Who watches the watches: on the delivery of the specifications of smart wearable devices and recommendations on the related best practices

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ABSTRACT

Smart wearable devices have taken the market by storm. They are now their own device category on the consumer market, their popularity is unquestioned due to their ever-increasing set of functionalities and the vigorous competition between some of the biggest companies, and they seamlessly integrated into our everyday lives, as well as into professional contexts. New models appear on the market regularly, particularly since the sensory system of such devices is continuously developing, adding more ways of data acquisition and processing, along with projections and analyses. However, while the devices of certain subcategories are nearly identical with regard to their core functionalities, there may be significant differences in their specifications. Furthermore, the delivery of specifications towards the users is highly manufacturer-dependent and lacks coherent standardization. This is particularly relevant to professional contexts, such as defense, where individuals competently familiarizing themselves with their personal devices is essential. In this paper, we investigate the delivery of the specifications of the state-of-the-art smart wearable devices. We separately study the commonalities and best practices by device subcategories and usage contexts. We also highlight certain deviations on the current market and provide recommendations for the further evolution of such practices. The paper introduces the results of a study on documentation-related user behavior as well, in order to support future research.

Keywords: Smart wearables, wearable devices, wearable sensor technologies, assistive wearable technologies, device specification

1. INTRODUCTION

As mobile phones became predominantly "smart" over the last decade, other devices inevitably started following them on the road they paved. For the phones, being smart means providing additional features beyond the core functionality of making and receiving calls. In the early years of the smartphone era, Charlesworth defined smartphones as devices that "carry email client, Web browser, GPS functionality, desktop synchronisation tools, as well as organizer-type functions such as diary, contacts, notepad and voice recorder".[1] As his work predicted that "yesterday's smartphone is tomorrow's ordinary mobile", today's smartphones provide all of the above mentioned features and even more: high-bandwidth Internet connection, news feed, social media, mobile games, built-in camera(s), various real-time services and many more – the possibilities are endless.

The continuous development of mobile phones was enhanced by its synergies with the reduction of different electronic component sizes, making such components suitable for integration into different devices. Nowadays,

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people can live in smart homes, drive smart cars, have smart devices that can be connected with each other and form the Internet of Things (IoT). While some smart devices are rather large, many others are quite compact and may be worn on the surface of the body, such as head-mounted, ear-, arm- and body-worn devices.

Although smartphones have many built-in sensors (e.g., accelerometer, gyroscope, magnetometer, GPS etc.) and they can "assist individuals in maintaining a healthy lifestyle by keeping track of their everyday behaviors",[2] yet there are specific devices to support users in their healthy lifestyle more efficiently.[3] These devices are typically less universal than smartphones; in fact, the vast majority of such equipment is dedicated to very-well-defined purposes. Such purposes may include health-related features such as heart rate measurement, blood oxygen level measurement, step counting, exercise tracking, body composition estimation, complex sleep analysis and so many-many more. Beyond the support of personal health, these devices may offer features such as Near-Field-Communication-based (NFC-based) payment, notifications and handling of connected systems, speech-to-text messaging, and in the world of IoT, virtually anything. For example, solutions of the Intelligent Transport System (ITS) of a future smart city may rely on such devices to efficiently accommodate pedestrians into the traffic ecosystem.

The features and capabilities of smart wearables are communicated via documentation to the user. While the majority of device manufacturers provide electronic documentation online, the default format of such delivery is the user manual that accompanies the purchased device. However, such documentation may immensely vary along numerous metrics. This is due to multiple reasons. First of all, the market already includes a great number of manufacturers, and this number is gradually growing[*]. Trivially, the market itself is rapidly growing: "The shipment volume of smart wearables globally stood at 266.3 million units in 2020, and it is projected to reach 776.23 million units by 2026"[†]. Specifically for smartwatches, shipment volume is expected to reach 131.6 million units by 2023, according to the Worldwide Quarterly Wearable Device Tracker of the International Data Corporation[‡]. With so many different devices coming from so many different manufacturers, the diversity among the delivery of device information is not surprising. According to the classic work of Doll and Torkzadeh,[4] user documentation should be complete and well written, and it should describe step-by-step how to use the device. At first glance, such formulation of the essence of good user documentation may be difficult to capture due to the apparent ambiguity. However, the field of technical communication contains numerous metrics to evaluate such documentation. For example, a keyword analysis checks the frequency and relative positions of the relevant keywords within a paragraph or a section. The appropriate usage of keywords may improve the quality of the documentation. For example, according to Acrolinx[§], content findability is fundamentally affected by the location of keywords within sentences, paragraphs and chapters. Mark Baker, the author of *Every Page is Page One* stated that "the real findability problem is how to get readers from the wrong place deep within your content to the right place deep within your content"[¶].

On the level of standardization, the ISO 01.110 standard family[‖] on technical product documentation consists of 27 published standards and 5 standards under development. They provide a comprehensive set of guidelines related to the creation of documentation – which even covers diagrams – however; they do not address the means of evaluating the quality of existing technical documentation.

The more complex a device is, the more information needs to be conveyed through documentation. Smartwatches and smartbands provide an abundance of features, the usage of which might greatly differ by device or by manufacturer, therefore, proper documentation is needed for better global product quality and user experience. Furthermore, smart wearables are perceived by the scientific community as the next generation of ubiquitous electronic devices[5,6] – it is expected that in the near future, people will own and use smart wearables as they do smartphones today, even if the rate of device abandonment and replacement is high.[7,8] This further increases the relevancy of appropriate delivery of device capabilities and documentation of such devices.

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[*] https://www.statista.com/statistics/435944/quarterly-wearables-shipments-worldwide-market-share-by-vendor/

[†] https://www.mordorintelligence.com/industry-reports/smart-wearables-market

[‡] https://www.idc.com/tracker/showproductinfo.jsp?containerId=IDC_P31315

[§] https://docs.acrolinx.com/coreplatform/latest/en/findability/prioritize-your-target-keywords-and-check-your-content

[¶] https://everypageispageone.com/2013/05/28/findability-is-a-content-problem-not-a-search-problem/

[‖] https://www.iso.org/ics/01.110/x/

In this paper, we introduce the results of an extensive analysis on the delivery of the specifications of smart wearable devices. We use a set of quality metrics to investigate and classify the documentation of the state-of-the-art devices. The manufacturer-independent trends of the sector are assessed and the notable deviations in delivery are highlighted. Based on the output of the research, we provide a set of recommendations and potential modifications regarding the current practices. The paper separately addresses smart watches and smart bands; other smart wearable devices – such as smart clothing, body-worn cameras, head-mounted devices etc. – are out of the scope of this analysis.

In addition to the in-depth analysis, we present a study on documentation-related user behavior. We addressed a series of practical issues regarding the documentation of smart wearable devices and collected data from a diverse population pool.

The remainder of this paper is structured as follows: Section 2 reviews the related work. Section 3 analyzes the documentation of the devices of the consumer market along various metrics. Based on the results, relevant recommendations are given in Section 4, along with the discussion of best practices. Section 5 introduces a study on documentation-related user behavior. Additional topics of discussion are introduced in Section 6. The paper is concluded in Section 7.

2. RELATED WORK

The work of Wingkvist *et al.*[9] utilizes the traditional approach of employing software assessment to determine the quality of the documentation. Building on the metrics of Barkmann *et al.*[10] and Lincke *et al.*,[11] the authors proposed a quality model based on the Goal-Question-Metric (GQM) paradigm.[12] GQM is generally applicable to any product or system, and it can even be used for high-level entities as well, such as companies. The goal of the GQM paradigm is the focal point of the metric, which is tested by questions, and the response to questions are series of quantitative data. The proposed metric uses clone detection and test coverage, both of which are used to evaluate software. Clone detection in the context of documentation quality provides a percentage which describes how different, how unique two documents are. Test coverage addresses the structure of the documentation and determines the coverage of all the documents that can be reached via links and pointers.

Gemoets and Mahmood[13] studied the correlations between documentation quality and user satisfaction. Empirical tests were carried out to assess the subjectively perceived quality of the documents. The test participants were asked to rate a list of 15 quality aspects – such as ease of use, completeness, straightforwardness etc. – on a 5-point Likert-type scale (1: strongly disagree; 2: disagree; 3: neutral; 4: agree; 5: strongly agree). This was followed by 20 more questions related to user satisfaction, using a similar scale. The authors conclude that "a well-organized user documentation that provides formal instructions for the use of a system, clearly explains the system capability by describing the function of each program module or procedural step of the system, and thereby provides a means to review and judge the overall system" is preferred.

The empirical study of Garousi *et al.*[14] particularly focused on technical software documentation in the phases of development and maintenance. The questionnaire similarly used a Likert-type scale – from 1 (very low) to 4 (very high) – to collect data on usefulness, organization, visualization, relevance, precision, readability, completeness, accuracy, consistency, up-to-dateness and the usage of examples. The authors emphasize the differences found between the two phases, and conclude that the most important factors of software documentation are up-to-dateness, completeness and accuracy.

Møller argues in her work[15] that expert reviews should be combined with user tests. The work presents an example in which user manuals were assessed by older adults. The 10 test participants were from an age range between 55 and 77. They were each provided a digital photo frame which was to be used based on the information provided by the documentation. The results of the tests indicate that such users benefit from step-by-step instructions. On the other hand, foreign technical terminologies may be difficult to understand. Additionally, the test participants commonly preferred shorter manuals. Finally, the authors elaborate that they were surprised by the fact that the vast majority of the test participants did not use the glossary and the index.

The work of Allwood and Kalén[16] presents a two-phase evaluation of a patient administrative system. In the first phase, 30 nurses were asked to assess the system via a qualitative approach. For example, the difficult-to-understand portions of the manual were to be underlined. Additionally, each page was to be rated on a scale ranging from -3 to $+3$ regarding the usability, comprehensibility, readability, as well as the "interesting" and "stimulating" nature of the page. The obtained data was used to create a revised version of the documentation, and 27 of the nurses assessed had to perform specific tasks on the system, randomly provided either the original or the modified version. Data obtained from the second phase indicates that task completion time was significantly lower for those who received the revised documentation, and error rate was lower as well.

The recent book of Bhatti *et al.*[17] includes a comprehensive overview of the state-of-the-art documentation quality metrics and approaches. Quality in this context is defined as functional and structural quality. Functional quality corresponds to the core purpose of the document, and structural quality is derived from the presentation of information. Functional quality can be decomposed into being accessible, purposeful, findable, accurate and complete. The subcategories of structural quality are being clear, concise and consistent. The authors highlight that the number of potential quality metrics are virtually inexhaustible, and therefore, they should be narrowed down to a more focused set of metrics, in order to serve a well-defined purpose. In the following section, we detail the metrics chosen for the analysis and introduce the obtained results.

3. DOCUMENTATION ANALYSIS

3.1 Scope

The scope of our analysis is limited to documentation available in PDF format; we did not consider interactive and printed formats. We collected documents for 153 products from 5 major manufacturers. 28 devices were smartbands, and 125 were smartwatches.

3.2 Methodology

Input data was collected from the official product support websites in PDF format. The input file set was processed using the OCR and PDF parsing software ABBYY FineReader 15[**]. Sequential file input and structured output file storage was automated via a custom Python script running on Python 3.10. Whenever available, the text layer of the PDF was extracted, with OCR being used as a fallback method.

After recognition, the parsed content of each file was saved in HTML format to a separate output file. HTML was chosen as the output format since it offered the optimal balance between structural fidelity and ease of processing. Other potential candidates were Office OpenXML Word documents and plain text. The former was ruled out due to the induced processing overhead, while the latter was discarded because it did not offer a faithful representation of formatting and structure.

Next, the HTML file set was processed by using a different Python script developed for this purpose. Following the removal of superfluous structures – such as style sheet sections and meta nodes in the header – the script processed the content, and generated an output in CSV format.

3.2.1 Script

The analysis script operates by using the body section of the input HTML file as the content that is to be processed. After reading the file, it strips the input of the head and other unused sections, and proceeds to analyze the rest of the text.

Images in the content are identified based on the applicable image tag. Next, list item nodes, as well as ordered and unordered lists are counted. The number of external links is determined based on the frequency of references to external URLs.

Since the PDF parsing tool converts internal references into bookmark links, the script looks for unique bookmark ID elements to determine the number of such reference targets. These bookmarks may include chapter titles and other areas of interest.

The script also calculates the total number of heading tags for each heading level within the content. Chapter titles are usually formatted as headings; therefore, this approach provides insight into how the text is structured. This is complemented by the average number of words per chapter, which is also calculated by the script based on text content in relation to each heading level.

[**] https://pdf.abbyy.com/

3.3 Results

The results of the analysis are summarized in Table 1. The complete output of data collection is provided in Appendix A. The dataset reports the unique ID assigned to the device (Dev.), indicates whether the device is a smartband (B) or a smartwatch (W), provides the page number (Pp.), the number of images (Img.), unordered lists (Unord.), ordered lists (Ord.), list items (Items), internal references (Int.), external references (Ext.), heading types (h1–h6) and words (Words).

