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Influence Factors on User Manual Engagement in the Context of Smart Wearable Devices

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Abstract: The emergence of smart wearable devices has gradually introduced a vast array of functions that may greatly serve the everyday needs of users. Although their ever-increasing list of capabilities may be compensated for by intuitive design, users may still have numerous reasons to engage with their user manuals. In this paper, we present four research efforts on the user manuals of smart wearable devices. Our work tackles various influence factors, investigates user behavior, and studies how the device itself affects user manual engagement, as well as the other way around. The research efforts address user experience and behavior, personal preference, device attributes, and the performance metrics of user manuals. We specifically studied smartwatches and smart bands, and explored engagement with medical-purpose smart wearables and their user manuals. As a novelty of our contribution, we classify test participants as regular users, professional users, and technical writers, based on their connection to user manuals, and separately analyze their responses to our questionnaire-based research efforts. The obtained results indicate that user experience and device complexity as influence factors have a statistically significant impact on user manual engagement for regular users, and highlight how regular users and technical writers differ in preference and search-related tasks.

Keywords: user manual; user experience; user preference; influence factor; smart wearable device; technical communication

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1. Introduction

User manuals are essential components of products, with scientifically measurable added value [1]. Yet they are often undervalued in numerous contexts. For example, they may be viewed as the "Cinderella" of information systems [2]. They are also known as the "best-seller that no one reads" [3], since they are distributed in huge numbers but are rarely opened. This phenomenon may be explained by various factors, such as the disappointment in the quality of user manuals [4]. Therefore, user manual quality is a highly investigated research topic in the field of science, as poor delivery may negatively affect the product itself. After all, even though user manuals are secondary products, still, they are products nonetheless.

It is important to highlight that at the time of writing this paper, international regulations make it mandatory that products are accompanied by user manuals. For example, this is determined by the Guide of the Machinery Directive 2006/42/EC within the European Union [5]. Moreover, while the utilization of digital user manuals (e.g., PDF documents) is indeed rising [6], the vast majority of consumer products are still provided with printed user manuals.

Among the many electronic devices that are accompanied by user manuals, smart wearables have gained immense popularity in the last decade [7]. This is partially due to the emergence of affordable, entry-level devices. A smart wearable device (e.g., smartwatch) may serve numerous functions. Beyond displaying the time like a regular watch, it may be used for messaging, calls, medical measurements, information updates (e.g., weather reports), localization, purchases, entertainment (e.g., music), and many more, not to mention its role as a fashionable accessory.

However, even though smart wearable devices—similarly to all other types of modern devices—are designed to be as intuitive as possible, their complexity (i.e., the sheer amount of functions they provide) makes user manuals highly relevant. Additionally, as a means of novelty, newer, more sophisticated models tend to enter the competition with even more functions and capabilities. While there may be dedicated models focusing on a narrow set of functions (e.g., medical measurements for physical training), universality (i.e., being capable of every major function) is understandably preferred by manufacturers. In the case of smartphones, while certain models tend to prioritize durability—commonly known as rugged smartphones—even those models share the full set of functionalities of regular devices, although their capabilities may be perceived differently [8].

While many works in the scientific literature address the subjective quality and the efficiency of user manuals, the case of smart wearable devices is greatly understudied. However, as stated earlier, such user manuals are highly relevant in the industry due to the emergence of advanced models with sprawling functionalities and capabilities.

In this paper, we present four research efforts on the user manuals of smart wearables. The different series of tests are identified by letters of the Greek alphabet. In Research Alpha, our first study, we addressed user experience, device complexity, device purpose (i.e., general-purpose and dedicated devices), and device price. In Research Beta, user manual length, writing tone, the ease of finding and understanding information, illustration amount and usefulness, and overall document quality were studied, as well as user behavior, personal preference, and experiences regarding devices purchased in the past 5 years. In Research Gamma—the preliminary results of which were recently published [9]—we specifically explored medical-purpose smart wearables, covering various user habits related to the device and its user manual. Finally, in Research Delta, we investigated performance metrics (e.g., time required to find information), user persistence (e.g., time until the user gives up to find information), alternate solutions (i.e., when the user manual is unable to help the user), and related user satisfaction.

We used surveys to collect the research data. The data were provided by 5211 individuals from Austria, China, France, Germany, Hungary, Italy, Montenegro, Poland, Sweden, the UK, and the US. The potential regional differences are not addressed by this work. Regarding the selection and classification of test participants, the individuals were grouped by their connection to user manuals. They were either regular users, professional users (i.e., those who encounter user manuals within their daily occupations), or technical writers (i.e., those who create user manuals). This is a novelty of our contribution, as such an approach is absent from the state-of-the-art scientific literature; this classification appears only in our prior contributions [9,10], paving the way for this work.

Within the scope of our work, smart wearable devices cover only smartwatches and smart bands. We acknowledge that investigating other smart wearables may also provide scientifically valuable information. However, in the case of our contribution, we used this constraint to have a well-defined research focus. Additionally, our work does not distinguish smartwatches and smart bands; such a differentiation is out of the scope of the presented research efforts.

The remainder of this paper is structured as follows. Section 2 provides a comprehensive review of the related work. The methodology of the research efforts are introduced in Section 3. Section 4 presents and analyzes the obtained results. The implications of the results and the limitations of our work are discussed in Section 5. Section 6 concludes the paper and highlights potential future research questions.

