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The information visualization to increase the usefulness of public PHR services

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With the escalating interest in health management, the provision and utilization of Personal Health Record (PHR) information, particularly regarding regular health check-up results, have gained substantial importance. Currently, the delivery of public PHR information provided by the government is transitioning to app-based platforms. Despite the transition of government-provided public PHR information into app-based platforms, there remains a research deficit concerning the structure of such information and the application of visual content to aid comprehension. Notably, discrepancies in the health examination criteria provided by different specialized agencies for domestic public PHR information can lead to confusion, potentially complicating personal health decisions. This study aims to clarify appropriate assessment standards and visualization methods for health check-up results within domestic public PHR services, using insights gleaned from user surveys. The primary objective of this study is to propose optimal strategies for structuring and visualizing domestic public PHR information, enhancing the effectiveness of user-centered PHR information services.

Keywords: information design; healthcare design; PHR; user research

1 Introduction

1.1 Study background and objective

The Personal Health Record (PHR) has gained importance due to a paradigm shift in healthcare services. Among various associated concepts, the Korean Health Information Service characterizes PHR as a service and technology that empowers individuals to manage and control the dissemination and application of their medical data. In response to this trend, South Korea has initiated national projects to create related platforms and launched the 'My Health Record' app in 2021. Simultaneously, numerous private enterprises have been releasing PHR services via apps, leading to a surge in mobile PHR service offerings domestically.

Six key functions and roles of PHR have been defined: (1) Patient-Provider Communication, (2) Personal Health Advocacy, (3) Personal Decision Support, (4) Personal Health Journaling, (5) Personal

Health Monitoring and Management, and (6) Personal Health Reminders (Johnston, D. et al., 2007). Most current PHR apps generally provide services related to categories (2) through (6). Interestingly, public PHR services in Korea appear to offer more features related to (2) and (3), i.e., assisting users in making decisions based on health information, in comparison to private PHR services. These features are made possible by delivering results from nationally conducted general health examinations.

In Korea, general health check-ups are performed by the National Health Insurance Service, and the evaluation criteria are divided into three categories: normal A, normal B (borderline), and disease suspicion. These categories are outlined in Annex 4 of the criteria announced by the Ministry of Health and Welfare in 2022. However, a 2015 research report from the National Health Insurance revealed discrepancies between these evaluation standards and established treatment guidelines, in addition to ambiguity in the basis for some check-up criteria. Despite these identified issues and the report's recommendation for revising the evaluation standards, the three-tier system continues to be used as of 2023. Remarkably, despite the transition of PHR services to mobile platforms, research on mobile visualization related to PHR is notably lacking in Korea.

This study focuses on the evaluation criteria for 'health check-up' results among the information provided by domestic public PHR services. The aim is to ascertain from a user's perspective which set of check-up results, delivered under different evaluation criteria, is considered appropriate. This examination seeks to improve understanding of effective PHR information visualization, propose strategies for information provision within public PHR app services, and enhance aspects of PHR like (1) Patient-Provider Communication, (2) Personal Health Advocacy, and (3) Personal Decision Support. Such efforts could lead to significant improvements in user-centric PHR app information services.

1.2 Research scope and methodology

This study conducted user surveys to explore the suitability of information provision based on evaluation criteria of health examination results within public Personal Health Record (PHR) app services. The initial survey assessed the appropriateness of judgment criteria information that could influence health check-up outcomes from four dimensions: comprehension, subjective information quantity, difficulty level, and preference. Based on the findings from the first survey, a subsequent survey was undertaken to unify the evaluation criteria information and set visual elements as variables. This second survey aimed to present design proposals and discern the comprehension and preference for each. The primary focus of this research was hypertension, as identified through blood test health check-up items. The rationale for this focus was predicated on previous research, which revealed that examinees found the content related to blood tests among health check-up items to be the most challenging. The design proposals for PHR were based on the 'My Health Record' app, provided by the Ministry of Health and Welfare, given its recent development and its status as a primary domestic public PHR service facilitated by the government.

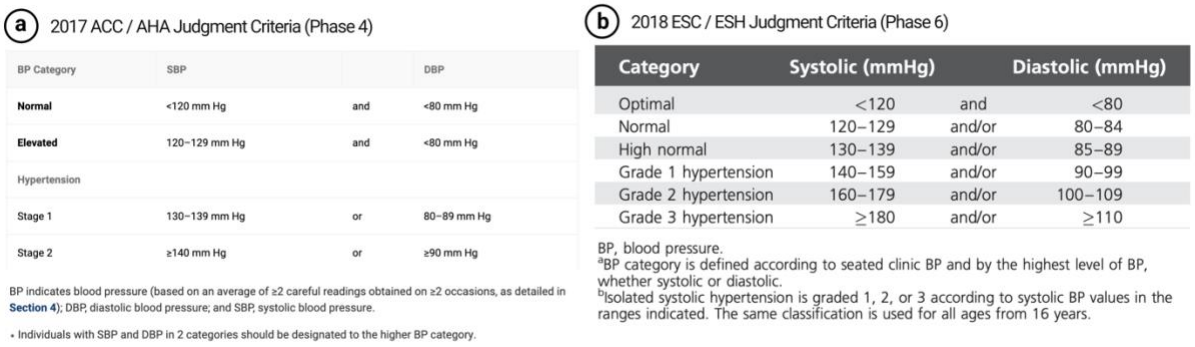
2 Preliminary research

2.1 Cases of hypertension evaluation criteria domestically and internationally

As previously indicated, the focal point of this study was 'hypertension' within health check-up items. Even though multiple guidelines have been offered by professional medical institutions worldwide

regarding hypertension evaluation criteria, this study introduces the guidelines established by the American College of Cardiology (ACC)/American Heart Association (AHA) in 2017, and by the European Society of Cardiology (ESC)/European Society of Hypertension (ESH) in 2018. The choice of these two guidelines is due to their relatively recent announcements. The ACC/AHA proposed a unique benchmark by revising the criteria for diagnosing hypertension to 130/80mmHg or higher in 2017. Meanwhile, the ESC/ESH has been consistently formulating and proposing their guidelines since 2003.