Metric	Smartbands	Smartwatches
Min. num. of pages	2	8
Avg. num. of pages	44.25	79.34
Max. num. of pages	128	182
Min. num. of words	347	1,832
Avg. num. of words	7,567.25	23,416.19
Max. num. of words	14,203	65,504
Min. num. of words per chapter	48.6	58.88
Avg. num. of words per chapter	143.37	187.44
Max. num. of words per chapter	437.37	491.68
Min. num. of lists	0	6
Avg. num. of lists	31.43	219.07
Max. num. of lists	78	485
Min. num. of unordered lists	0	5
Avg. num. of unordered lists	29.43	204.92
Max. num. of unordered lists	78	460
Min. num. of ordered lists	0	0
Avg. num. of ordered lists	2.00	14.15
Max. num. of ordered lists	10	47
Min. num. of list items	0	17
Avg. num. of list items	90.64	545.87
Max. num. of list items	258	1,428
Min. num. of internal references	10	19
Avg. num. of internal references	180.29	305.98
Max. num. of internal references	354	758
Min. num. of external references	1	0
Avg. num. of external references	9.25	10.70
Max. num. of external references	30	39
Min. num. of images	6	2
Avg. num. of images	36.68	56.97
Max. num. of images	123	209
Min. num. of images per page	0.41	0.14
Avg. num. of images per page	1	0.78
Max. num. of images per page	3	2.86

Table 1. Output of data analysis.

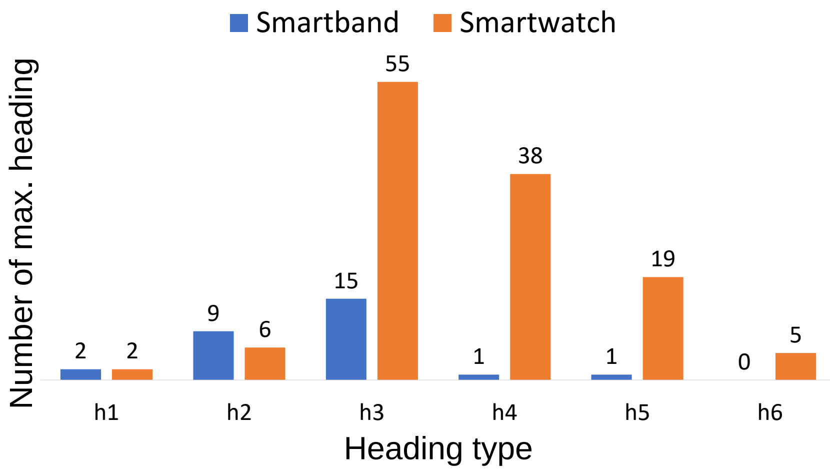

Figure 1. Number of maximum heading levels for the investigated smartband and smartwatch documentation.

First of all, compared to smartbands, the average number of pages is roughly twice as much in case of smartwatches. However, the average number of words presented over the course of those pages is more than three times of the corresponding value for smartbands. One assumption could be that words are compensated by images, based on the well-known adage: "a picture is worth a thousand words". However, on average, there are actually more words in the documentation of smartwatches. This may be due to the higher numbers of capabilities and functions of such devices.

The most significant differences are in terms of lists. On average, there are nearly 220 lists in the documentation of smartwatches, while the corresponding value for smartbands is less than 32. However, the lists for smartbands are typically longer in terms of list items (ratio of 2.88) compared to smartwatches (ratio of 2.49).

In case of smartbands, around 6.8% of the lists are ordered, and the rest is unordered. For smartwatches, this average value is precisely the same, indicating a common practice.

Regarding references, while there is no notable difference in terms of external references, the average number of internal references are 180.29 and 305.98 for smartbands and smartwatches, respectively. Yet, if we consider the average number of pages, we get roughly the same rate of 4 for internal references (4.07 and 3.86, respectively).

As for the aforementioned case of images, for smartbands, there is an image on every page on average, while for smartwatches, this number is 0.78. Having an image assigned to a specific text (e.g., instructions) is common practice. The lower number for smartwatches can be explained by the higher number of lists and longer lists in general – again, due to capabilities and functions.

One particular limitation of the analysis is the lack of publication date in the dataset. Although, most of the considered devices are more-or-less state-of-the-art solutions, and thus, there should be no major temporal difference between them, it would be interesting to see the intra- and inter-manufacturer trends as well in future work, which reflect the evolution of best practices. Technically speaking, there may be a trend that the average number of images per page increases over time. The testing of such hypothesis is yet to be performed.

The average number of words per chapter does not differ much between the documentation of smartbands and smartwatches. These outputs are independent from the volume of the documentation. Therefore, due to the small deviations in this regards, they also contribute to best practices and recommendations.

In terms of heading types, there is a major difference between smartbands and smartwatches. The distribution of the number of maximum heading levels by document is shown in Figure 1. It is apparent that heading types beyond `h3` are particularly rare in case of smartbands. Yet, for smartwatches, over 30% of the investigated documentation has `h4` as maximum heading, over 15% for `h5`, and 4% for `h6`.

4. BEST PRACTICES AND RECOMMENDATIONS

Based on the output of the analysis (see Appendix A), we can determine certain best practices and provide recommendations regarding the documentation of smart wearable devices:

- Lists are recommended for the documentation. They are more compact, straightforward alternatives for textual descriptions.
- Based on the complexity of the device, lists should contain 2 or 3 items on average. Longer lists are easily justifiable (e.g., for troubleshooting). However, lists should not span over several pages; they should be self-contained on a single page.
- Internal references help the reader navigate within the documentation. The documentation of a device should have references pointing to relevant / thematically-connecting parts of the document. Having 4 references per page on average – as seen in the analysis – is a good approach.
- Images support users in tasks related to functions, or in understanding their device. Therefore, using demonstrative images is greatly welcomed in the documentation. There should be roughly 1 image per page on average. Furthermore, there should be at least 1 image associated to a specific step list or descriptive part of the device.
- It is recommended to have descriptions with such content amount that is minimally necessary for the users to understand their devices or execute an instruction. Our analysis shows that this amount of words is around 150–200 words, therefore, we suggest that each chapter contains approximately 150–200 words. Longer chapters are not advised – yet may be justifiable in certain cases – while shorter ones are quite plausible.
- The number of maximum heading should be 3. If sufficiently justified, 4 or 5 are plausible as well. Going beyond `h5` is not advised.

5. STUDY ON DOCUMENTATION-RELATED USER BEHAVIOR

5.1 Research questions

The aim of the research is to explore current user behavior patterns related to documentation usage, and to address potential correlations between specific behavioral patterns. Data was collected via a questionnaire provided to volunteers. The questionnaire is detailed below.

5.2 Questionnaire

The questionnaire began with the collection of demographic information, such as gender, age, and highest level of education. No other information was collected about the volunteers and special care was taken to protect their anonymity; no volunteer can be identified via the demographic information.

The questionnaire addressed the motivation behind document usage, the frequency of document usage during product life cycle, the methods of information extraction and the formats (i.e., electronic or printed) of such documents. The majority of the questions separately investigated general electronic devices, smart devices and smart wearable devices. The complete list of items of the questionnaire (without the items on demographic information) are provided in Appendix B.

5.3 Results

A completed questionnaire was considered valid only if each and every question was answered. Since every volunteer completed the questionnaire correctly, no data was discarded. The questionnaire was completed by 105 individuals. 54 (51.4%) were male and 51 (48.6%) were female. The age of the volunteers varied between 22 and 72, and the average age was 40. 21 (20%) and 2 (1.9%) of the volunteers did and did not hold a high school degree, respectively, 25 (23.8%) went to college, 45 (42.9%) finished a university program, and 12 (11.4%) completed post-graduate education (e.g., Ph.D. degree).

The figures of the analysis are provided in Appendix C. Based on the results, we can conclude the following:

- The documentation of general electronic devices is commonly viewed prior to first usage. This is not applicable to smart devices and smart wearables; users rely more on intuitive usage.
- For all devices, the most frequent purpose of viewing the documentation is troubleshooting. Meanwhile, the most frequent "other" answer was that individuals attempt to find the solution or help on the Internet.
- The most preferred format of device documentation is the online format (PDF).
- Those who prefer the interactive documentation format do not usually have access to such.
- Individuals with higher levels of education are more likely to access the documentation for troubleshooting purposes for general electronic devices.
- General electronic devices are typically reset based on documentation by those with higher levels of education.
- The documentation of smart devices and smart wearable devices is rarely used for device reset purposes.
- Those who tend to completely ignore device documentation are typically younger individuals and those with higher level of education.
- Smart wearable devices are mostly used by younger and older individuals; it is less frequent among those in their 40s and 50s.
- Female users are much less likely to attempt resetting a general electronic device based on the documentation.
- Female users more frequently access the documentation of general electronic devices and smart devices.
- Comparing users with close connection (e.g., technical writers) and loose connection (i.e., professional documentation users, who need technical documentation for their daily occupations, e.g., developers) with user manuals to average users, we conclude that users with loose connection are likely to start using the newly purchased devices (general electronic, smart and smart wearable devices) and they open user manuals only if they encounter difficulties. Others are more likely to access the documentation.
- For general electronic devices, users with close connection with user manuals are more likely to access user manuals and they access them more frequently.
- For smart devices, users with loose connection with user manuals are less likely to access user manuals and they rely more on intuition.

The miscellaneous answers contain interesting insights to user behavior. Many of them reveal rather personal motivations. For example, one individual noted the following as a reason for accessing device documentation:

> "I read the documentation if I attempt to resolve the issue without my husband,
> who is a computer engineer."

6. DISCUSSION

In this section, we briefly discuss the investigated area of the paper in defense applications. More specifically, we consider such devices and their documentation in use by military personnel.

Intelligent electronic devices and advanced tracking solutions have a long history in the army. For example, already "in 1996, the first smart shirt was created when the U.S. Navy's Defense invested on a research project a technology institution in Georgia to track the physical condition of soldiers",[3] as emphasized by the works of Park *et al.*[18] and Wright *et al.*[19] Today, the equipment provided to military personnel is smarter than ever and capable of countless functionalities.

The most common practice for introducing such new technologies to military personnel is through education; it is mandatory for them to participate in training courses dedicated to the use of the device. Indeed, such approach may be considered more time-efficient than other alternatives. Still, it should be noted that documentation is provided to military personnel for on-demand usage.

However, for the sake of efficiency, such documentation is provided in concise variations. Additionally, such excerpts are typically available in printed format instead of digital content. These two statements have strong synergies, since longer, more detailed documentation not only increases the expected time for information retrieval, but also requires more physical space and has more total weight.

On the other hand, reducing the length of documentation puts more pressure on the quality-related aspects. Technically, the same information needs to be conveyed in fewer pages (i.e., fewer words and figures). This also limits the potential redundancies for the transfer of safety-critical and other vital types of information.

In our analysis, the average page number and word number of the documentation of the investigated smart watches were 79.34 and 23,416.19, respectively. It is a reasonable, failure-resistant approach to provide printed documentation to military personnel. Yet this also means that digital functions such as searching are not available. Efficiently finding a very specific piece of information in an eighty-page-long document is not necessarily a trivial task. Having shorter documents cannot be avoided.

Unfortunately, reducing the available space to deliver information may evoke the potential of quality-metric-related degradation. This is particularly applicable to "completeness", which is among the most essential attributes of technical documentation. While shortening the written content does contribute to straightforwardness, it raises the question whether the documentation still contains every single bit of information that may be relevant to the user of the device.

7. CONCLUSION

In this paper, we presented our research on the delivery of the specifications of smart wearable devices. The appendices of the paper provide an extensive dataset on the analysis of 153 smart wearable devices and a study on documentation-related user behavior, completed by 105 individuals. In future research, apart from addressing the evolution of documentation in terms of the number of images, the correlation between user behavior, the functional complexity and the price of the device shall be addressed.

