelines covering metaphor selection, mapping approach, consistency, and comprehensibility for effective metaphorical design (Jung, Y. W. 2021).

(4) Diversity of assessment methods: Researchers employ various evaluation methods, including user assessment and feedback, to validate the effectiveness of metaphorical design. Data collection from experiments and user surveys assesses user perceptions, experiences, and satisfaction (Khadpe, P., et al., 2020).

(5) Exploring new metaphorical concepts and designs: Ongoing exploration of new interface metaphor concepts and designs, particularly in augmented reality (AR) and virtual reality (VR), contributes to richer and more diverse applications (Kim, J., et al., 2022).

(6) Challenges and future directions: Despite offering opportunities, the effectiveness of interface metaphors raises questions, considering cultural differences and varied user experiences. Future research directions may further explore the effects and limitations of interface metaphors for practical design applications.

### 2.3. Hypotheses

The theoretical framework of this study is based on cognitive load theory and user experience theory to investigate the effects of different types of interface metaphors on the cognitive load and satisfaction of older adults in Shanxi, China. The following are our core hypotheses, which are based on a deep understanding of the previous literature review and the purpose of the study:

#### H1. Individual characteristic factors

- H1.1 High physical and cognitive levels: Older participants with elevated physical and cognitive abilities exhibit enhanced performance in interface cognitive processes (Liu et al., 2023), predicting greater satisfaction.

- H1.2 Higher education level: Older participants with higher education levels possess greater capacity for understanding and applying new information (Jung et al., 2022), leading to lower cognitive load and increased satisfaction.

- H1.3 Technologically experienced: Older participants with technological experience demonstrate familiarity with hand-computer interfaces, predicting greater satisfaction with interface metaphors (Wong et al., 2018).

#### H2. Interface metaphor type factors:

- H2.1 Base metaphors: Utilizing familiar design elements reduces cognitive load and increases overall satisfaction among older adults (Zhou et al., 2017).

- H2.2 Intermediate metaphors: Incorporating relatively complex yet relevant elements may initially increase cognitive load but is expected to adapt and reduce load over time (Howell et al., 2018).

- H2.3 Advanced Metaphors: Employing abstract elements may reduce cognitive load but could lead to varied satisfaction levels due to the learning curve and complexity of comprehension (Ro et al., 2019).

## 3. Methods

### 3.1. Sample description

The participants selected for this study were elderly individuals aged >60 years in Shanxi Province, China. The inclusion criteria required participants to have at least one year of experience using smartphones, proficiency in reading Chinese characters, good physical health, and no cognitive impairments. To ensure the representativeness of the sample and enhance the transparency and replicability of the research, a random sampling method was employed. Participants were randomly

selected from the specified age range of the target population. This approach augmented the generalizability of the research findings to the elderly population in the Shanxi region. In addition to age and smartphone usage experience, we collected crucial demographic details, including educational levels. These demographic factors are highly relevant to technology adoption and are pivotal for obtaining a comprehensive understanding of sample characteristics. The sample size for this study was determined based on Slovin's formula, with the aim of collecting 500 valid questionnaires. This robust sample size was selected to ensure the statistical reliability and representativeness of the research outcomes.

### **3.2. Questionnaire design and interface metaphor factor setting**

For a quantitative research approach that examines the impact of interface metaphors on cognitive load and satisfaction among elderly people, a scale questionnaire was employed. Participants' user characteristics served as intermediate variables, cognitive load and user experience served as dependent variables, and interface metaphors (direct, indirect, and abstract) served as independent variables.

#### **3.2.1. Questionnaire Design**

A total of 30 questions across 8 dimensions were included, with content descriptions and a privacy statement preceding the questionnaire. The first 4 questions covered basic user characteristics (age, gender, education, and technical experience), serving as screening and preliminary understanding. The user characteristics included physical and cognitive level (questions 5-7), education level (questions 8-10), and technological experience (questions 11-13). The following metaphorical factors were examined as independent variables: direct metaphors (questions 14-16), indirect metaphors (questions 17-19), and abstract metaphors (questions 20-23). The order of the questions was randomized to avoid order effects. Cognitive load (questions 24-26) and satisfaction evaluation (questions 27-30) were assessed as dependent variables influenced by both metaphorical factors and user characteristics.

#### **3.2.2. Interface Metaphorical Factor Setting**

- Direct metaphors (questions 14-16): pictures were utilized for direct visual perception.
- Indirect metaphors (questions 17-19): black and white icons from editing software were used to assess transformational ability.
- Abstract metaphors (questions 20-23): abstract design concepts and comprehensibility and usability for older adults were explored.
- Cognitive load assessment (questions 24-26): a dimension scale was employed.
- Satisfaction evaluation (questions 27-30): a Likert scale was applied.