As depicted in Figure 1, according to the (a) 2017 ACC/AHA Judgment Criteria, the hypertension diagnosis criteria consist of four stages: 'normal blood pressure - elevated blood pressure - hypertension stage 1 - hypertension stage 2,' with hypertension defined as 130/80mmHg or higher. Conversely, the (b) 2018 ESC/ESH Judgment Criteria present a six-stage criteria for diagnosing hypertension: 'optimal blood pressure - normal blood pressure - high-normal blood pressure - grade 1 hypertension - grade 2 hypertension - grade 3 hypertension', defining hypertension as 140/90mmHg or higher. These distinctions underscore the ACC/AHA's strategy to enhance hypertension control rates by strengthening the diagnostic criteria, whereas the ESC/ESH elected to maintain the previous standard of 140/90mmHg or higher due to insufficient supporting evidence. Moreover, the term 'normal blood pressure' in U.S. guidelines corresponds to 'optimal blood pressure' in European guidelines. While the U.S. subdivides hypertension into stages 1 and 2, Europe offers a more detailed classification into high-normal blood pressure, and hypertension stages 1, 2, and 3.



(a) 2017 ACC / AHA Judgment Criteria (Phase 4)

BP Category	SBP		DBP
Normal	<120 mm Hg	and	<80 mm Hg
Elevated	120–129 mm Hg	and	<80 mm Hg
Hypertension			
Stage 1	130–139 mm Hg	or	80–89 mm Hg
Stage 2	≥140 mm Hg	or	≥90 mm Hg

BP indicates blood pressure (based on an average of ≥2 careful readings obtained on ≥2 occasions, as detailed in Section 4); DBP, diastolic blood pressure; and SBP, systolic blood pressure.

* Individuals with SBP and DBP in 2 categories should be designated to the higher BP category.

(b) 2018 ESC / ESH Judgment Criteria (Phase 6)

Category	Systolic (mmHg)		Diastolic (mmHg)
Optimal	<120	and	<80
Normal	120–129	and/or	80–84
High normal	130–139	and/or	85–89
Grade 1 hypertension	140–159	and/or	90–99
Grade 2 hypertension	160–179	and/or	100–109
Grade 3 hypertension	≥180	and/or	≥110

BP, blood pressure.
[a]BP category is defined according to seated clinic BP and by the highest level of BP, whether systolic or diastolic.
[b]Isolated systolic hypertension is graded 1, 2, or 3 according to systolic BP values in the ranges indicated. The same classification is used for all ages from 16 years.

Figure 1 .(a)ACC/AHA Judgment Criteria from 2017, (b) ESC/ESH Judgment Criteria from 2018.

In South Korea, the diagnostic criteria for hypertension are based on the standards stipulated in the 2018 Treating Hypertension Guidelines issued by the Korean Society of Hypertension, as shown in Figure 2 (a). Following a revision by the Korea Disease Control and Prevention Agency in 2019, these criteria were segmented into five stages: 'normal blood pressure - attentional pre-hypertensive - stage 1 high blood pressure - stage 2 high blood pressure - systolic solitary hypertension.' In contrast, the National Health Insurance Service, which conducts health examinations, applies a three-stage classification system: 'Normal A - Normal B (Borderline) - Disease Suspicion,' as illustrated in Figure 2 (b). This system is currently employed in public Personal Health Records (PHR) services. The present study aims to enhance the usability of PHR information by first determining the appropriateness of the PHR's judgement criteria from a user-centric perspective.

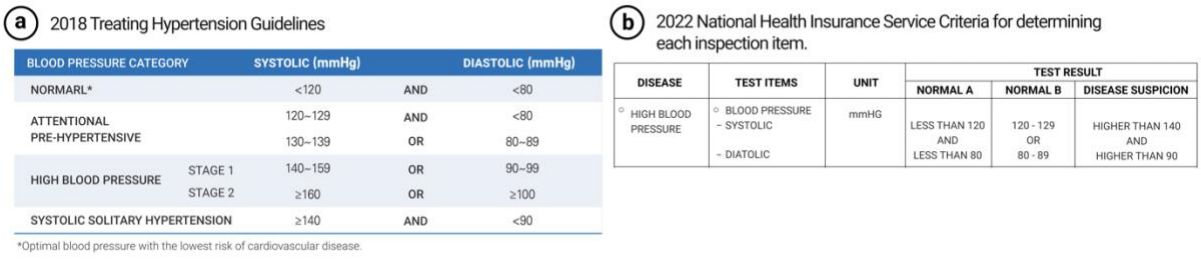


Figure 2. (a) Treating Hypertension Guidelines from the Korean Society of Hypertension, (b) Service Criteria from the National Health Insurance Service