APPENDIX A. COLLECTED USER MANUAL DATA

Dev.	Type	Pp.	Img.	Unord.	Ord.	Items	Int.	Ext.	h1	h2	h3	h4	h5	h6	Words
1	B	41	25	14	2	34	222	9	13	55	6	0	0	0	5246
2	B	49	31	14	3	55	262	7	14	66	7	0	0	0	6982
3	B	33	25	7	1	22	172	10	11	37	8	0	0	0	4855
4	B	40	37	15	1	49	213	13	11	51	9	0	0	0	6571
5	B	46	39	16	1	50	240	11	12	59	9	0	0	0	7587
6	B	46	42	42	0	124	246	12	15	62	0	0	0	0	9132
7	B	65	49	29	5	76	324	8	17	77	14	0	0	0	10176
8	B	66	46	36	6	93	351	10	18	82	17	0	0	0	11503
9	B	71	49	33	8	92	354	8	14	83	21	0	0	0	12904
10	B	33	24	27	3	129	181	10	12	44	23	0	0	0	6864
11	B	34	14	46	0	184	149	11	1	1	1	13	46	0	8363
12	B	33	24	21	0	66	185	30	1	12	48	0	0	0	6449
13	B	37	24	49	3	181	233	25	1	10	38	35	0	0	8404
14	B	33	17	42	3	158	113	19	12	44	0	0	0	0	7121
15	B	65	44	29	7	70	324	7	15	81	12	0	0	0	11047
16	B	48	37	20	2	50	237	9	13	58	8	0	0	0	6560
17	B	58	41	23	6	62	288	9	14	70	12	0	0	0	8296
18	B	61	33	30	4	67	339	7	13	80	20	0	0	0	10600
19	B	69	78	77	0	258	82	4	4	29	0	0	0	0	14203
20	B	61	78	78	0	250	87	4	4	29	0	0	0	0	13599
21	B	2	6	0	0	0	10	1	1	4	0	0	0	0	347
22	B	38	18	62	0	132	144	7	6	25	23	0	0	0	6888
23	B	46	58	56	0	186	51	4	4	15	0	0	0	0	10307
24	B	8	14	6	0	10	24	2	1	11	0	0	0	0	1243
25	B	8	15	6	0	10	24	2	1	11	0	0	0	0	1246
26	B	128	123	34	1	88	150	17	75	0	0	0	0	0	12464
27	B	13	21	6	0	14	18	1	9	0	0	0	0	0	1332
28	B	7	15	6	0	28	25	2	1	10	0	0	0	0	1594
29	W	49	39	50	1	149	255	15	1	16	64	0	0	0	9540
30	W	78	49	43	3	127	386	13	15	89	24	0	0	0	14383
31	W	93	54	72	6	175	451	9	17	103	30	0	0	0	17849
32	W	49	49	64	3	233	59	8	1	1	1	16	0	0	11241
33	W	82	52	40	5	109	423	11	19	102	20	0	0	0	14879
34	W	91	52	72	4	165	457	9	17	108	27	0	0	0	17447
35	W	81	54	49	5	137	384	13	15	90	23	0	0	0	14691
36	W	12	8	42	0	104	99	11	3	32	11	3	0	0	5655
37	W	10	5	35	4	92	79	4	4	28	6	0	0	0	4483
38	W	16	9	97	2	248	196	10	2	51	32	12	0	0	11235
39	W	26	18	147	20	415	304	25	3	78	62	8	0	0	21924
40	W	46	42	251	20	768	452	34	1	94	101	25	1	0	34287

Table 2. Output of data collection: device 1–40

Dev.	Type	Pp.	Img.	Unord.	Ord.	Items	Int.	Ext.	h1	h2	h3	h4	h5	h6	Words
41	W	54	30	367	23	1103	640	39	2	119	161	29	1	0	54205
42	W	58	19	434	25	1343	693	36	3	116	157	56	6	0	59834
43	W	130	23	424	31	1346	620	35	0	102	138	50	15	0	63469
44	W	132	23	427	34	1361	629	35	0	103	140	51	15	0	64116
45	W	90	29	312	28	945	520	31	0	95	128	32	2	0	43451
46	W	54	17	172	19	528	330	22	0	72	76	15	0	0	23154
47	W	64	22	225	18	699	392	23	0	81	90	23	0	0	29530
48	W	114	39	399	26	1200	644	34	0	115	150	53	0	0	56292
49	W	124	43	427	35	1303	704	34	0	120	160	62	4	1	60851
50	W	30	14	220	18	692	365	29	3	79	81	16	1	0	29534
51	W	68	19	222	20	683	394	26	0	87	84	24	0	0	30347
52	W	38	19	109	0	297	202	19	1	69	27	3	0	0	15003
53	W	128	31	436	47	1428	716	37	1	137	166	47	2	0	63106
54	W	58	22	445	25	1343	743	38	6	131	173	48	5	0	62250
55	W	24	15	163	0	443	306	25	2	59	81	7	0	0	21179
56	W	62	20	460	25	1416	758	38	3	126	166	67	8	0	65504
57	W	74	18	238	21	734	398	34	0	89	82	24	0	0	32720
58	W	68	20	222	20	682	395	26	0	87	84	24	0	0	30262
59	W	12	13	34	1	85	94	10	2	31	7	5	0	0	5930
60	W	12	9	23	0	74	70	8	1	22	10	0	0	0	4328
61	W	36	13	117	0	323	204	20	0	65	32	4	0	0	16055
62	W	18	14	102	0	287	190	21	3	59	28	4	0	0	14358
63	W	133	170	210	39	677	379	4	4	41	104	0	0	0	35815
64	W	133	170	210	39	677	379	4	4	41	104	0	0	0	35815
65	W	117	67	197	34	753	363	5	4	52	89	0	0	0	31746
66	W	117	67	197	34	753	363	5	4	52	89	0	0	0	31746
67	W	117	67	197	34	753	363	5	4	52	89	0	0	0	31746
68	W	117	67	197	34	753	363	5	4	52	89	0	0	0	31746
69	W	117	67	197	34	753	363	5	4	52	89	0	0	0	31746
70	W	117	67	197	34	753	363	5	4	52	89	0	0	0	31746
71	W	117	67	197	34	753	363	5	4	52	89	0	0	0	31746
72	W	117	67	197	34	753	363	5	4	52	89	0	0	0	31746
73	W	135	172	203	43	666	373	4	4	41	101	0	0	0	35859
74	W	117	67	197	34	753	363	5	4	52	89	0	0	0	31746
75	W	117	67	197	34	753	363	5	4	52	89	0	0	0	31746
76	W	117	67	197	34	753	363	5	4	52	89	0	0	0	31746
77	W	117	67	197	34	753	363	5	4	52	89	0	0	0	31746
78	W	117	67	197	34	753	363	5	4	52	89	0	0	0	31746
79	W	117	67	197	34	753	363	5	4	52	89	0	0	0	31746
80	W	117	67	197	34	753	363	5	4	52	89	0	0	0	31746

Table 3. Output of data collection: device 41–80

Dev.	Type	Pp.	Img.	Unord.	Ord.	Items	Int.	Ext.	h1	h2	h3	h4	h5	h6	Words
81	W	117	67	197	34	753	363	5	4	52	89	0	0	0	31746
82	W	135	172	203	43	666	373	4	4	41	101	0	0	0	35859
83	W	135	172	203	43	666	373	4	4	41	101	0	0	0	35859
84	W	117	67	197	34	753	363	5	4	52	89	0	0	0	31746
85	W	117	67	197	34	753	363	5	4	52	89	0	0	0	31746
86	W	117	67	197	34	753	363	5	4	52	89	0	0	0	31746
87	W	117	67	197	34	753	363	5	4	52	89	0	0	0	31746
88	W	117	67	197	34	753	363	5	4	52	89	0	0	0	31746
89	W	81	26	201	0	452	390	6	6	39	111	0	0	0	17680
90	W	83	26	216	1	476	388	6	6	36	114	0	0	0	17881
91	W	81	26	201	0	452	390	6	6	39	111	0	0	0	17680
92	W	76	25	156	0	341	324	6	7	26	86	0	0	0	15127
93	W	76	25	156	0	341	324	6	7	26	86	0	0	0	15127
94	W	76	25	156	0	341	324	6	7	26	86	0	0	0	15127
95	W	76	25	156	0	341	324	6	7	26	86	0	0	0	15127
96	W	67	24	150	0	339	281	10	7	28	66	0	0	0	14151
97	W	81	24	166	0	390	327	8	6	27	83	0	0	0	15841
98	W	81	24	166	0	390	327	8	6	27	83	0	0	0	15841
99	W	102	21	263	4	591	355	4	2	11	29	2	3	59	17213
100	W	102	21	263	4	591	355	4	2	11	29	2	3	59	17213
101	W	98	44	168	1	362	188	8	6	72	0	0	0	0	15779
102	W	93	48	157	0	336	199	8	6	75	0	0	0	0	15689
103	W	76	11	170	1	351	229	1	3	7	8	41	49	0	10781
104	W	74	89	119	0	306	157	9	5	56	0	0	0	0	14641
105	W	74	88	117	0	304	157	9	5	56	0	0	0	0	14604
106	W	117	27	304	2	585	372	3	3	7	18	8	41	101	16806
107	W	115	25	299	2	576	354	3	3	7	25	40	94	0	16239
108	W	112	46	303	1	569	442	5	4	1	46	58	106	0	17147
109	W	117	27	304	2	585	372	3	3	7	18	8	41	101	16804
110	W	113	40	324	1	604	451	5	4	1	46	37	132	0	17708
111	W	115	25	299	2	576	354	3	3	7	25	40	94	0	16239
112	W	112	46	303	1	569	442	5	4	1	46	58	106	0	17147
113	W	109	16	280	1	580	322	4	5	12	47	26	65	0	16001
114	W	46	22	202	5	458	144	5	5	38	19	1	0	0	16197
115	W	66	101	251	9	491	192	11	5	60	16	3	0	0	21946
116	W	50	29	231	5	514	174	5	5	43	25	5	0	0	18683
117	W	61	51	259	18	505	193	13	6	63	16	0	0	0	22721
118	W	71	64	278	23	546	214	13	7	64	22	1	0	0	25710
119	W	66	58	263	21	518	198	15	7	62	18	0	0	0	23969
120	W	12	2	8	0	17	20	3	10	0	0	0	0	0	1856

Table 4. Output of data collection: device 81–120

Dev.	Type	Pp.	Img.	Unord.	Ord.	Items	Int.	Ext.	h1	h2	h3	h4	h5	h6	Words
121	W	49	31	225	5	486	164	5	5	42	24	3	0	0	17640
122	W	124	73	217	39	461	325	7	0	14	38	46	10	0	23476
123	W	122	55	187	40	446	253	7	0	15	33	29	11	0	22335
124	W	38	70	177	3	284	132	3	6	34	16	2	0	0	12278
125	W	41	66	183	4	309	135	3	7	36	16	2	0	0	13159
126	W	61	94	258	8	478	199	3	8	48	27	6	0	0	20651
127	W	61	91	261	9	482	199	4	8	48	27	6	0	0	20518
128	W	182	190	201	3	601	408	10	16	37	76	18	0	0	27001
129	W	64	95	266	6	524	218	4	7	53	28	8	0	0	22667
130	W	66	100	265	9	524	220	5	9	54	26	8	0	0	22526
131	W	57	159	253	2	559	174	7	16	38	21	0	0	0	15946
132	W	65	180	283	4	639	196	7	18	44	22	0	0	0	17934
133	W	73	209	316	7	710	225	7	19	53	25	0	0	0	20808
134	W	66	161	319	11	685	230	8	5	49	44	2	0	0	22807
135	W	52	121	258	5	542	185	8	5	42	32	2	0	0	17784
136	W	57	137	282	6	606	206	8	5	44	39	2	0	0	19601
137	W	58	131	293	8	621	216	8	5	49	38	2	0	0	19883
138	W	120	127	285	5	569	341	14	20	43	24	0	0	0	19540
139	W	33	21	178	2	303	135	4	11	27	23	0	0	0	10699
140	W	29	14	54	8	119	68	10	0	6	15	0	0	0	4470
141	W	37	32	71	14	152	95	10	0	6	18	6	0	0	5506
142	W	53	24	118	0	238	131	7	13	28	0	0	0	0	8975
143	W	54	76	231	7	424	183	8	5	53	21	3	0	0	17383
144	W	58	83	243	12	451	198	9	5	55	24	3	0	0	19057
145	W	56	77	244	6	445	192	9	5	54	23	3	0	0	18353
146	W	52	77	241	4	427	182	9	5	52	21	3	0	0	16965
147	W	57	81	233	9	431	192	8	5	55	22	3	0	0	17912
148	W	44	53	218	7	439	163	7	5	41	26	0	0	0	14220
149	W	42	45	216	5	437	157	7	5	39	26	0	0	0	13534
150	W	14	8	8	0	37	34	2	1	10	6	0	0	0	1945
151	W	8	17	5	1	17	19	0	1	8	0	0	0	0	1832
152	W	14	8	8	0	37	36	1	1	1	10	6	0	0	1994
153	W	122	98	23	6	152	102	15	51	0	0	0	0	0	17985

Table 5. Output of data collection: device 121–153

APPENDIX B. ITEMS OF THE QUESTIONNAIRE

- What is your connection to user manuals?
  — Part of my daily occupation (e.g., I write user manuals)
  — I encounter them in my daily occupation (e.g., I need to use them for my occupation)
  — I encounter them as a user / customer

- When do you first open the user manual of general electronic devices (e.g., television, washing machine, camera etc.)?
  — After purchase (prior to first use)
  — After first use (on demand, e.g., to check functionalities)
  — If the device is not intuitive enough for me (e.g., if I cannot find a specific function)
  — If the device is not functioning correctly (i.e., suspicion of fault)
  — If the device is faulty / broken
  — Never
  — Other

- When do you first open the user manual of smart devices (e.g., smartphone, tablet)?
  — After purchase (prior to first use)
  — After first use (on demand, e.g., to check functionalities)
  — If the device is not intuitive enough for me (e.g., if I cannot find a specific function)
  — If the device is not functioning correctly (i.e., suspicion of fault)
  — If the device is faulty / broken
  — Never
  — I do not own / use such devices
  — Other

- When do you first open the user manual of smart wearable devices (e.g., smartwatch, smartband)?
  — After purchase (prior to first use)
  — After first use (on demand, e.g., to check functionalities)
  — If the device is not intuitive enough for me (e.g., if I cannot find a specific function)
  — If the device is not functioning correctly (i.e., suspicion of fault)
  — If the device is faulty / broken
  — Never
  — I do not own / use such devices
  — Other

- When do you usually open the user manual of general electronic devices (e.g., television, washing machine, camera etc.)?
  — To explore novel functionalities
  — To customize the device
  — To reset the device
  — For troubleshooting
  — Other

- When do you usually open the user manual of smart devices (e.g., smartphone, tablet)?
  — To explore novel functionalities
  — To customize the device
  — To reset the device
  — For troubleshooting
  — I do not own / use such devices
  — Other

- When do you usually open the user manual of smart wearable devices (e.g., smartwatch, smartband)?
  — To explore novel functionalities
  — To customize the device
  — To reset the device
  — For troubleshooting
  — I do not own / use such devices
  — Other

- During the complete life cycle of your most recent general electronic device (e.g., television, washing machine, camera), how many times did you use its user manual?
  — 0
  — 1–2
  — 3–4
  — 5–10
  — More than 10