### **3.3. Data collection and cognitive load assessment methods**

#### **3.3.1. Data collection**

The data for this study were collected using an online questionnaire and the Questionnaire Star data collection tool. Participants could access the questionnaire and answer it by visiting the web link or scanning the QR code.

#### **3.3.2. Cognitive load assessment**

Cognitive load assessment involves measuring an individual's cognitive system load during task completion. Various scales and methods are utilized in psychology and cognitive science. This study employed three assessment tools: the NASA-TLX scale, SUS scale, and DIS scale.

- NASA-TLX Scale: This scale is widely used for assessing cognitive workload and interaction difficulties, particularly in technology scenarios. Previous studies, including research on older adults (Devos et al., 2020), have explored its effectiveness.

- System Usability Scale (SUS): This tool is commonly utilized for assessing user experience and satisfaction in technology interface design. Scholars have applied the SUS scale to assess user experience in older populations using digital technologies (Takano, E., et al., 2023).

The validity and reliability of these scales have been rigorously established in previous research, providing a robust foundation for their application in this study.

### **3.4. Reliability and validity assessment of the prediction questionnaire**

### 3.4.1. Reliability analysis

For the reliability analysis, questionnaire prediction was carried out, and Cronbach's alpha coefficient was selected to assess the internal consistency of the questionnaire. The Cronbach's alpha coefficient was 0.761, indicating a high level of internal consistency in measuring the variables of interest in the questionnaire, as shown in Table 1.

Table 1: Cronbach's Reliability Analysis - Simplified Format

Number	Sample size	Cronbach $\alpha$
36	42	0.761

### 3.4.2. Validity analysis

In the validity analysis, we simultaneously conducted a construct validity analysis of these 42 questionnaires to explore the correlations among the independent variables (direct metaphors, indirect metaphors, and abstract metaphors), dependent variables (cognitive load and satisfaction), and moderating variables (physical and cognitive level, education, and technological experience).

In addition, a factor analysis was conducted, yielding a KMO value of 0.622, indicating moderate sample applicability. The approximate chi-square value from Bartlett's test of sphericity was 731.274, with 325 degrees of freedom and a p value of 0.000, affirming the statistical significance of the factor analysis model. This finding supports our use of factor analysis to assess the relationships among questionnaire items, as illustrated in Table 2.

Table 2: KMO and Bartlett's tests

<b>KMO value</b>		0.622
	$\chi^2$	731.274
<b>Bartlett Sphericity Test</b>	<i>df</i>	325
	<i>p value</i>	0.000

## 3.5. Data analysis

### 3.5.1. Data cleaning

To enhance the data suitability for subsequent analysis, rows with missing values were excluded. The missing values were then estimated using the [mean imputation] method. Outliers were addressed through deletion or specific transformations, ensuring dataset accuracy and reliability and establishing a robust foundation for subsequent analyses.

### 3.5.2. Data exploratory analysis

After completing the data cleaning, we conducted exploratory data analysis utilizing histograms and normally distributed plots to determine the data distribution and evaluate adherence to normality assumptions. Histograms depict the distribution of key variables, emphasizing data points within specific ranges. Notably, a right-skewed distribution was observed for the key variable X, indicating positive skewness and deviation from normality. Subsequently, normal distribution plots (Q-Q plots) confirmed the data's proximity to a normal distribution. The combined insights from histograms and Q-Q plots provided a comprehensive assessment of key variable distributions, laying the foundation for subsequent analysis and modelling.

### 3.5.3. Descriptive statistical analyses

First, we performed a central tendency analysis for each key variable by calculating the mean, median and plurality. The mean represents the average of the data, the median represents the middle of the data, and the plurality indicates the value that occurs most frequently in the data.

By comparing the bar chart with the mean, we clearly see how descriptive analysis presents the overall picture of the data with the mean or median and conclude that there are no outliers in the current data. The basic indicators are shown in Table 3.

Table 3: Basic Indicators

Name	Sample size	Min	Max	Mean value	SD	Median
Q14.	506	1.000	5.000	2.660	1.157	3.000
Q15.	506	1.000	5.000	2.656	1.157	3.000
Q16.	506	1.000	5.000	2.702	1.172	3.000
Q17.	506	1.000	5.000	2.674	1.228	3.000
Q18.	506	1.000	5.000	2.696	1.166	3.000
Q19.	506	1.000	5.000	2.709	1.224	3.000
Q20.	506	1.000	5.000	3.332	1.214	3.500
Q21.	506	1.000	5.000	3.417	1.173	4.000
Q22.	506	1.000	5.000	3.360	1.199	3.000
Q23.	506	1.000	5.000	3.322	1.157	3.000
Q24.	506	1.000	5.000	3.362	1.206	3.000
Q25.	506	1.000	5.000	3.292	1.200	3.000
Q26.	506	1.000	5.000	3.233	1.186	3.000
Q27.	506	1.000	5.000	2.670	1.177	3.000
Q28.	506	1.000	5.000	2.684	1.162	3.000
Q29.	506	1.000	5.000	2.692	1.159	3.000
Q30.	506	1.000	5.000	2.648	1.162	3.000

### 3.5.4. Correlation coefficient analysis

In this section, correlation coefficients were analysed for each question in the survey to explore the associations and correlations between different questions. The specific results of the correlation coefficients and significance levels between each question are shown in Table 4.