3 Primary survey: evaluating the appropriateness of information structure

3.1 Survey design

The primary survey was designed to discern the optimal information structure for a PHR service, with a particular focus on health examination judgement stages. As such, two distinct designs, depicted in Figure 3, were developed. Each design was anchored in specific guidelines: (a) was based on the judgement criteria of the 2018 treatment guidelines of the Korean Society of Hypertension, whereas (b) was founded on the item-specific judgement criteria of the National Health Insurance Service. The General User Interface (GUI) within the design was modelled on 'My Health Record,' a recent public PHR service provided by the Ministry of Health and Welfare. Moreover, the color differentiation for judgement categorization (marked as (c) within the design) was inspired by the 'The Health Insurance' application provided by the National Health Insurance Service. This design approach was intended to ensure uniformity while comparing judgement criteria information. The selection of design elements was informed by the findings of a preceding study, which revealed users' preference for the GUI of 'My Health Record' and the color distinctions used in 'The Health Insurance' judgement criteria.

Figure 3. Design Proposal for the Primary Survey

3.2 Survey structure and methodology

The survey was conducted to capture users' preferred judgement criteria information amid the varied information provided by the National Health Insurance Service and disease-specific societies. The survey utilized the 2022 criteria of the National Health Insurance Service and the 2018 guidelines from the Korean Society of Hypertension. The survey's purpose was to ascertain the suitability of judgement criteria information by gauging users' comprehension, difficulty level, information preference, and the adequacy of the volume of information. The methodology leveraged metrics from the Important Performance Analysis (IPA)—a technique widely used across numerous service sectors, including healthcare and public policy, for strategy development. The IPA examines elements such as importance and performance. In addition, health literacy measures from tools like the Test of Functional Health Literacy in Adults (TOFHLA) were used, which evaluate comprehension (Reading) and numerical skills (Numeracy).

The survey was conducted online, involving a total of 480 adults from South Korea in their 30s, 40s, and 50s who were eligible for general health screenings. Recruitment was executed via online panel services, targeting 80 individuals per age and gender group. Following recruitment, participants were categorized into one of six groups based on their age (30s, 40s, 50s) and gender (male, female). The survey excluded individuals in their 20s due to their lower health screening rates, as well as those aged 60 and above, based on a '2020 Senior Citizen Status Survey' published by the Ministry of Health and Welfare, which reported that 74.1% of the elderly had difficulties with online information services and digital device usage. The survey spanned six days, from December 9th to December 14th, 2022.

The survey procedure involved presenting participants with two distinct health examination result types, referred to as Type A and Type B. Participants were then asked to answer questions assessing both their objective understanding and subjective perception of these results. The survey comprised twelve questions: two each for comprehension, difficulty level, information preference, and the appropriateness of the volume of information, along with one open-ended opinion question and three questions related to sociodemographic variables (age/gender/previous health screening experience). Participants with fewer than two health screenings in the past decade were excluded due to potential discrepancies in understanding examination procedures and medical terminology. In Korea, health screenings are typically conducted every two years. The details of the survey questions are described in Table 1.

Table 1. Primary Survey Questions

No.	Category	Method	Content
Q1/2	Comprehension	Multiple Choice	Questions assessing the accuracy of the respondent's comprehension of the presented information, with a focus on judgment calls based on current hypertension (systolic/diastolic) values
Q3/4	Difficulty Level	Likert 5-point Scale	Questions measuring the subjective difficulty in understanding the presented information, using a 5-point scale ranging from 1 (easy) to 5 (difficult)
Q5/6	Information Preference	Multiple Choice	Questions asking respondents to select their preferred information type from the two options provided

Q7/8	Adequacy of Information Volume	Likert 5-point Scale	Questions evaluating the respondent's subjective perception of the adequacy of the amount of information, rated on a 5-point scale from 1 (insufficient) to 5 (sufficient)
Q9	Subjective Perception (Additional Opinions)	Open-ended	Question soliciting the reasons behind their evaluations of difficulty, information preference, and the adequacy of information volume
Q10/11/12	Sociodemographic Variables	Multiple Choice	Questions on age/gender, aiming to detect possible variations in responses based on these variables

The collected survey data were intended to test the following hypotheses:

1. H1 [Comprehension]: Type A will be better understood than Type B (H1a), and there will be no significant differences based on gender (H1b) or age (H1c).
2. H2 [Difficulty Level]: Type A will be perceived as less difficult than Type B (H2a), and there will be no significant differences based on gender (H2b) or age (H2c).
3. H3 [Information Preference]: Type A will be preferred over Type B (H3a), and there will be no significant differences based on gender (H3b) or age (H3c).
4. H4 [Adequacy of Information Volume]: Type A will be perceived as having less information than Type B (H4a), and there will be no significant differences based on gender (H4b) or age (H4c).

3.3 Analysis of primary survey results

3.3.1 H1: Comprehension

The comprehension data for Types A and B were initially examined through frequency analysis to establish the overall accuracy rate. This was followed by employing a proportion test to detect any notable differences according to type (H1a). To discern differences predicated on gender (H1b) and age (H1c), a chi-square test was conducted to identify any significant variances in the accuracy rate across these particular variables. Table 2 represents the correct response rates of each item, categorized by type, gender, and age.