- During the complete life cycle of your most recent smart device (smartphone, tablet), how many times did you use its user manual?
  — 0
  — 1–2
  — 3–4
  — 5–10
  — More than 10
  — I do not own / use such devices

- During the complete life cycle of your most recent smart wearable device (smartwatch, smartband), how many times did you use its user manual?
  — 0
  — 1–2
  — 3–4
  — 5–10
  — More than 10
  — I do not own / use such devices

- During the complete life cycle of your general electronic devices (e.g., television, washing machine, camera), how many times do you usually use their user manuals?
  — 0
  — 1–2
  — 3–4
  — 5–10
  — More than 10

- During the complete life cycle of your smart devices (smartphone, tablet), how many times do you usually use their user manuals?
  — 0
  — 1–2
  — 3–4
  — 5–10
  — More than 10
  — I do not own / use such devices

- During the complete life cycle of your smart wearable devices (smartwatch, smartband), how many times do you usually use their user manuals?
  — 0
  — 1–2
  — 3–4
  — 5–10
  — More than 10
  — I do not own / use such devices

- When you open a user manual, do you primarily seek information in figures or text?
  — In figures
  — In text

- Which format of user manuals do you personally prefer?
  — Online (interactive web format)
  — Online (PDF or other electronic document)
  — Offline (printed document)

- What was the format of the user manual you most recently used?
  — Online (interactive web format)
  — Online (PDF or other electronic document)
  — Offline (printed document)

- Which format of user manuals do you usually use?
  — Online (interactive web format)
  — Online (PDF or other electronic document)
  — Offline (printed document)

APPENDIX C. RESULTS OF THE QUESTIONNAIRE

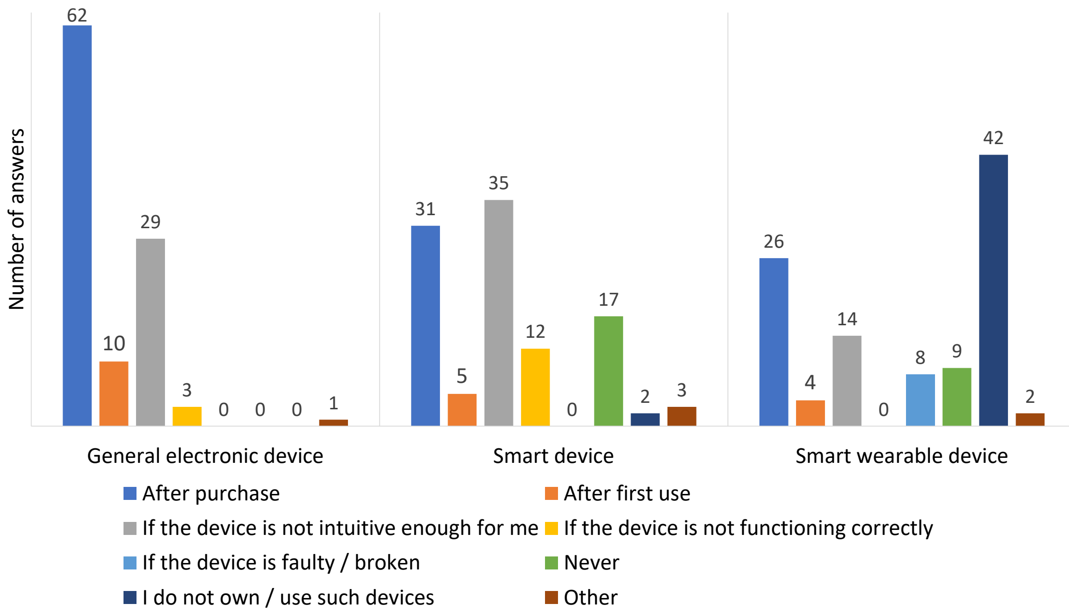

Figure 2. When do you first open the user manual of general electronic devices / smart devices / smart wearable devices?

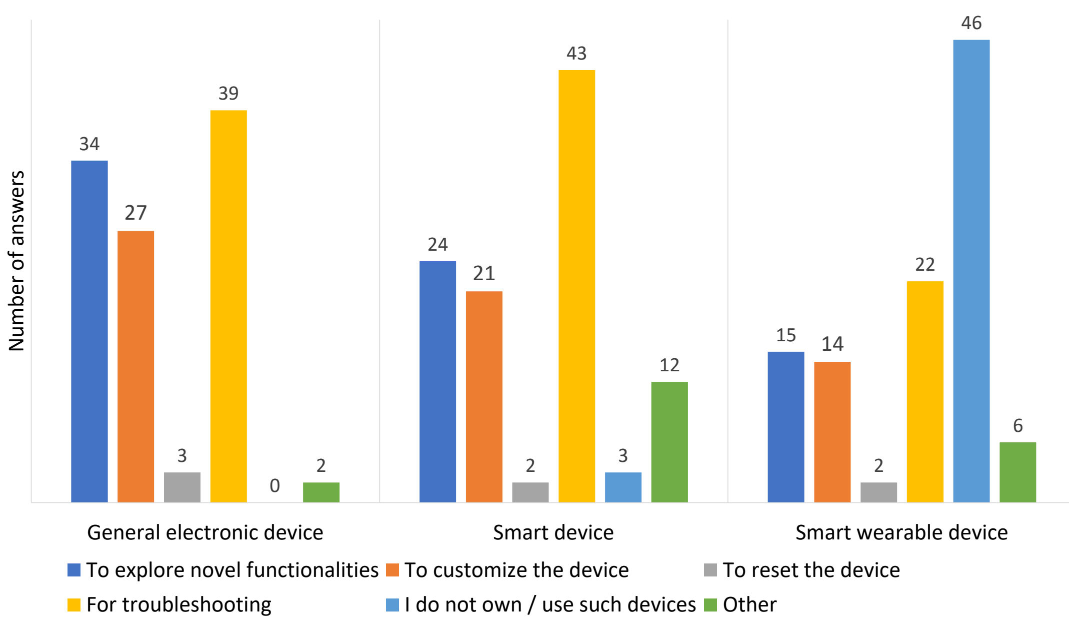

Figure 3. When do you usually open the user manual of general electronic devices / smart devices / smart wearable devices?

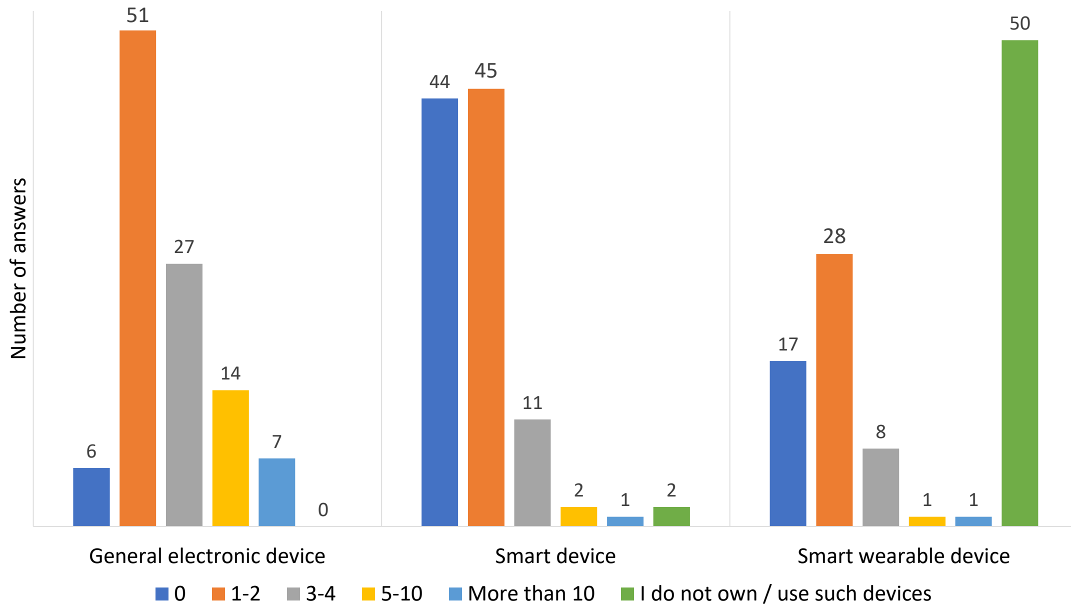

Figure 4. During the complete life cycle of your most recent general electronic device / smart device / smart wearable device, how many times did you use its user manual?

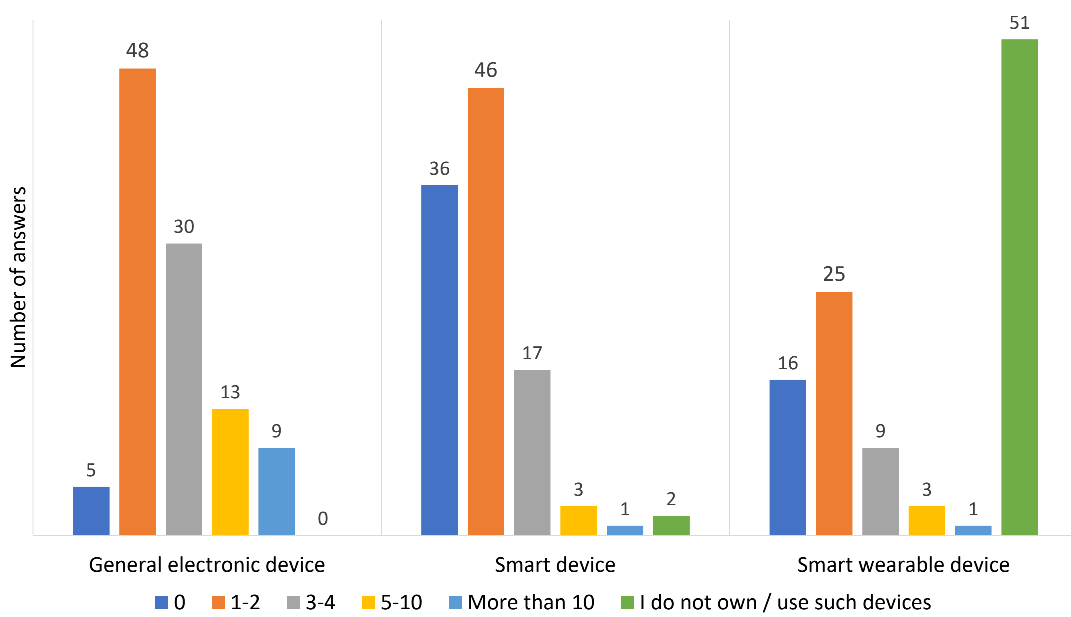

Figure 5. During the complete life cycle of your general electronic devices / smart devices / smart wearable devices, how many times do you usually use their user manuals?

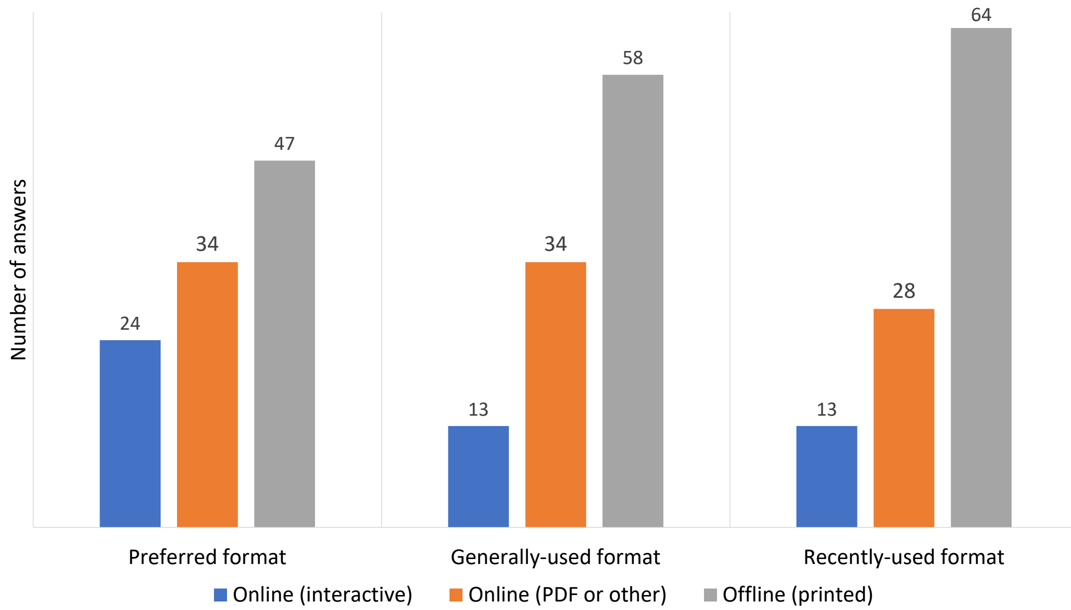

Figure 6. Which format of user manuals do you prefer / do you usually use / did you recently use?