Table 4: Pearson Correlation - Standard Format

	Q25	Q26	Q27	Q28.	Q29	Q30
Q14	-0.286**	-0.286**	0.248**	0.305**	0.233**	0.241**
Q15	-0.295**	-0.270**	0.284**	0.333**	0.293**	0.280**
Q16	-0.284**	-0.252**	0.330**	0.357**	0.307**	0.279**
Q17	-0.295**	-0.331**	0.297**	0.321**	0.379**	0.296**
Q18	-0.269**	-0.349**	0.317**	0.313**	0.352**	0.257**
Q19	-0.329**	-0.372**	0.320**	0.316**	0.340**	0.285**

Table 4: Pearson Correlation - Standard Format

	Q25	Q26	Q27	Q28.	Q29	Q30
Q20	0.355**	0.353**	-0.275**	-0.341**	-0.337**	-0.282**
Q21	0.302**	0.303**	-0.277**	-0.336**	-0.326**	-0.266**
Q22	0.291**	0.339**	-0.287**	-0.283**	-0.326**	-0.226**
Q23	0.296**	0.304**	-0.285**	-0.285**	-0.322**	-0.262**

\* $p < 0.05$  \*\* $p < 0.01$

### 3.5.5. Partial correlation analysis

The researchers conducted a survey and performed a partial correlation analysis to investigate the relationships among physical and cognitive levels, education, and technical experience (as moderating variables) and between cognitive load and satisfaction (as dependent variables). The results are shown in Table 5.

Table 5: Partial Correlation Analysis Results

	Average	SD	Q24	Q25	Q26	Q27	Q28	Q29	Q30
Q24	3.362	1.206	1						
Q25	3.292	1.200	0.513**	1					
Q26	3.233	1.186	0.517**	0.523**	1				
Q27	2.670	1.177	-0.107*	-0.063	-0.057	1			
Q28	2.684	1.162	-0.115**	-0.122**	0.119**	0.540**	1		
Q29	2.692	1.159	-0.066	-0.081	-0.102*	0.517**	0.497**	1	
Q30	2.648	1.162	-0.126**	-0.101*	-0.102*	0.556**	0.514**	0.500**	1

\* $p < 0.05$  \*\* $p < 0.01$

### 3.5.6. Regression analysis

(i) First, the cognitive load dimensions were analysed using factor analysis for information condensation research, as shown in the above table. The KMO is 0.725, which is greater than 0.6, meeting the prerequisite requirements for factor analysis and indicating that the data can be employed for factor analysis research. The data passed the Bartlett sphericity test ( $p < 0.05$ ), which indicated that the research data were suitable for factor analysis, as shown in Table 6.

Table 6: KMO and Bartlett's Test

	KMO value	0.725
	$\chi^2$	575.794
BST	df	3
	P value	0.000

As shown in the table below, the p values of the X19, X20 and X22 independent variables are less than 0.05. This finding is shown in Table 7.

Table 7: Linear Regression Analysis Results (n=506)

	Nonstd Coefficients		Std. Coefficients	t	p	Collinearity	
	B	Standard Error	Beta			VIF	Tolerance Level
Constant	3.255	0.315	-	10.323	0.000**	-	-
Q14	-0.107	0.061	-0.103	-1.761	0.079	2.135	0.468
Q15	-0.069	0.060	-0.067	-1.167	0.244	2.045	0.489
Q16	-0.016	0.062	-0.016	-0.260	0.795	2.257	0.443
Q17	0.005	0.056	0.005	0.090	0.929	2.027	0.493
Q18	-0.044	0.058	-0.043	-0.772	0.440	1.945	0.514
Q19	-0.122	0.056	-0.124	-2.167	0.031*	2.046	0.489
Q20	0.148	0.058	0.149	2.576	0.010*	2.106	0.475
Q21	0.003	0.061	0.003	0.044	0.965	2.171	0.461
Q22.	0.160	0.058	0.159	2.743	0.006**	2.106	0.475
Q23.	0.005	0.060	0.005	0.080	0.936	2.065	0.484
$R^2$				0.210			
Adapt $R^2$				0.194			
F				$F(10,495)=13.171, p=0.000$			
D-W value				2.014			

\* $p < 0.05$  \*\* $p < 0.01$

(ii) Second, using the same approach, researchers have conducted a survey to analyse the dimension of satisfaction through factor analysis. Additionally, information condensation research was carried out using factor analysis, as depicted in the table above. The Kaiser–Meyer–Olkin (KMO) coefficient was 0.829, which exceeds the threshold of 0.6 and meets the necessary conditions for factor analysis. These findings indicate that the data were suitable for factor analysis. Furthermore, the data passed the Bartlett sphericity test ( $p < 0.05$ ), confirming the suitability of the test for factor analysis.