Table 2. Comprehension (Correct Response Rate) of Types A and B

Category		Type A		Type B		(n)		p-value	
Total		266	55.42%	244	50.83%	480	100.00%	one-sample proportion	0.14
Gender	Male	135	56.25%	113	47.08%	240	100.00%		
	Female	131	54.58%	131	54.58%	240	100.00%		0.32
Age	30s	101	63.13%	100	62.50%	160	100.00%		
	40s	87	54.38%	85	53.13%	160	100.00%	Chi-Squared	0.42
	50s	78	48.75%	59	36.88%	160	100.00%		

According to the frequency analysis, out of a total of 480 participants, the correct response rate for Type A was 55.42% (266 individuals), and for Type B, it was 50.83% (244 individuals). This suggests

that there was no significant difference (H1a) between the two groups (p = 0.14). Similarly, the chi-square test results did not indicate any significant divergence in responses based on gender (H1b) (p = 0.32) or age (H1c) (p = 0.42).

As a result, although Type A exhibited a higher correct response rate than Type B for H1 [Comprehension], this difference did not reach statistical significance. Thus, the hypothesis suggesting no difference in responses based on gender and age (H1b, H1c) was partially validated.

3.3.2 H2: Difficulty Level

The difficulty level data for Types A and B were collected using a 5-point Likert scale. A normality distribution test of this data indicated a deviation from a normal distribution (p < .001). Therefore, the Wilcoxon rank-sum test was executed to evaluate differences depending on the type (H2a) and gender (H2b). Concurrently, the Kruskal-Wallis test was applied to assess differences resulting from age (H2c). Table 3 illustrates the differences in difficulty level as per type (H2a), gender (H2b), and age (H2c).

Table 3. Difference in Difficulty Level According to Type (H2a), Gender (H2b), and Age (H2c)

	Group	Type	mean	p
H2a	All	A	2.64	0.35
		B	2.71	
	M	A	2.67	0.99
		B	2.69	
	F	A	2.60	0.20
		B	2.73	
	30s	A	2.71	0.81
		B	2.76	
	40s	A	2.55	0.40
		B	2.65	
	50s	A	2.65	0.60
		B	2.73	

	Type	Gender	mean	p
H2b	A	M	2.67	0.45
		F	2.60	
	B	M	2.69	0.61
		F	2.73	

	Type	Age	mean	p
H2c	A	30s	2.71	0.39
		40s	2.55	
		50s	2.65	
	B	30s	2.76	0.63
		40s	2.65	
		50s	2.73	

The results demonstrated that Type B (mean = 2.71) was relatively more difficult than Type A (mean = 2.64), but the disparity in difficulty levels between the two types was not statistically significant (p = 0.35). Furthermore, both Types A and B did not exhibit any significant variations concerning gender (H2b) and age (H2c). As a result, the hypotheses associated with the differences in difficulty level based on gender (H2b) and age (H2c) were accepted due to the lack of statistically significant discrepancies.

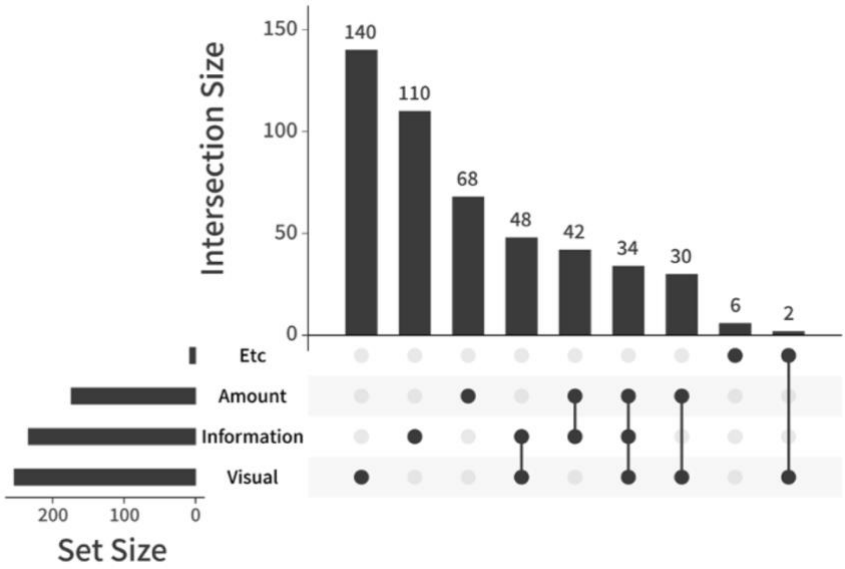


Figure 4. Subjective Opinions Pertaining to Difficulty.

As demonstrated in Figure 4, subjective opinions regarding factors that impact difficulty were compiled. This compilation revealed that visualization elements, such as gradient graphs and tables – particularly noted in the context of Type A and Type B – significantly influence perceived difficulty. This insight was gathered from responses where participants identified the utility of tables and graphs as the main reasons for their preference for a specific type. As a result, 'visualization' was identified as the most commonly selected factor affecting difficulty among participants, with a total of 254 individuals citing it as a contributing factor.

3.3.3 H3: Information Preference

For Type A and Type B, a frequency analysis was initially conducted to understand the overall preferences for information. Subsequently, to further investigate the reasons underlying these preferences, open-ended responses were collected and analyzed.