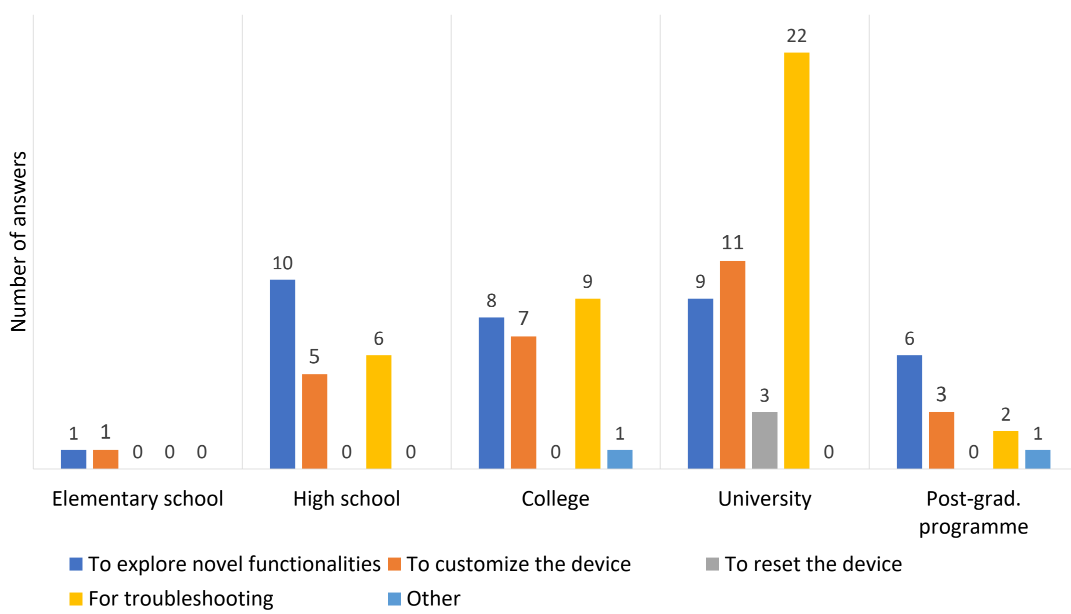

Figure 7. Usual user manual usage for general electronic devices by level of highest education.

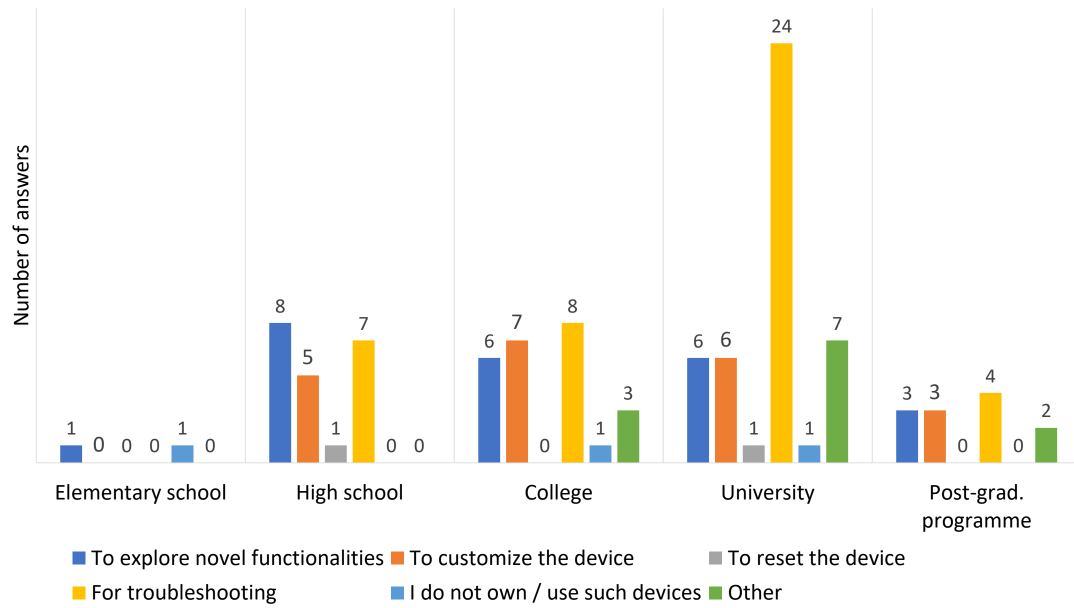

Figure 8. Usual user manual usage for smart devices by level of highest education.

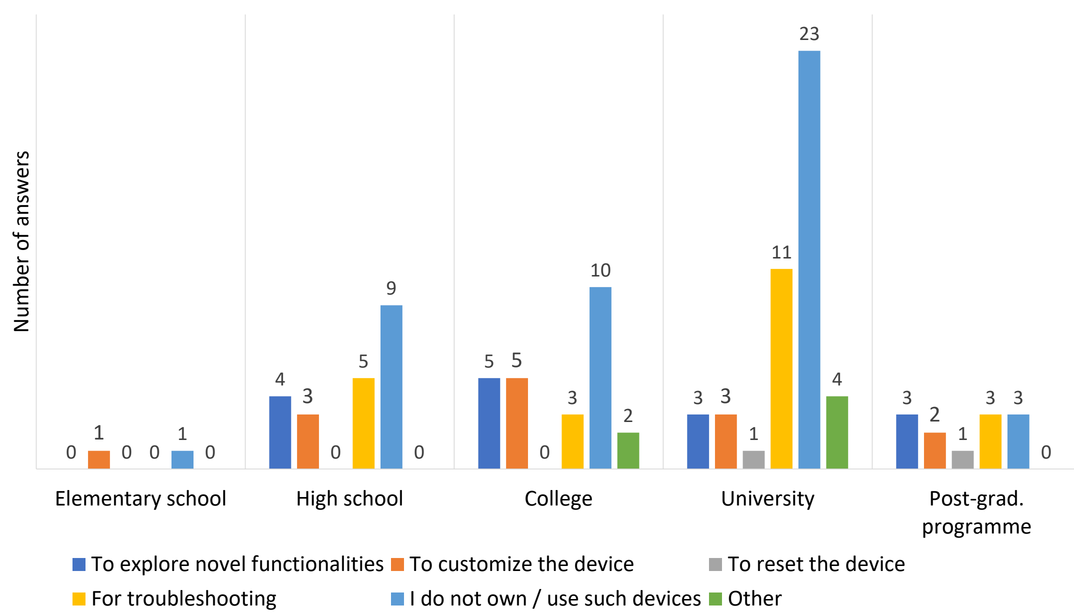

Figure 9. Usual user manual usage for smart wearable devices by level of highest education.

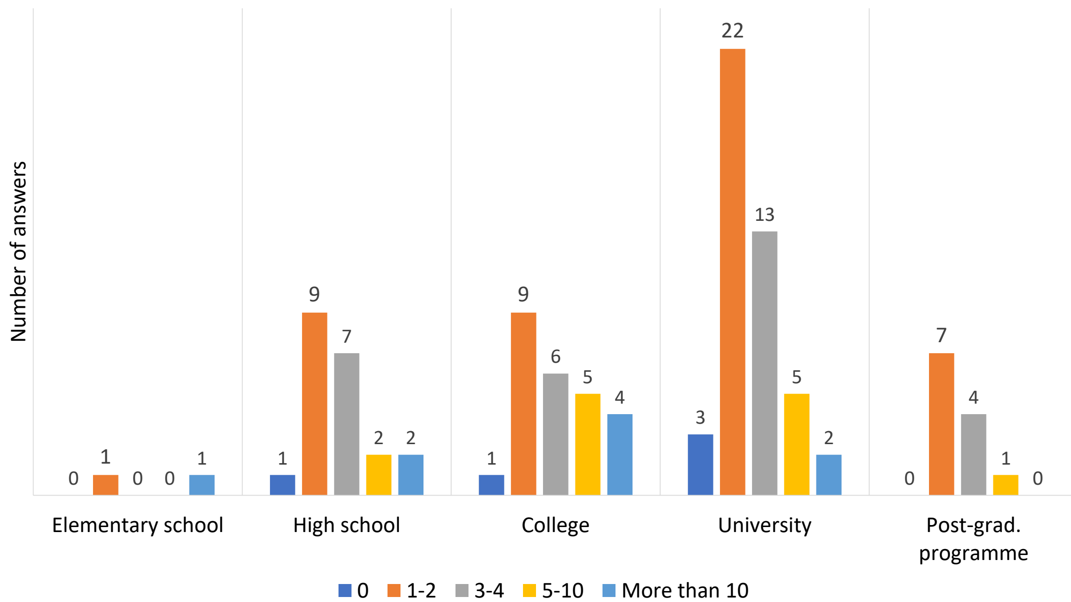

Figure 10. Usual user manual usage number for general electronic devices by level of highest education.

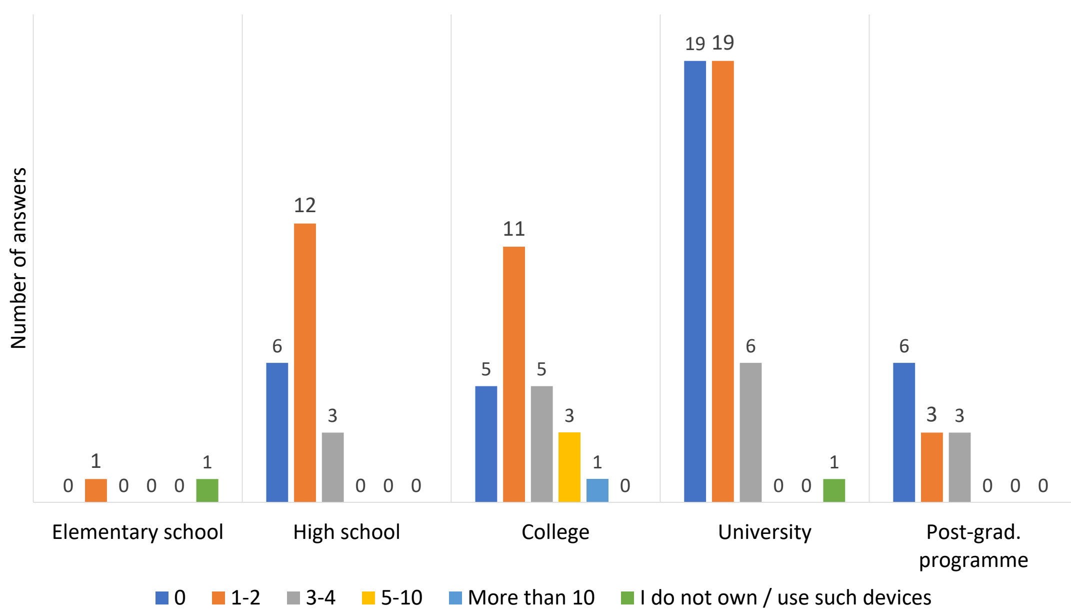

Figure 11. Usual user manual usage number for smart devices by level of highest education.

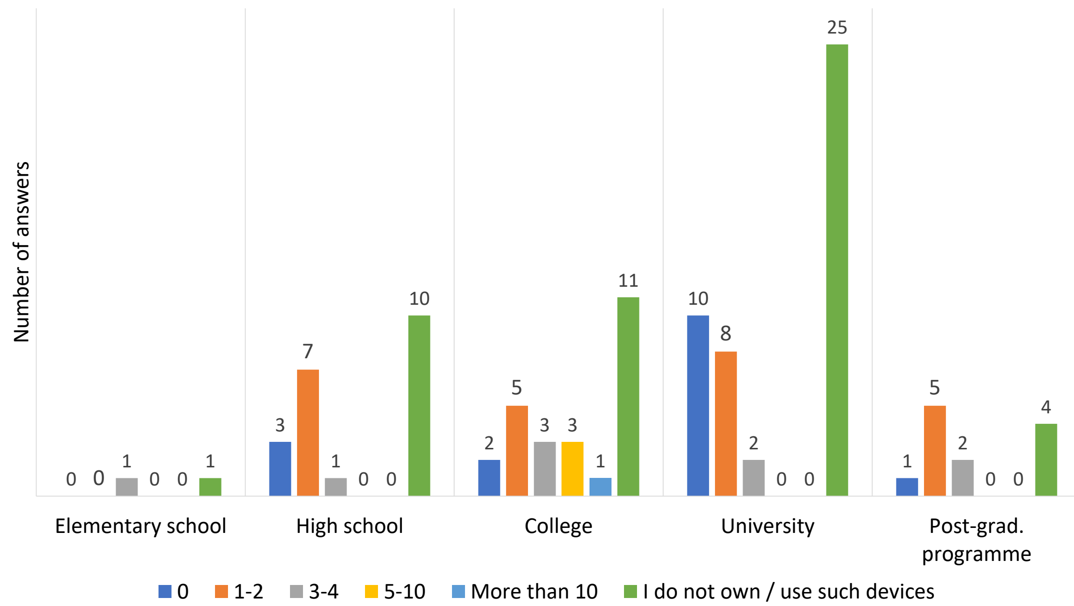

Figure 12. Usual user manual usage number for smart wearable devices by level of highest education.