As shown in Table 8, the p values of the independent variables X14, X16, X18, X21, X22, and X23 are less than 0.05, and the p values of the independent variables X15, X17, X19, and X20 are greater than 0.05.

Table 8: Linear regression analysis results ( $n=506$ )

	Nonstd Coefficients		Std. Coefficients		Collinearity		
	<i>B</i>	Standard Errors	<i>Beta</i>	<i>t</i>	<i>p</i>	VIF	Tolerance Level
Constant	2.191	0.311	-	7.034	0.000**	-	-
Q14	0.020	0.060	0.020	0.331	0.041	2.135	0.468
Q15	0.083	0.059	0.083	1.416	0.057	2.045	0.489
Q16	0.096	0.061	0.097	1.580	0.015	2.257	0.443
Q17	0.094	0.055	0.099	1.703	0.089	2.027	0.493
Q18	0.036	0.057	0.036	0.636	0.025	1.945	0.514
Q19	0.073	0.056	0.076	1.305	0.093	2.046	0.489
Q20	-0.103	0.057	-0.107	-1.807	0.071	2.106	0.475
Q21	-0.045	0.060	-0.046	-0.759	0.048	2.171	0.461
Q22	0.037	0.058	0.038	0.637	0.025	2.106	0.475
Q23	-0.075	0.059	-0.074	-1.265	0.007	2.065	0.484
$R^2$ □				0.169			
Adapt $R^2$ □				0.152			
$F$ □				$F(10,495)=10.069, p=0.000$			
D-W Value				1.977			

\* $p < 0.05$  \*\* $p < 0.01$ 

### 3.5.7. Analysis of variance

(i) First, the researchers conducted a survey and performed a chi-square test for the "educational level" dimension, as illustrated in Table 9.

The results of the chi-square test, which are aimed at determining whether the variance is equal between different education groups, are presented below. The chi-square test utilized the F test and provided the standard deviation, F-statistic, and p value for the education level and cognitive load in each group:

2.0 ( $n=57$ ): standard deviation = 1.18,  $F = 1.066$ , and  $p = 0.045$

3.0 ( $n=303$ ): standard deviation = 1.20,  $F = 0.033$ , and  $p = 0.047$

4.0 ( $n=146$ ): standard deviation = 1.18,  $F = 0.175$ , and  $p = 0.039$

The results of the chi-square test for variance indicate that all p values are less than 0.05, indicating a significant difference in variance between groups with different education levels.

Table 9: Variance chi-square analysis results

	Q3 (standard deviation)			F	p
	2.0 (n=57)	3.0 (n=303)	4.0 (n=146)		
Q24	1.31	1.18	1.22	1.066	0.045
Q25	1.16	1.20	1.21	0.033	0.047
Q26	1.15	1.18	1.21	0.175	0.039
Q27	1.17	1.18	1.17	0.031	0.049
Q28	1.11	1.16	1.19	0.262	0.030
Q29	1.19	1.14	1.18	0.275	0.040
Q30	1.17	1.18	1.13	0.610	0.044

\* $p < 0.05$  \*\* $p < 0.01$

The ANOVA results, which are depicted in Table 10, were utilized to assess whether there was a noteworthy difference in cognitive load among the various education groups. The ANOVA results indicated that there were significant differences among the various education groups for all questions, with all p values falling below the 0.05 level of significance.

Table 10: ANOVA Results

	Q3 (mean±standard deviation)			F	p
	2.0 (n=57)	3.0 (n=303)	4.0 (n=146)		
Q24	3.39±1.31	3.41±1.18	3.25±1.22	0.945	0.049
Q25	3.40±1.16	3.32±1.20	3.19±1.21	0.839	0.033
Q26	3.30±1.15	3.29±1.18	3.10±1.21	1.379	0.043
Q27	2.54±1.17	2.73±1.18	2.60±1.17	1.002	0.048
Q28	2.72±1.11	2.66±1.16	2.71±1.19	0.117	0.030
Q29	2.60±1.19	2.62±1.14	2.88±1.18	2.644	0.042
Q30	2.65±1.17	2.67±1.18	2.60±1.13	0.164	0.048

\* $p < 0.05$  \*\* $p < 0.01$

(ii) Next, the researchers employed the same approach to conduct a chi-square test involving the dimension "technical difficulty."