Table 4. Preference for Information in Types A and B

Category		**Type A**		**Type B**		**(n)**		**p-value**	
Total		387	80.63%	93	19.38%	480	100.00%	one-sample proportion	**< .001**
Gender	**Male**	189	78.75%	51	21.25%	240	100.00%		0.36
	Female	198	82.50%	42	17.50%	240	100.00%		
Age	**30s**	128	80.00%	32	20.00%	160	100.00%	Chi-Squared	0.59
	40s	133	83.13%	27	16.88%	160	100.00%		
	50s	126	78.75%	34	21.25%	160	100.00%		

As demonstrated in Table 4, a substantial difference (H3a) emerged based on the type of information. Of the 480 participants, 387 (80.63%) expressed a preference for information from Type A, while 93 participants (19.38%) preferred the information from Type B. Statistical testing uncovered a significant discrepancy between these two groups ($p < .001$). No substantial disparities were found when

considering variables such as gender (H3b; p = 0.36) or age (H3c; p = 0.59). Hence, the hypothesis concerning preference for information (H3) suggested a stronger inclination towards Type A (H3a). Given that no divergent opinions were uncovered, even after incorporating variables such as gender and age, the hypothesis on information preference (H3) was accepted.

Additional analysis of the open-ended responses revealed a majority preference for Type A, which provided a five-step blood pressure examination, over Type B. The reason behind this preference was the opportunity to gain a clearer understanding of their current health status, made possible by the more detailed information provided by Type A.

3.3.4 H4: Adequacy of Information Volume

Data on the adequacy of the volume of information for Types A and B was collected using a 5-point Likert scale. Given the non-normal distribution of the data (p < .001), the Wilcoxon rank-sum test was employed to discern differences based on type (H4a) and age (H4b). Meanwhile, the Kruskal-Wallis test was utilized to ascertain gender-based variations (H4c). The outcomes of these analyses are depicted in Table 5.

Table 5. Variations in the Adequacy of Information Volume Based on Type (H4a), Gender (H4b), and Age (H4c)

H4a

Group	Type	mean	p
All	**A**	3.80	<.001
	B	3.16	
M	**A**	3.76	<.001
	B	3.15	
F	**A**	3.83	<.001
	B	3.17	
30s	**A**	3.84	<.001
	B	3.07	
40s	**A**	3.77	<.001
	B	3.15	
50s	**A**	3.78	<.001
	B	3.25	

H4b

Type	Gender	mean	p
A	**M**	3.76	0.47
	F	3.83	
B	**M**	3.15	0.88
	F	3.17	

H4c

Type	Age	mean	p
A	**30s**	3.84	0.54
	40s	3.77	
	50s	3.78	
B	**30s**	3.07	0.21
	40s	3.15	
	50s	3.25	

As reflected in the table, a statistically significant difference in the adequacy of the quantity of information was found depending on the type (H4a), with Type A (mean = 3.80) being rated as providing a more adequate amount of information than Type B (mean = 3.16) (p < .001). Detailed analyses of information volume for Types A and B, divided by gender and age, showed that Type A's information was assessed as more suitable, and the difference was statistically significant (p < .001). Therefore, the hypothesis regarding the difference according to type (H4a) was accepted. Furthermore, no notable variations were detected in the adequacy of the volume of information for both types based on gender and age.

As a result, the hypotheses concerning variations based on gender (H4b) and age (H4c) were also accepted, given that they did not manifest any statistically significant differences.

3.3.5 Findings from the primary investigation

The administration of the survey substantiated the acceptance of Hypotheses H3 [Information Preference] and H4 [Appropriateness of Information Volume]. An analysis of the responses indicated that there was no significant difference in the levels of comprehension and complexity between the two health examination types, A and B, which were presented in the survey. In addition, the survey determined that Type A, offering an appropriate amount of information, was preferred. As a result of this investigation, it was inferred that respondents had no difficulty understanding more detailed diagnostic criteria than currently available, expressed a preference for such refined information, and considered 'visualization elements' as a crucial factor impacting the complexity of the information.

The results of the primary investigation set the foundation for the subsequent survey, aiming to examine the comprehension levels and preferences for information, with a particular focus on various visualization elements. Therefore, in preparing the design for the second survey, the five-stage diagnostic criteria from the Korean Society of Hypertension was utilized under the 'Information Volume' category, and different visualization elements were implemented to create the design.

4 Public PHR visualization case studies

4.1 Domestic public health check visualization case studies

Prior to conducting the subsequent survey, visualization examples related to health examination criteria provided by domestic public institutions were reviewed. In South Korea, as the majority of hypertension diagnostic criteria were found to be similar to those previously introduced, this section intends to present visualization examples associated with health check results. There are three primary types of public PHR services domestically. Figure 5 illustrates the visualization of health examination results within each service: (a) represents the 'My Health Record' app, (b) signifies the printed health examination results sheet, and (c)denotes the examination results from the 'The Health Insurance' app, including the hypertension component. Both (a) and (c)employ a tabular format, while (b) utilizes a horizontal bar graph. Notably, (b) differentiates the diagnostic criteria into 2-3 levels for each test item, denotes the range via intensity levels, and exhibits the numeric results and status of the examinee on the graph.