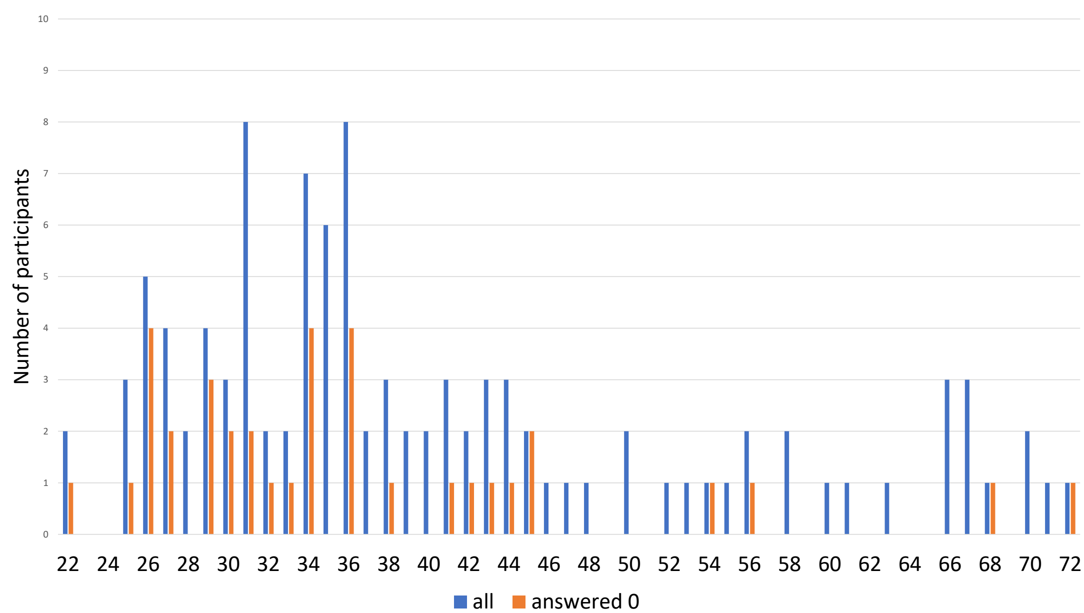

Figure 13. Age distribution of all participants and those participants who answered 0 to Question 12.

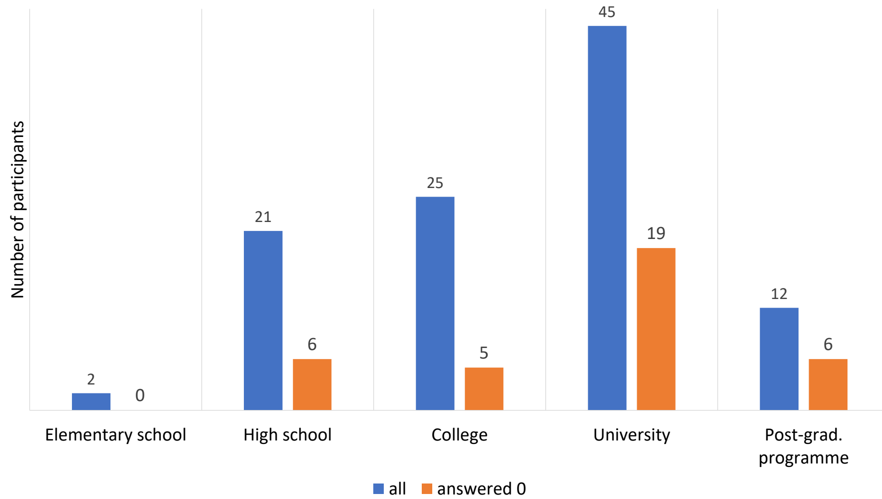

Figure 14. Distribution of all participants and those participants who answered 0 to Question 12 by level of highest education.

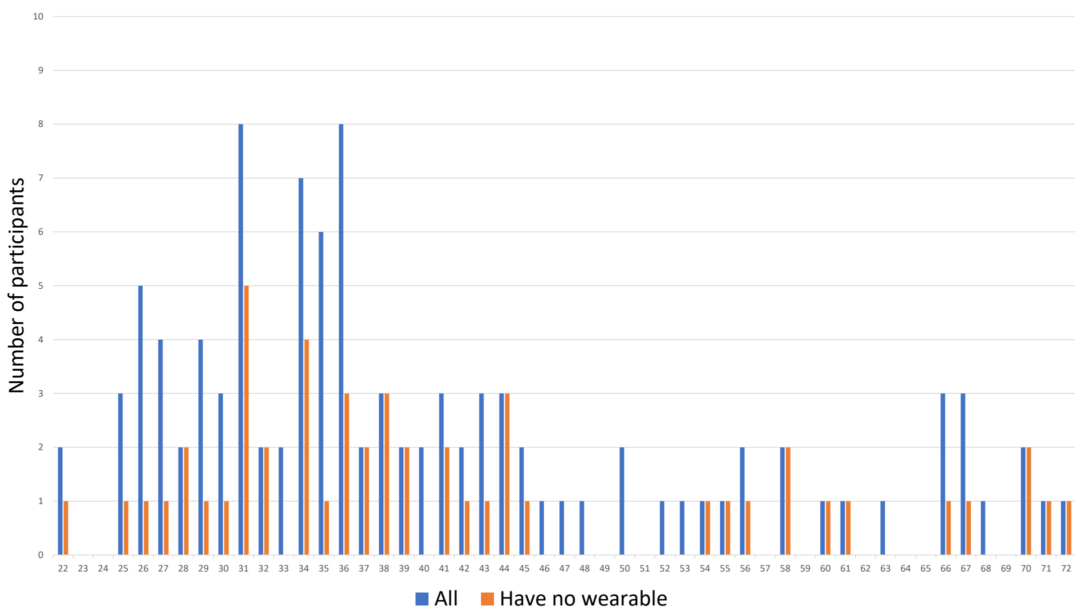

Figure 15. Distribution of all participants and those participants who have no smart wearable device by age.

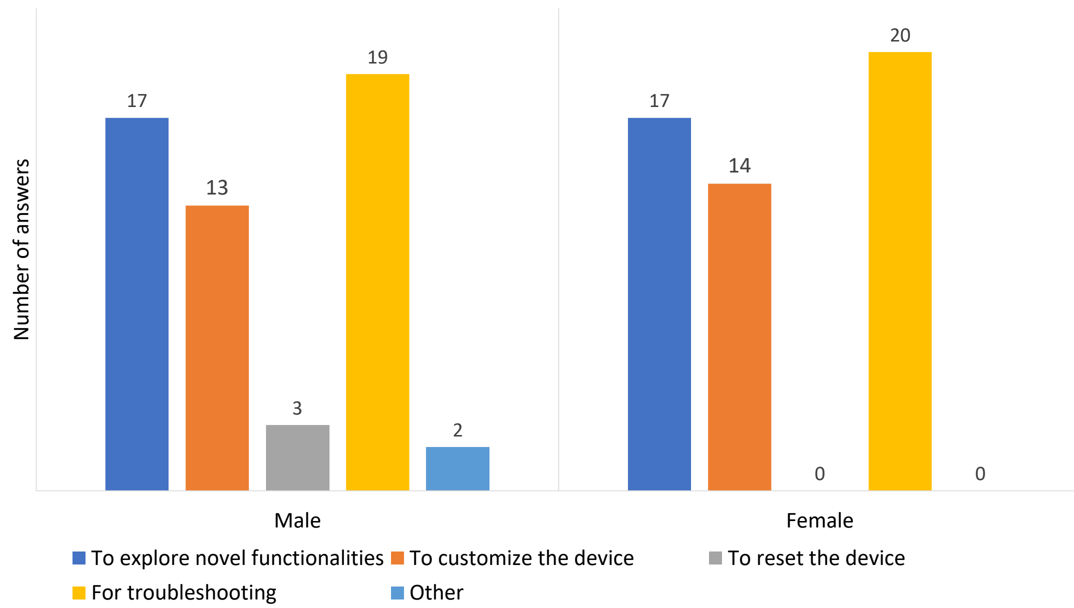

Figure 16. Usual user manual usage for general electronic devices by gender.

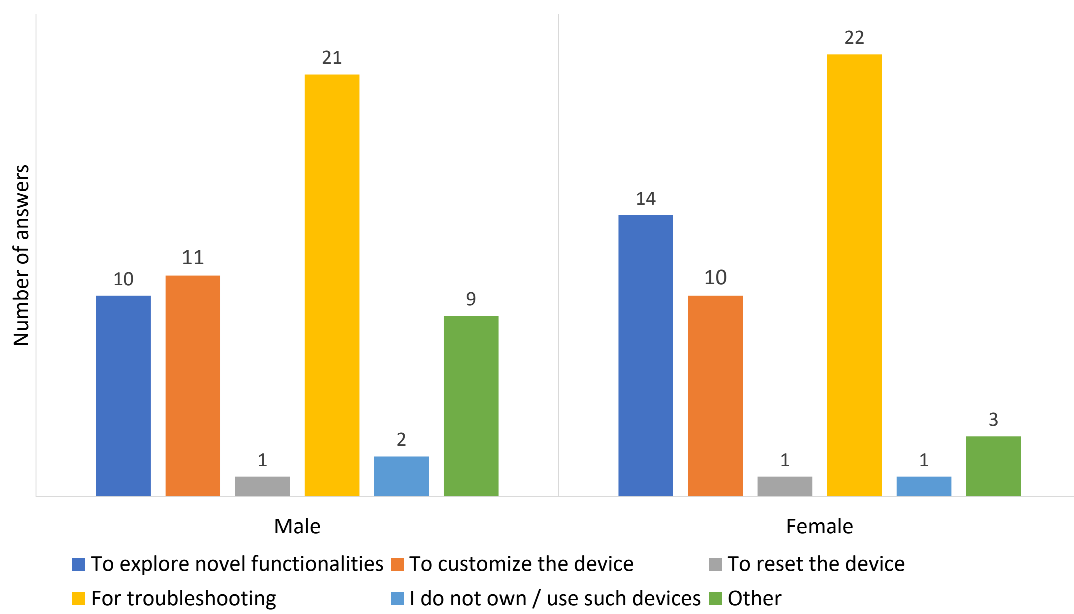

Figure 17. Usual user manual usage for smart devices by gender.

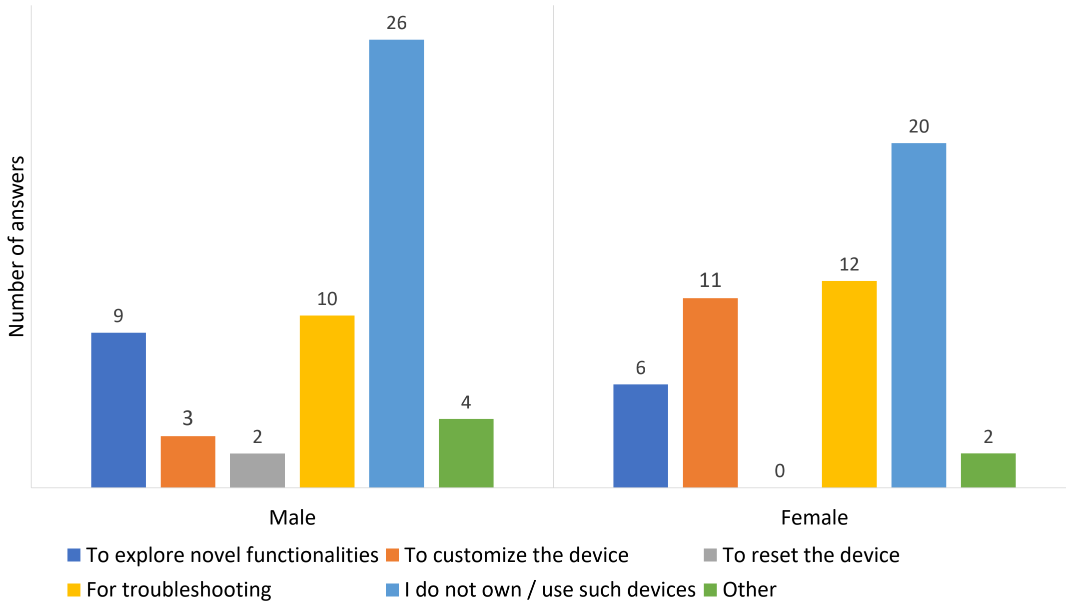

Figure 18. Usual user manual usage for smart wearable devices by gender.

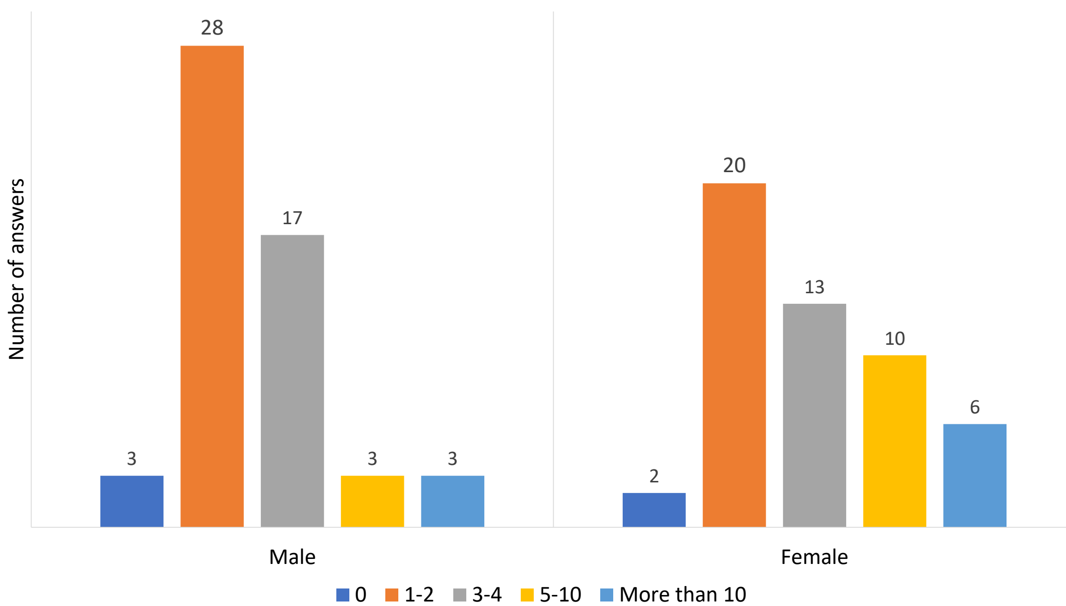

Figure 19. Usual user manual usage number for general electronic devices by gender.