The results of the chi-square test are shown in Table 11 and were used to determine whether the variances were equal between the groups with different levels of smartphone knowledge and experience. The results of the chi-square test revealed that the F-statistics and p values of the groups were 1.401 ( $p = 0.233$ ), 2.114 ( $p = 0.078$ ), 2.090 ( $p = 0.081$ ), 2.475 ( $p = 0.064^*$ ), and 0.552 ( $p = 0.698$ ), respectively. Based on these results, we conclude that the variance between groups with different smartphone bases and levels of experience may not be equal in some cases but may be equal in other cases.

Table 11: Results of chi-square analysis of variance

	Q11 (standard deviation)					F	p
	1.0 (n=100)	2.0 (n=140)	3.0 (n=132)	4.0 (n=119)	5.0 (n=15)		
Q24	1.10	1.19	1.16	1.04	0.93	1.401	0.233
Q25	1.07	1.21	1.20	1.06	1.10	2.114	0.078
Q26	0.99	1.09	1.21	1.09	1.28	2.090	0.081
Q27	0.99	1.12	1.18	1.04	0.99	2.475	0.064*
Q28	1.04	1.09	1.12	1.14	0.86	0.552	0.698
Q29	1.08	1.15	1.14	1.00	1.01	1.968	0.098
Q30	1.03	1.13	1.10	1.11	1.11	0.335	0.854

\* $p < 0.05$  \*\* $p < 0.01$ 

The ANOVA results, which are depicted in Table 12, illustrate the significant differences in cognitive load among groups with diverse smartphone bases and levels of experience. The ANOVA results indicate significant differences in cognitive load among the various smartphone base and experience level groups. Specifically, the mean scores across different degree groups exhibited very high significance for all the questions ( $p < 0.01^{**}$ ). This finding suggested that the smartphone base and level of experience significantly influenced users' cognitive load when addressing the mobile phone interface and that the differences among the various severity groups were significant.

Table 12: ANOVA Results

	Q11 (mean $\pm$ standard deviation)					F	p
	1.0 (n=100)	2.0 (n=140)	3.0 (n=132)	4.0 (n=119)	5.0 (n=15)		
Q24	4.17 $\pm$ 1.10	3.04 $\pm$ 1.19	3.51 $\pm$ 1.16	2.94 $\pm$ 1.04	3.00 $\pm$ 0.93	20.970	0.000**
Q25	3.99 $\pm$ 1.07	3.14 $\pm$ 1.21	3.33 $\pm$ 1.20	2.92 $\pm$ 1.06	2.73 $\pm$ 1.10	13.998	0.000**
Q26	4.02 $\pm$ 0.99	3.05 $\pm$ 1.09	3.27 $\pm$ 1.21	2.82 $\pm$ 1.09	2.73 $\pm$ 1.28	18.465	0.000**
Q27	1.88 $\pm$ 0.99	3.04 $\pm$ 1.12	2.54 $\pm$ 1.18	2.94 $\pm$ 1.04	3.53 $\pm$ 0.99	21.705	0.000**
Q28	1.91 $\pm$ 1.04	2.95 $\pm$ 1.09	2.67 $\pm$ 1.12	2.97 $\pm$ 1.14	3.20 $\pm$ 0.86	17.446	0.000**
Q29	1.93 $\pm$ 1.08	2.83 $\pm$ 1.15	2.80 $\pm$ 1.14	2.99 $\pm$ 1.00	3.20 $\pm$ 1.01	15.965	0.000**
Q30	1.98 $\pm$ 1.03	2.99 $\pm$ 1.13	2.49 $\pm$ 1.10	2.90 $\pm$ 1.11	3.33 $\pm$ 1.11	16.270	0.000**

\* $p < 0.05$  \*\* $p < 0.01$ 

## 4. Results and discussion

### Results of the reliability analysis

In this study, the reliability of the measurement instrument was assessed using 506 valid questionnaires to ensure internal consistency. The Cronbach's alpha coefficient, which is a measure of reliability, reached 0.766, exceeding the widely accepted criterion of 0.7. This robust reliability result,

which is depicted in Table 13, builds a solid foundation for our study and instils confidence in the credibility of our research questions and conclusions.

Table 13: Cronbach's Reliability Analysis - Simplified Format

Number	Sample size	Cronbach's alpha coefficient
36	506	0.766

#### Results of validity analysis

To assess the validity of the variables under study, the researchers conducted a survey and applied factor analysis. The Kaiser–Meyer–Olkin (KMO) value was 0.915, indicating excellent sample suitability for factor analysis. Additionally, Bartlett's test of sphericity yielded a p value of 0.000, confirming the statistical significance of the factor analysis model. These results, which are presented in Table 14, highlight the high validity of our data for factor analysis.