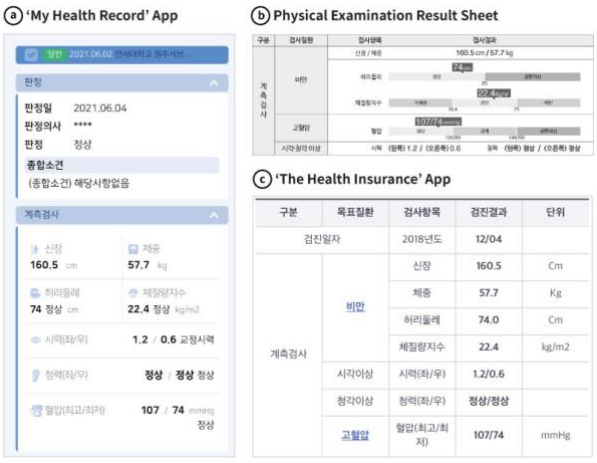


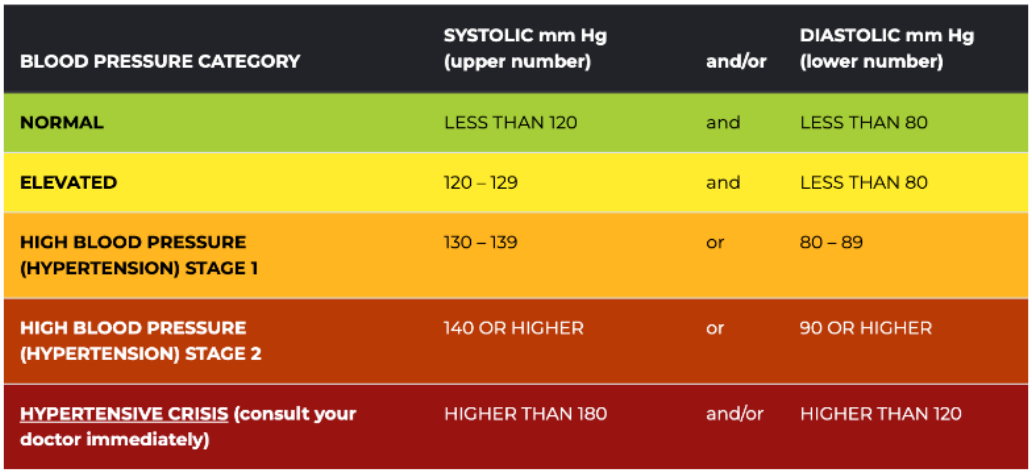
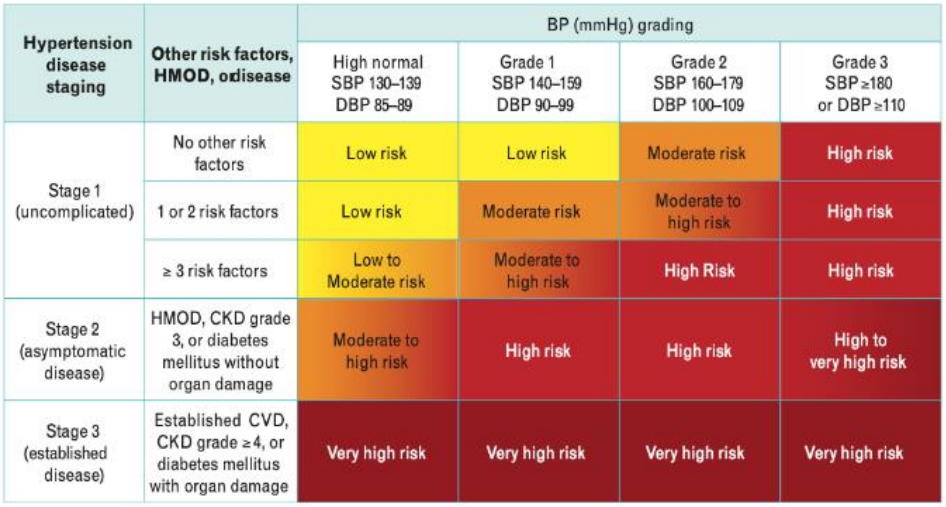
Figure 5. Domestic Public PHR Health Examination Result Visualization Examples. Source: (a) 'My Health Record' App, (b) Physical Examination Result Sheet, (c)'The Health Insurance' App

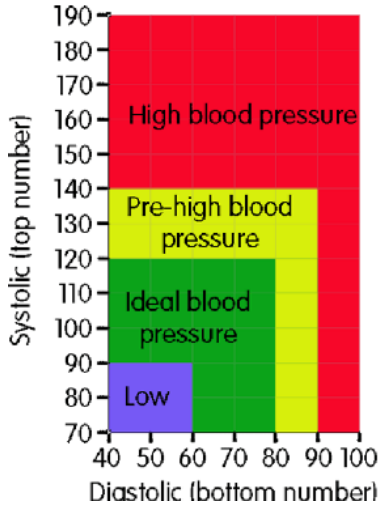
4.2 International Public Health Examination Visualization Case Studies

This section intends to introduce examples provided by public institutions and organizations from the United States, Europe, and the United Kingdom, among other countries, concerning overseas public health examination diagnostic visualizations. Given that personal health examination results are inaccessible, this paper provides examples of diagnostic criteria visualizations.

Overall, visualizations were implemented in the form of tables and graphs, with some differences noticeable in their detailed representations. Table 6 showcases these visualization examples along with their respective characteristics.