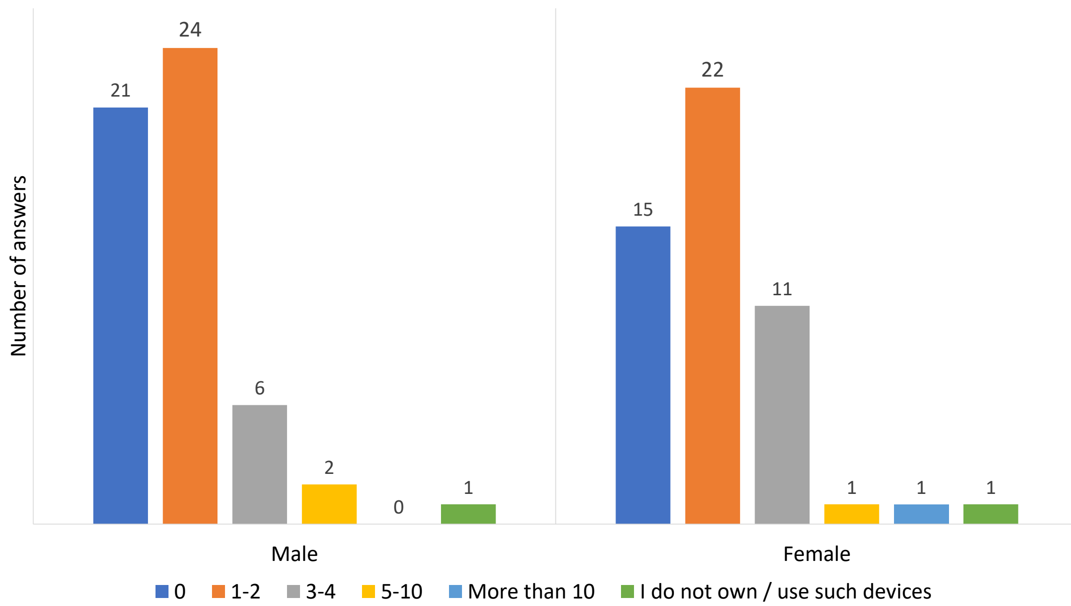

Figure 20. Usual user manual usage number for smart devices by gender.

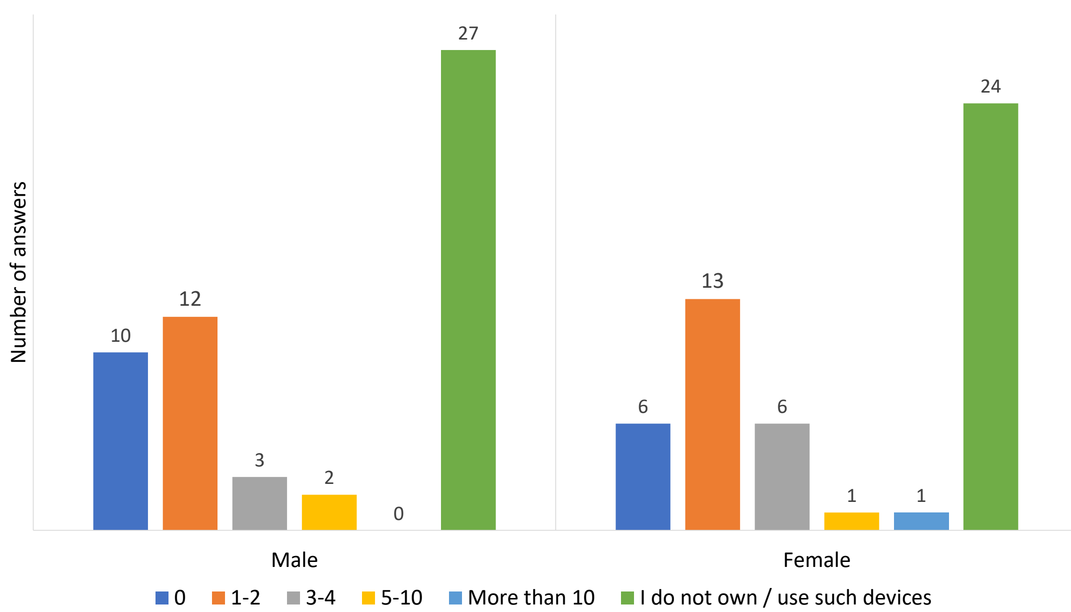

Figure 21. Usual user manual usage number for smart wearable devices by gender.

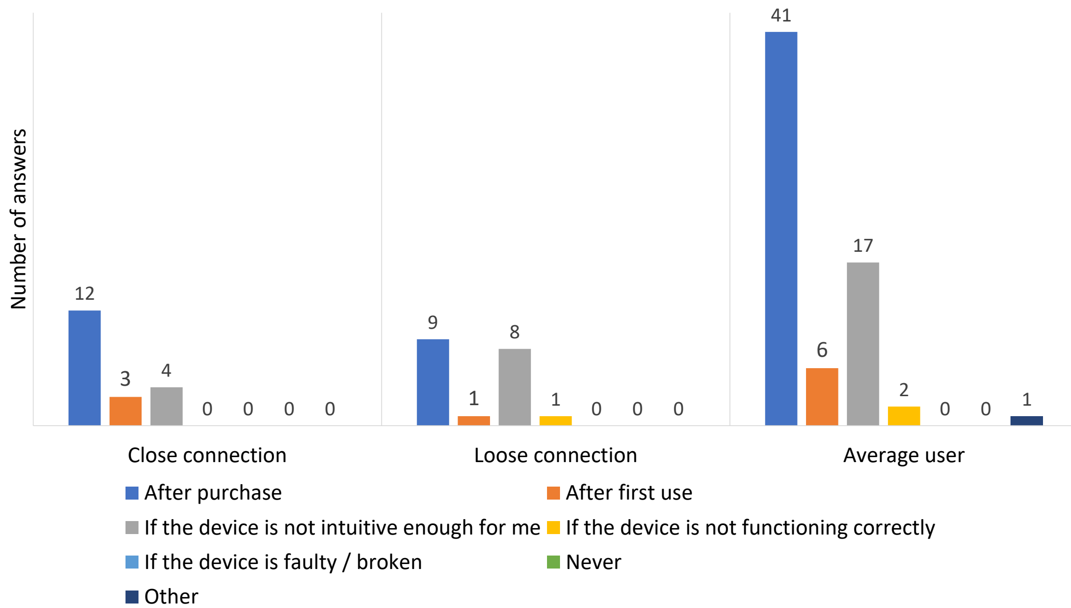

Figure 22. First user manual usage for general electronic devices by relationship to user manuals.

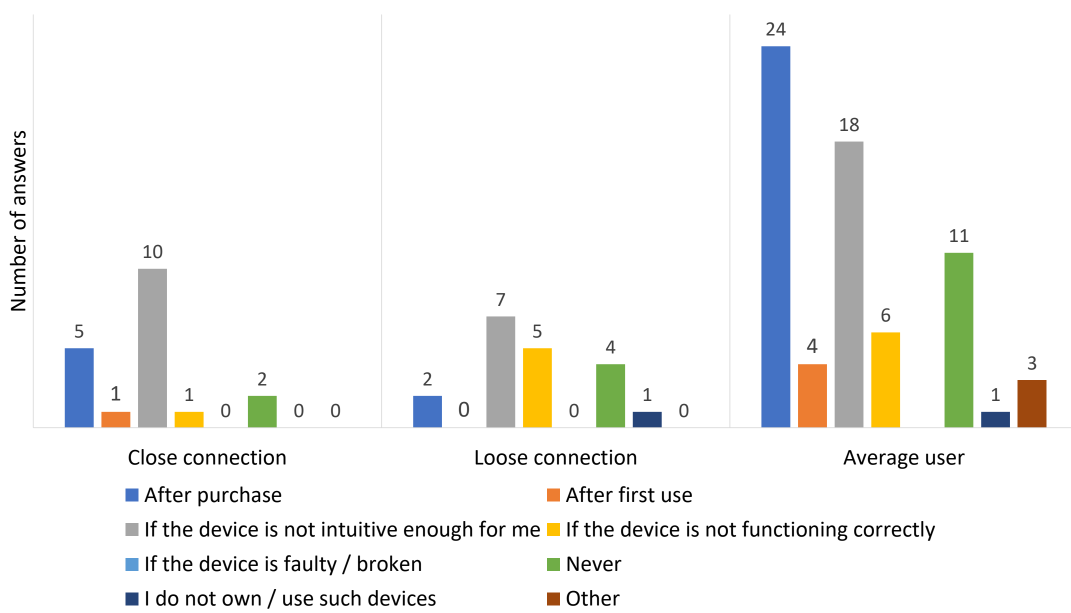

Figure 23. First user manual usage for smart devices by relationship to user manuals.

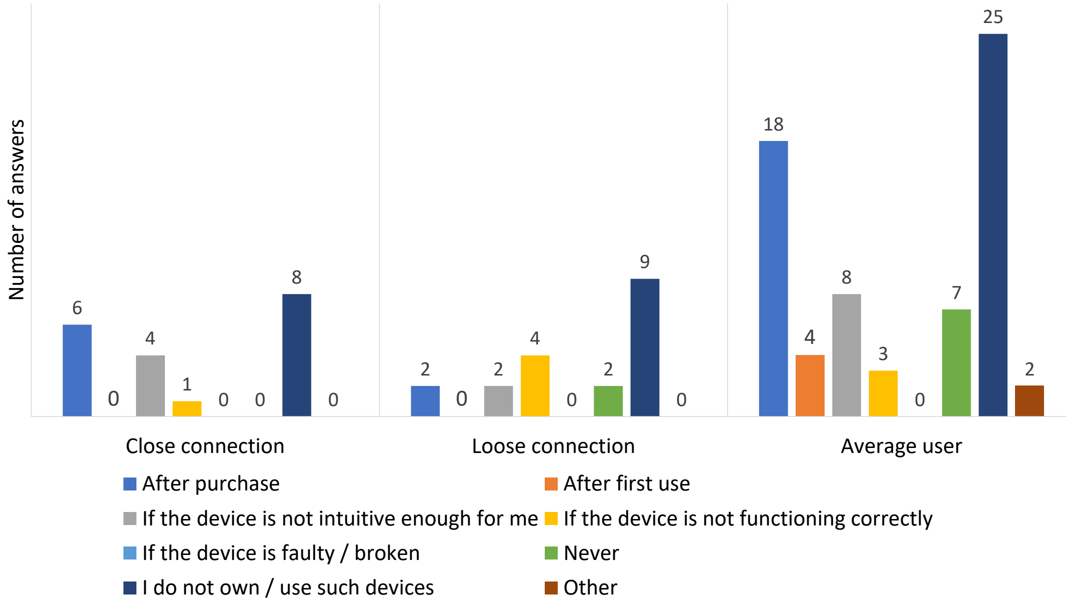

Figure 24. First user manual usage for smart wearable devices by relationship to user manuals.

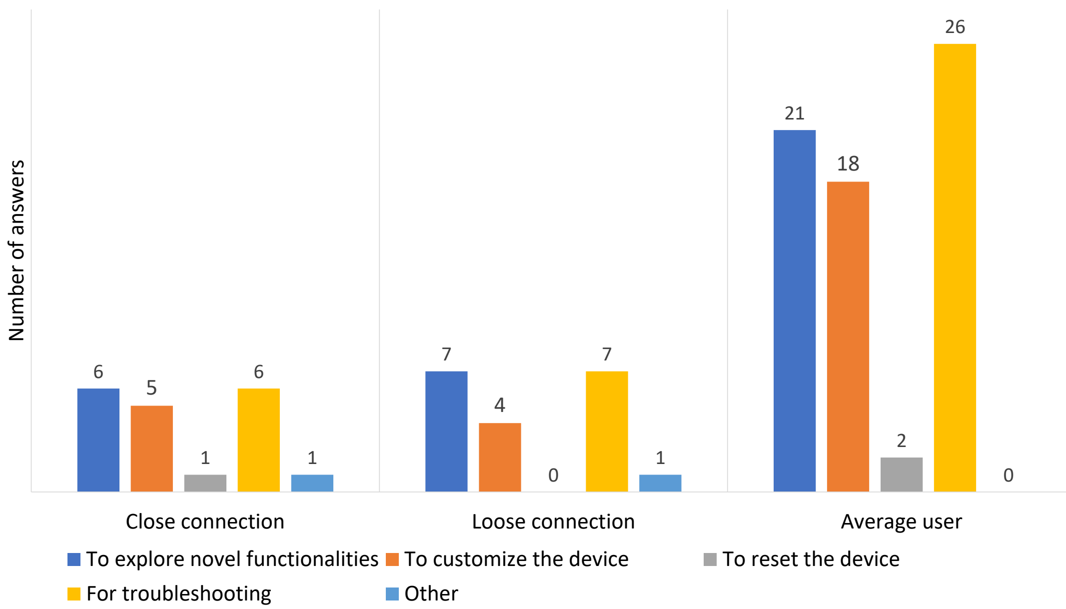

Figure 25. Usual user manual usage for general electronic devices by relationship to user manuals.