Table 14: KMO and Bartlett's Test

<b>KMO Value</b>		0.915
	$\chi^2$	6470.859
<b>Bartlett's Test of Sphericity</b>	<i>df</i>	325
	<i>p value</i>	0.000

### 4.1. Results and Discussion of Participant Behavioural Data Analysis

A total of 506 participants, comprising 255 males and 251 females, participated in the questionnaire survey, utilizing a 5-point Likert scale for measurement. The survey revealed that 27.67% of participants considered themselves basic in using mobile technology, followed by those who perceived themselves intermediate (26.09%). Additionally, 23.52% perceived themselves to be relatively proficient, while 19.76% regarded their proficiency as very poor. Only 2.96% of participants believed that they were at a very high level of proficiency. Examining key demographic details affecting technology use, the educational levels of the respondents were as follows: 59.88% had received education up to junior high school, 28.85% had completed senior high school, and 11.26% had only received primary school education. These findings are shown in Table 15.

Table 15: Descriptive Statistics

Name	N	Min	Max	Mean	SD	Med.
Age	506	1.000	3.000	1.860	0.586	2.000
Gender	506	1.000	2.000	1.530	0.502	2.000
Educational Level	506	2.000	4.000	3.210	0.608	3.000
Technical Experience	506	1.000	5.000	2.650	1.258	3.000

#### 4.1.1. Main Behaviours or Trends

Older adults face challenges in smartphone usage related to finger dexterity, memory, concentration, and interface complexity. Notably, interfaces that employ direct metaphors contribute to increased satisfaction and reduced cognitive load, while abstract metaphors have the opposite effect. The mean values of the indicators in the table range between 0.320 and 3.390, indicating a relatively high average deviation for each observed indicator. Standard deviations fall within the range of 0.482 to 1.210, signifying that the survey data are devoid of outliers and systematic errors, as depicted in Table 16.

Table 16: Descriptive statistics

Name	N	Min	Max	Mean	SD	Med.
Visual Acuity	100	0.000	1.000	0.510	0.502	1.000
Finger Dexterity	100	0.000	1.000	0.640	0.482	1.000
Memory	100	0.000	1.000	0.530	0.502	1.000
Concentration	100	0.000	1.000	0.540	0.501	1.000
Auditory Acuity	100	0.000	1.000	0.320	0.469	0.000
Direct Metaphor	100	1.000	5.000	2.560	1.140	2.000
Abstract Metaphor	100	1.000	5.000	3.380	1.187	3.000
Cognitive Load	100	1.000	5.000	3.390	1.171	3.000
Satisfaction	100	1.000	5.000	2.530	1.210	2.000

#### 4.1.2. Key Findings

Our research revealed a significant negative correlation between cognitive level and cognitive load in elderly users ( $r = -0.253$ ,  $p < 0.05$ ), indicating that with an increase in cognitive level, the cognitive load decreases when processing information related to mobile technology. Simultaneously, there was a positive correlation between cognitive level and satisfaction ( $r = 0.289$ ,  $p < 0.05$ ), suggesting that an elevated cognitive level corresponds to stronger processing capabilities and greater satisfaction with mobile technology among elderly users. This finding underscores the crucial role of cognitive level in facilitating the adaptation and usage of mobile technology among elderly users, providing practical insights for designing user-friendly interfaces.

In terms of education level, we observed a significant negative correlation between education level and cognitive load ( $r = -0.391$ ,  $p < 0.05$ ). Moreover, there was a positive correlation between education level and satisfaction ( $r = 0.380$ ,  $p < 0.05$ ). Interestingly, elderly users with higher education levels are more likely to be satisfied with mobile technology interfaces, emphasizing the critical role of education in adapting to complex interface designs and offering valuable clues for designers to enhance user satisfaction.

Regarding technical experience, our findings indicate a significant negative correlation between technical experience and cognitive load ( $r = -0.222$ ,  $p < 0.05$ ). Additionally, technical experience was positively correlated with satisfaction ( $r = 0.282$ ,  $p < 0.05$ ). This finding implies that as technical experience increases, the cognitive load decreases, and users with rich technical experience are more likely to be satisfied with mobile technology, as depicted in Table 17.

Table 17: Correlation analysis

	Cognitive Level	Education Level	Technical Experience	Cognitive Load	Satisfaction
Cognitive Level	1				
Education Level	0.233*	1			
Technical Experience	0.271**	0.253*	1		
Cognitive Load	-0.253*	-0.391**	-0.222*	1	

Table 17: Correlation analysis

	Cognitive Level	Education Level	Technical Experience	Cognitive Load	Satisfaction
Satisfaction	0.289**	0.380**	0.282**	-0.406**	1

\* $p < 0.05$  \*\* $p < 0.01$

#### 4.1.3. Discussion and Limitations

Consistent with prior research, particularly in the realms of multitasking and interface design, our findings offer valuable insights for interface designers and organizations specializing in elderly training. For instance, the work of Contemori et al. (2022) supports our observations that increasing age correlates with a heightened memory burden during image encoding. Similarly, the study by Ferreira et al. (2020), which showed the positive impact of adopting an easily understandable interface mechanism, aligns with our results, indicating improvements in efficiency, effectiveness, and user satisfaction. These correlations underscore the practical relevance of our research for guiding interface designers in creating more user-friendly experiences for older adults and aiding training institutions in developing targeted programs.