Table 6. Hypertension Diagnostic Criteria Visualization Examples

Visualization of criteria for determining hypertension	
AHA	
	Presented in a tabular format Stages are distinctly separated using colors, with a sequence from green to yellow to orange to red denoting the escalating risk of hypertension
ESH	
	Different colors are employed from the 'high normal' stage, which has a direct correlation with hypertension, onwards, with each numerical value assigned a unique shade Risk levels are indicated using shades of yellow, orange, and red, with gradients illustrating relative risk levels at intermediate stages

UK		An area graph is produced with diastolic blood pressure values on the x-axis and systolic blood pressure values on the y-axis Solid colors, ranging from blue (inclusive of the hypotension stage) to green, yellow, and red, are used

5 Secondary research: appraisal of visualization

5.1 Design for the survey

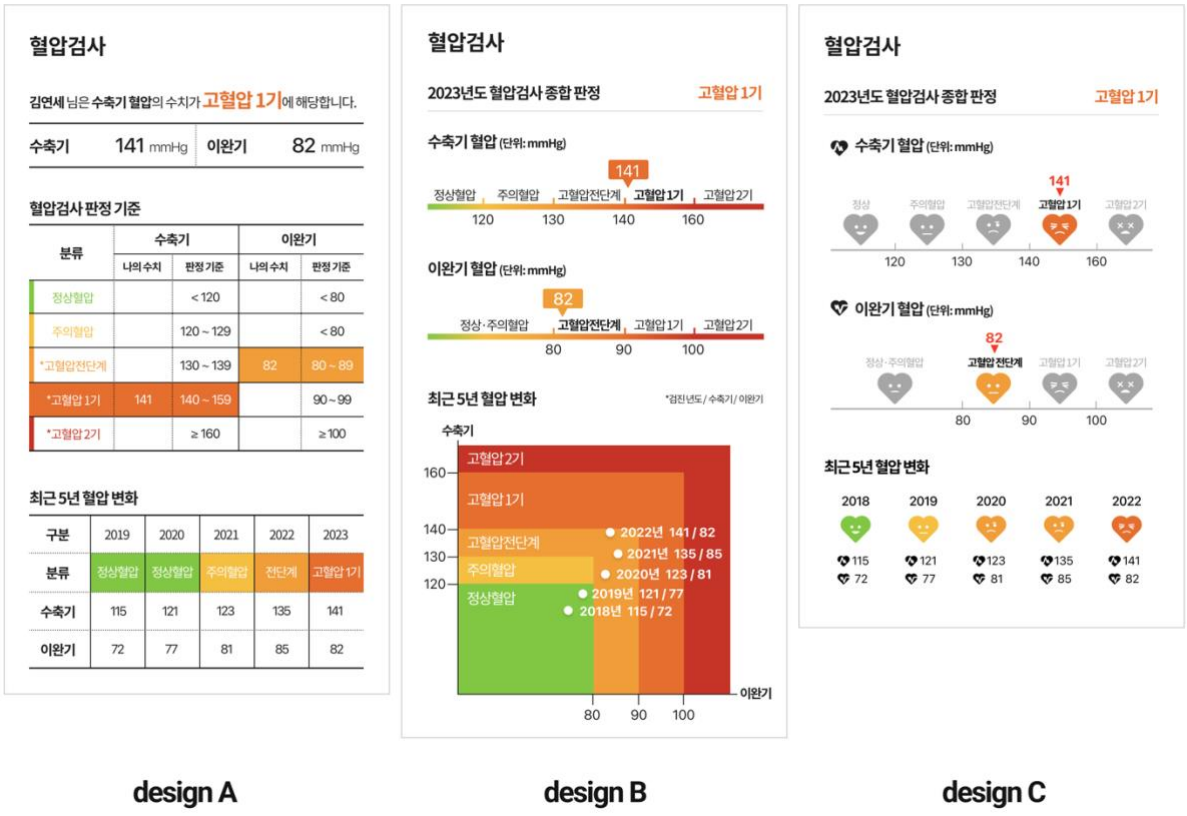


Figure 6. Secondary Survey Design

The design for the second round of the survey, as illustrated in Figure 6, incorporated three unique modes to exhibit the results of blood pressure tests. Primarily intended for a Personal Health Record (PHR) application on a mobile platform, all designs maintained a uniform volume of information. The decision-making criteria were established based on a five-tier system derived from the results of the

initial survey. In addition, these designs included data on the past five years' examination results to showcase trends compared to the preceding year. Each design employed a different visualization method: Design A was table-based, Design B focused on graphs, and Design C utilized an icon-based approach. This strategy improved upon conventional visualization techniques (tables and graphs) to foster easier comprehension and introduced a graphic icon style for a more user-friendly design. The staged color representation was rooted in 'The Health Insurance's PHR information design used in the initial survey.

5.2 Survey structure and methodology

The second survey was designed to verify the effectiveness of the three designs developed based on the findings from the initial survey. It was conducted online with a balanced participation of male and female respondents aged between 30 and 50. Each age group comprised 10 individuals, resulting in a total of 30 participants.

The survey consisted of 20 questions, categorized into segments concerning sociodemographic variables for each design, understanding (both objective and subjective), preference, and subjective opinions (on comprehension and preference). Table 7 outlines the arrangement of these questions.

Table 7. Secondary Survey Questions

No.	Category	Method	Content
Q1~3	Sociodemographic Variables	Multiple Choice	Gathered participant information (gender/age/health examination status) for the purpose of maintaining a balanced distribution of age and gender
Q4~9	Comprehension (Objective)	Multiple Choice	Provided multiple-choice questions to ascertain whether the information presented in designs A/B/C was accurately comprehended. Respondents who failed to answer all questions correctly were excluded from responding to the subsequent queries
Q10~12	Comprehension (Subjective)	Likert 5-point Scale	Assessed understanding of designs A/B/C using a Likert scale (Scale-5), with lower scores indicating easier comprehension (1 point: easy – 5 points: difficult)
Q13~16	Preference	Likert 5-point Scale	Measured preference for designs A/B/C using a Likert scale (Scale-5), with higher scores indicating greater preference (1 point: not preferred – 5 points: preferred)
Q17/18	Subjective Opinions (Preference)	Subjective	Participants were asked to select one design from A/B/C that they preferred the most and to provide their reasons for the selection
Q19/20	Subjective Opinions (Comprehension)	Subjective	Participants were asked to choose one design from A/B/C that they found most comprehensible and to explain their choice

5.3 Analysis of secondary survey results

As demonstrated in Table 8, the results of the secondary survey indicate the comprehension and preferences towards each design.