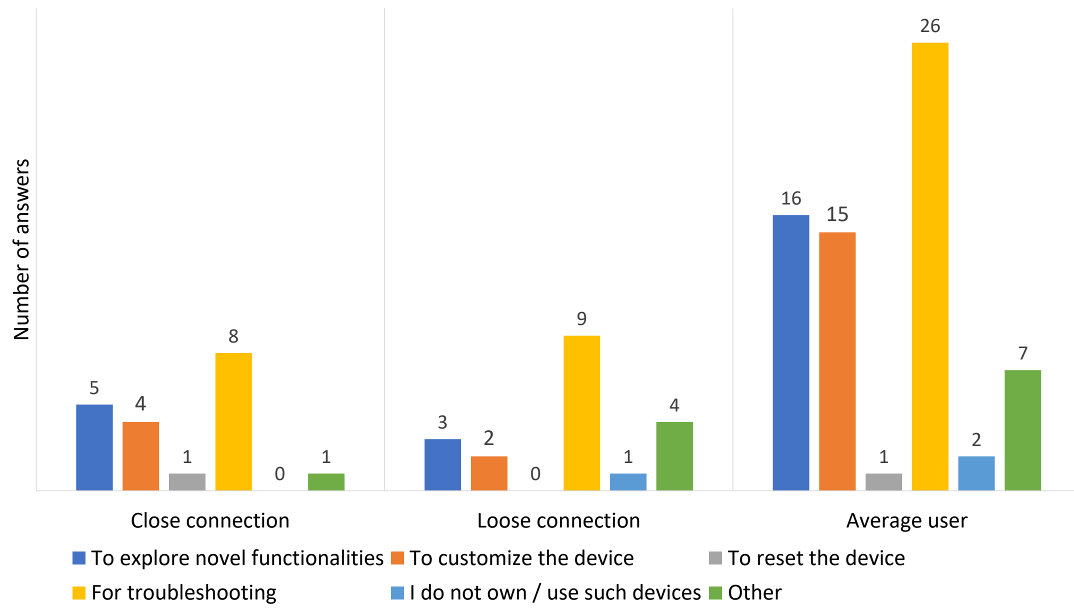

Figure 26. Usual user manual usage for smart devices by relationship to user manuals.

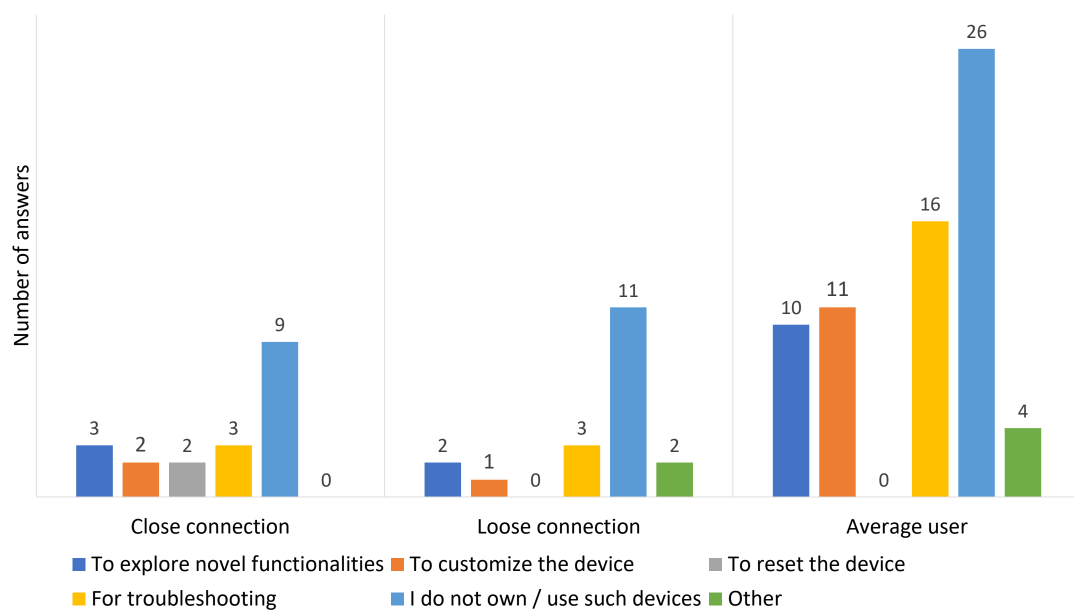

Figure 27. Usual user manual usage for smart wearable devices by relationship to user manuals.

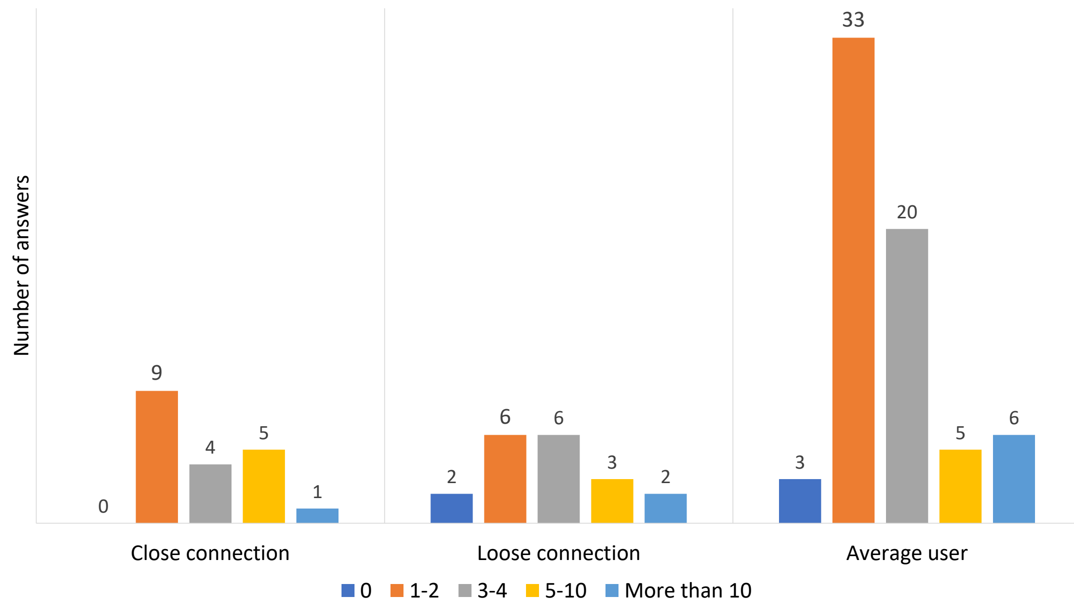

Figure 28. Usual user manual usage number for general electronic devices by relationship to user manuals.

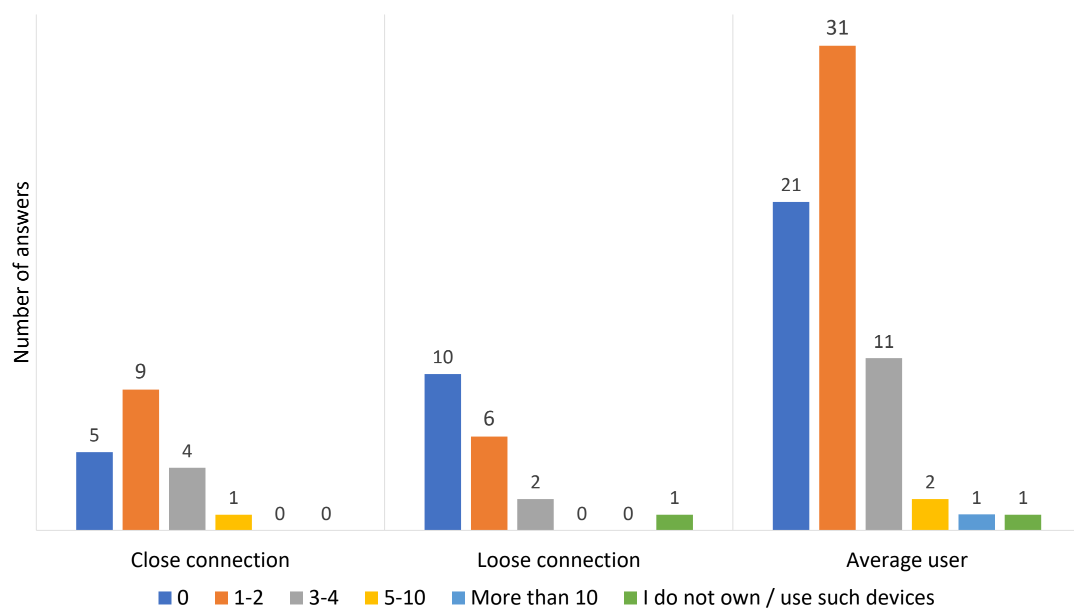

Figure 29. Usual user manual usage number for smart devices by relationship to user manuals.

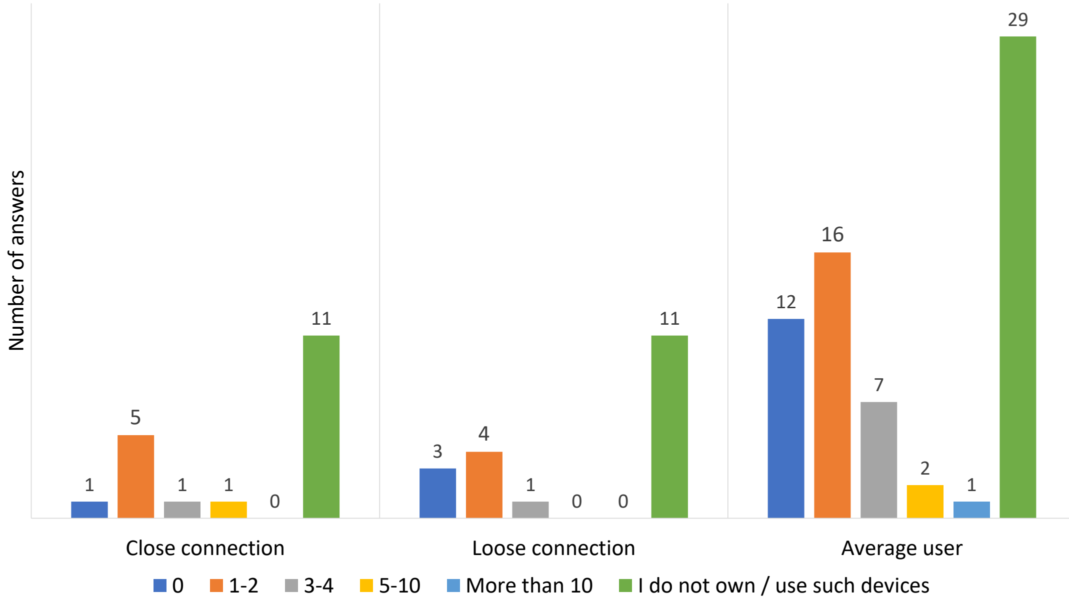

Figure 30. Usual user manual usage number for smart wearable devices by relationship to user manuals.

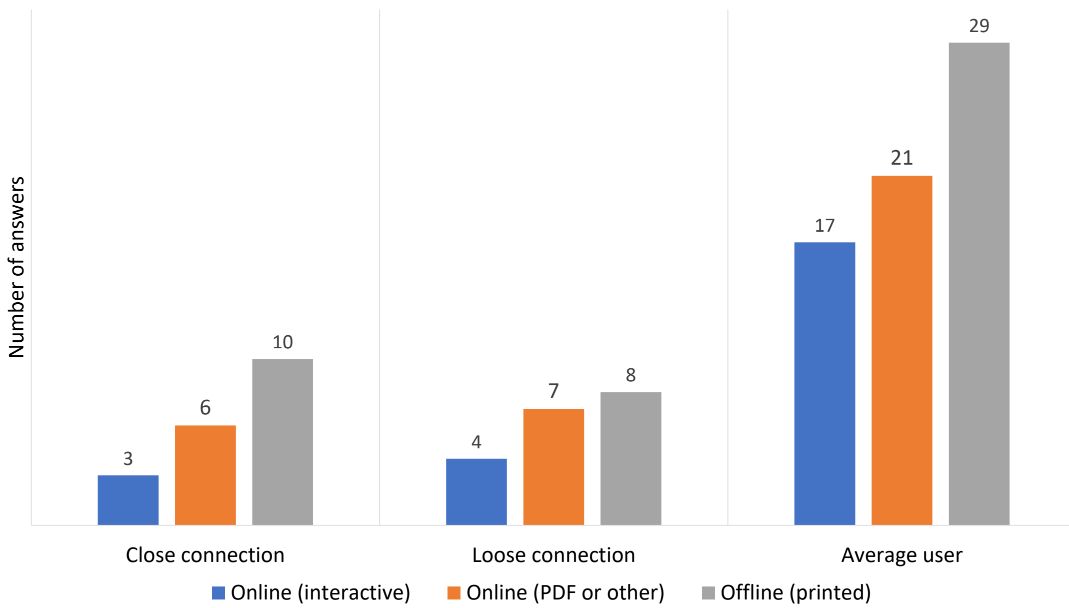

Figure 31. Preferred user manual formats by relationship to user manuals.

ACKNOWLEDGMENTS

The research reported in this paper is part of project no. BME-NVA-02, implemented with the support provided by the Ministry of Innovation and Technology of Hungary from the National Research, Development and Innovation Fund, financed under the TKP2021 funding scheme.

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