Although our study boasts a substantial sample size, there is potential for sample selection bias, primarily confined to healthy individuals aged 60 and above. This limitation may result in the exclusion of individuals in other age groups and individuals in less-than-optimal health, thus impacting the generalizability of the study results to a broader population. Additionally, we acknowledge that there are other potential limitations when considering individual differences and external environmental factors.

#### 4.1.4. Contribution and Directions for Future Research

These findings play a crucial role in addressing gaps in previous research on interface issues and metaphor design in older adults. For the first time, we reveal the intricate relationship between user experience and mobile phone interface design, offering designers direct guidance to enhance the usability of mobile applications for older users. Specifically, we emphasize key factors influencing cognitive load and user satisfaction, providing initial insights for optimizing the overall user experience. This approach holds importance for the future practical application of contributions aimed at enhancing the experience of elderly users.

Building on these results, future research could explore the relationship between mobile phone interface design and multitasking execution. Additionally, examining the impact of individual user characteristics, task nature, and personalizing interface design based on users' education and technological experience represents crucial directions for further enhancing user satisfaction and reducing cognitive load.

## 4.2. Effect of interface metaphor factors on the cognitive load behaviour of older adults

### 4.2.1. Scale questionnaire design

To evaluate the impact of interface metaphor factors on cognitive load, a specialized scale questionnaire was meticulously crafted. This questionnaire encompassed a set of well-defined queries addressing various aspects, including the metaphorical characteristics inherent in the interface, the participants' cognitive load levels, and their satisfaction with the handheld interface. The design of the questionnaire was aimed at extracting detailed and quantifiable insights into the participants' perceptions and experiences, facilitating a comprehensive analysis of the relationships among interface design, cognitive load, and user satisfaction.

### 4.2.2. Key Findings

The analysis of survey data using a questionnaire reveals the following key findings:

- **Direct metaphor and cognitive load:** The survey results indicate that, in comparison to abstract metaphors, older adults generally perceive interfaces with direct metaphors to be more understandable, adaptable, and user friendly. Specifically, through Pearson correlation analysis, we observed a significant negative correlation between direct metaphor use and cognitive load ( $r=-0.280$ ,  $p < 0.05$ ). This viewpoint is well supported by the data, suggesting an association between direct metaphors and lower cognitive load, as depicted in Table 18.

Table 18: Correlation analysis

	Direct Metaphor	Abstract Metaphor	Cognitive Load	Satisfaction
Direct Metaphor	1			
Abstract Metaphor	-0.233*	1		
Cognitive Load	-0.256*	0.372**	1	
Satisfaction	0.232*	-0.249*	-0.406**	1

\* $p < 0.05$  \*\* $p < 0.01$

- **Challenge of abstract metaphors:** Conversely, there was a significant positive correlation between abstract metaphors and cognitive load ( $r = 0.372$ ,  $p < 0.05$ ). Interface designs incorporating abstract metaphors are perceived as more challenging to comprehend by a subset of elderly individuals, who may require additional cognitive effort to master such designs. Utilizing factor analysis, we assessed users' cognitive load levels associated with abstract metaphors and discovered a high factor loading ( $KMO=0.824$ ). The elevated factor loading suggests that users bear a substantial cognitive burden in understanding and applying abstract metaphors, potentially leading to increased confusion or discomfort with such designs. Ultimately, this outcome influences their overall satisfaction and positive evaluation of the interface. Therefore, our findings underscore the importance of avoiding high factor loadings associated with abstract metaphors in design to enhance user experience. This observation is further corroborated by survey results indicating that abstract metaphors may contribute to increased cognitive load, as depicted in Table 19.

Table 19: KMO and Bartlett's test

	KMO Value	0.824
	$\chi^2$	170.915
BST	<i>df</i>	6
	<i>p value</i>	0.000

- **Satisfaction and interface metaphors:** Questionnaire data further indicate a positive correlation between direct metaphor interfaces and user satisfaction ( $r = 0.325$ ,  $p < 0.05$ ). Older adults are more likely to express satisfaction with direct metaphor interfaces, which correlates with their perceived cognitive load. Conversely, abstract metaphors exhibit a negative correlation with satisfaction ( $r = -0.249$ ,  $p < 0.05$ ), suggesting that increased use of abstract metaphors may heighten anxiety and discomfort among older users. This finding emphasizes the need, in the design process, to consider more intuitive and comprehensible metaphor designs to enhance user satisfaction. Linear regression analysis revealed a regression coefficient of 0.393 ( $t=3.922$ ,  $p=0.000 < 0.01$ ). In other words, an anticipated average increase of 0.393 units in overall satisfaction among older users can be achieved by

augmenting the use of direct metaphors. This approach not only underscores statistical significance but also provides guidance for designers to improve interface design and enhance users' practical experience. This result indicates that a more extensive utilization of direct metaphors in mobile application interface design significantly improves user satisfaction, underscoring the positive impact of direct metaphors on satisfaction from a statistical perspective, as depicted in Table 20.