Table 8. Comprehension, preferences, and subjective views regarding Designs A, B, and C

Design	Comprehension (mean)	Subjective Opinion	Preference (mean)	Subjective Opinion
A	2.40	"Severity is indicated through color, and immediate identification is possible via the wording." "Intuitive comparison is enabled through the color application corresponding to table cells."	3.10	"Due to clear segmentation of each cell, there is no chance of information misinterpretation, and exact values can be easily confirmed."
B	2.67	"It is possible to intuitively ascertain the level of one's measurements within the relevant judgment."	3.27	"The overall assessment results are easy to understand, and the increasing deterioration is readily apparent through the graph."
C	2.03	"The health status for each year can be instantly recognized through the icons. By rendering areas of non-relevance in black and white, fewer colors are used compared to other designs, thus offering clearer and more immediate information."	3.93	"The expressions of the icons are friendly and seem to alleviate psychological pressure. In contrast to other designs, which only convey information and might thus feel too rigid, the use of icons provides the appealing sense of an infographic."

All three designs received comprehension scores of less than 3 points (indicating average understanding), suggesting that participants generally did not struggle to understand them. Notably, Design C was rated highest for comprehension (mean = 2.03), followed by Design A (mean = 2.40) and Design B (mean = 2.67). Based on the participants' subjective opinions regarding comprehension, the use of fewer colors and simplistic icons were beneficial to the understanding of Design C. When discussing preferences, participants mentioned that while health-related information can be serious, the utilization of icons allowed for a more comfortable reception of the information. Furthermore, Design A was praised for the intuitive differentiation and comparison of judgements facilitated by the use of numbers and colors on the table. Design B was commended for the ability to easily discern the current range of hypertension judgments and the areas within which systolic-diastolic blood pressure falls, using the graph.

The visual appeal of each design was evaluated at a score of above 3 points (indicating average liking), reflecting an overall preference above the mean across all designs. Specifically, Design C emerged as the most preferred (mean = 3.93), followed by Design B (mean = 3.27) and then Design A (mean = 3.10). According to the subjective feedback, the most appreciated feature of Design C was its ability to deliver health-related information in a more user-friendly manner through icons. Additional comments highlighted that Design B enabled easy comprehension of changes in assessment results, while Design A was commended for its explicit demarcation of information facilitated by tables.

To summarize, factors that enhanced participants' understanding of Personal Health Record (PHR) information included intuitiveness of design, while factors linked to the level of information acceptance contributed to higher preference scores. This infers that the provision of PHR services

requires visualizations that can bolster ease of understanding and elevate the level of information acceptance, accomplished by incorporating intuitive and familiar elements.

Compared to Designs A and B, which used common table or graph formats typical in existing PHR data, Design C, employing graphic icons depicting a step-by-step progression of facial expressions, was presumed to receive the highest scores in both understanding and preference. Contrary to the conventional presentation of a three-tier judgment criteria, this study extended to a five-tier criteria and included data from the past five years, thereby increasing the overall volume of information. This might have led to the selection of a more straightforward and intuitive visualization format. Nevertheless, this study emphasizes the need for more intuitive methods to map PHR information structure to visual elements, going beyond the conventional usage of tables and graphs.

6 Conclusion

This research has centered on surveying and analyzing user perspectives, with the aim of suggesting improvements and visualization strategies for health screening information in domestic public Personal Health Record (PHR) services. The first stage of the user investigation focused on the appropriateness of information composition regarding examination judgment stages. The second stage surveyed user understanding and preference concerning various visual variables based on the results from the first stage of investigation. Key findings revealed that 1) users experienced no difficulty comprehending a more nuanced health screening judgment scale, showing a clear preference for this level of detail, visualization emerged as the most influential factor affecting the perceived difficulty of information. 2) Moreover, it was observed that users favored visualization techniques that increased both the intuitiveness and the receptivity of information. Notably, the application of graphic icons, designed to assist in the intuitive understanding of information and expressed in a straightforward and approachable manner, proved to be effective. This approach greatly influenced user preference in the visualization of PHR information.

With the high prevalence of mobile app usage for accessing PHR information, it is vital to establish standards and solutions for information organization and visualization tailored to the attributes of mobile platforms. This research aimed to discover suitable volumes of PHR information and potential visualization techniques that are effective on the small screen interfaces typical of mobile devices.

From a user standpoint, this research discussed what volume of information should be provided, such as health screening judgment criteria, and the corresponding visualization strategies. Nevertheless, the study faced certain limitations: the mobile online survey method could have posed participation difficulties for users over 60 years old, the research only addressed the ‘hypertension’ section of PHR information, and there’s a need for a more thorough examination of statistical significance concerning differences in visualization understanding and preference. Despite these limitations, this study’s findings are significant, providing insights into the considerations required for structuring and visualizing information when delivering public PHR information services via mobile platforms.

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