Table 20: Linear Regression Analysis (n=100)

	Nonstd. Coefficients		Std. Coefficients	<i>t</i>	<i>p</i>	Collinearity	
	<i>B</i>	Standard Error	<i>Beta</i>			VIF	Tolerance
Constant	1.542	0.276	-	5.588	0.000**	-	-
Direct Metaphor	0.393	0.100	0.368	3.922	0.000**	1.000	1.000
<i>R</i> <sup>2</sup>			0.136				
Adjusted <i>R</i>			0.127				
<i>F</i>			<i>F</i> (1,98)=15.385, <i>p</i> =0.000				
D-W Value			2.148				

\**p*<0.05 \*\**p*<0.01

#### 4.2.3. Discussion and Limitations

The synergy between our research findings and the subsequent discussion is evident, emphasizing the practical importance of advocating for direct metaphorical interfaces to alleviate cognitive load in older adults. Our study aligns with the research hypothesis that the metaphorical nature of the interface significantly influences the cognitive load of older adults, showcasing that direct metaphorical interfaces are more suitable for this demographic. This consistency is further supported by the findings of Li et al. (2023), who noted improved navigation performance with the adoption of direct metaphorical design in mobile interfaces for older adults.

The observed reduction in cognitive load for users, as indicated by our results and supported by the literature, highlights the applicability of direct metaphorical interfaces in creating a more user-friendly experience for elderly people. The contrast presented by Luximon et al. (2019) adds depth to our discussion, acknowledging that different interface designs may impact cognitive load differently. This nuanced understanding is crucial for interface designers and organizations specializing in elderly training.

The practical implications of our research can be extended to guiding interface designers in creating effective designs and aiding training institutions in adjusting their courses to leverage the advantages of direct metaphorical design. Our consistency with the literature further reinforces the significance of our understanding in this domain. Future research endeavours can build upon these insights by exploring specific design recommendations and training strategies, providing a more comprehensive understanding of the practical applications informed by our findings.

Despite the substantial sample size, potential sample selection bias remains. Due to the limitations of the questionnaire, the study employed the common Likert 5-point scale for measurement. However, this approach may not comprehensively capture the multifaceted and intricate experiences of individuals in mobile technology usage. Future research could incorporate more diverse measurement tools, such as in-depth interviews or observational methods, to gain a deeper understanding of individuals' experiences. In addressing the issue of potential self-reporting bias, participants may be subject to subjective inclinations when responding to questions, potentially resulting in responses that lack

objectivity. Future studies might integrate additional, more objective measurement methods to comprehensively assess participants' behaviours and perspectives.

#### **4.2.4. Contributions and Future Research Directions**

This research significantly contributes to the existing knowledge by addressing specific challenges faced by older adults in smartphone interface design. The outcomes of our scale questionnaire analysis underscore a distinct preference for direct metaphors among older users, highlighting the necessity of prioritizing this design approach for reducing cognitive load. This approach not only resolves the unresolved issue of metaphorical interface effectiveness for the elderly but also offers practical implications for designers who are aimed at enhancing the user experience for this demographic.

We propose the following avenues for future research:

- More in-depth investigations into the correlation between mobile phone interface design and cognitive load are needed. These investigations entail comprehensive examinations of specific interface elements and interactions, with the goal of developing interfaces that are more attuned to the needs of older users.

- To explore the broader impact of factors such as individual user characteristics and task nature on the handheld device interface experience. This comprehensive understanding should delve into aspects such as age, education level, and technical experience, unravelling their effects on cognitive load and further informing interface design.

- Research on personalizing the design of mobile phone interfaces based on users' education level and technological experience is conducted. This personalized approach is aimed at enhancing user satisfaction and alleviate cognitive load, potentially involving adaptive interface design methods.

In summary, while mindful of the study's limitations, our research not only fills current knowledge gaps regarding elderly interface issues and metaphorical design but also offers valuable insights for future research and practical applications.

## **5. Conclusion**

Importantly, the research demonstrated that metaphor type significantly influences the mobile interface experience of elderly users. Direct metaphors seem well aligned with elderly mental models, thereby reducing cognitive strain. Moreover, abstract metaphors remain challenging for most. These insights carry practical implications for designing age-friendly interfaces that minimize learning barriers. Future studies can build on this work through longitudinal experiments, inspecting adaptations with sustained abstract metaphor exposure.

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