2. Related Work

Technical writing is a subset of technical communication. It is a practice-oriented professional activity, the best practice of which is primarily developed over time within the relevant industrial sectors. However, similarly to technical communication, technical writing has its own scientific literature, which also contributes to its continuous progress.

Gould and Lewis [11] suggested that those who write the user manual should be the ones who design the product. However, this would mean that designers and developers should be highly trained in the best practices of technical writing, as well as in the usage of the related professional tools. The work of Webb [12] provides a guideline for technical writers who are not experts in the field that they need to create documents for. Eriksson [13] highlighted that communication between technical writers and designers is important yet lacking. The author promoted the systematical view of user manuals, which could improve the addition and update of information. Fowler and Roeger [14] emphasized communication between technical writers and programmers.

In the late 1970s, Muller [15] reviewed the user manuals of statistical computing packages. Based on the findings, the author promoted the need for user guide standardization. Maynard [16] suggested the utilization of user polls in order to tailor user manuals to their target audiences. Additionally, the author proposed the inclusion of a learning section, as well as a retrieval section. Ramsay and Oatley [17] created a minimalist instruction for an email service. The work was based on the prior efforts of Carroll [18]. Wright [19] specifically addressed user-oriented computer documentation, similarly to Brockmann [20], and Miles [21] investigated user manuals in software engineering education.

Barrett [22] published a comprehensive overview of the issues related to user manuals. Schneider et al. [23] conducted an experiment on fault detection in user manuals. Wright [24] addressed the issue that users do not read the user manual carefully, and provided recommendations for manufacturers to change the related tendencies. Considerations regarding safety were emphasized by Zeitlin [25]. Williams-Deane and Potter [26] highlighted that instructions in a user manual may be conflicting and contradicting, which is definitely counterproductive. Jansen and Balijon [27] addressed the frequency of use for user manuals and other aspects of interaction. An important finding of the work is that 63% of the test participants blame themselves if they cannot find something in the user manual. Comstock and Clemens [28] also highlighted the difficulty of finding information within user manuals. It is noteworthy that some even question whether users read the manual at all [3,29]. Millar [30] argued that user manuals as separate, secondary products are obsolete, and Zajc [31] approached the nature of user manuals as limiting.

The interpretation of information is a highly investigated topic within the scientific literature [32–36]. Mason et al. [37] studied the response of 52 high school students on the topic of text interpretation via a questionnaire. The results highlight the positive effects of providing specific instructions instead of generic ones. Miller et al. [38] utilized three methodologies to investigate the potential improvements of variable message sign (VMS) efficiency on the levels of interpretation and understanding. Robinson and Robinson [39] studied children between the ages of 5 and 7, assembling Lego according to instructions. They concluded that children with better communication skills were more successful in the completion of the task at hand. Mallenius et al. [40] investigated user manuals as an influence factor that affects the use of mobile devices by the elderly. The work emphasizes that they should be written in such a way that even the elderly may understand them without issues. The work of Ishihara et al. [41] addressed the impact of technical terms on the usage of smartphone manuals among the elderly. Van Hees [42] emphasized the fact that the elderly may find it more difficult to follow instructions due to potential cognitive issues. Nygård and Starkhammar [43] particularly focused on dementia. Tsai et al. [44] concluded that the elderly are invested in getting to know the user manual, as it is key to understanding novel technologies. Atlas [45] discussed the creation of user manuals for individuals who are new to a specific product type.

Dontcheva-Navratilova et al. [46] examined Aristotle's rhetoricality according to pathos, logos, and ethos, discussing the importance of creating a caring and responsible framework for the users of technical documentation. Dale and Chall [47] proposed a formula regarding average sentence length and the ratio of technical terminologies that may be unfamiliar to the users. Lam [48] found that not even high-quality user manuals abide the spatial-contiguity principle. The author suggested the repetition of images in user manuals where the corresponding text spans across multiple pages. Pham and Setchi [49] advocated the concept of adaptive product manuals, which means that virtual documents are generated in real time, in order to answer the queries of users. Lemmen [50] suggested the reuse of online user manuals. Information in such a context is layered, going from more general toward more specific, which may assist users in finding the appropriate level of abstraction. Holt [51] proposed an iterative approach to writing user manuals. In such a scenario, the writing of the user manual begins prior to the completion of the product.

Showers [52] studied the usage of user manuals. Gillihan et al. [53] addressed usability testing and customer feedback. The work emphasizes their role in the improvement of user manuals. Woolgar [54] specifically investigated usability trials. Chafin [55] found that user-compatible terminology (i.e., one that the user interprets without issues) and a concise manner of user manuals are the most important to users. Herbert and Attridge [56] emphasized the user manual criteria of identifying, validity, and practicality. Alexander [57] approached quality from the aspects of effectiveness, retention, satisfaction, and preference in the contexts of print and online video instructions. The author found that for shorter instructions, online video instructions perform better, but no significant difference was measured for longer instructions. Additionally, for this latter scenario, users preferred the printed version. Li et al. [58] addressed the understanding of human preferences by machines. Pham et al. [59] investigated intelligent product manuals. Loorbach et al. [60] proposed the introduction of motivational elements in user manuals. The findings indicate that motivational elements do not increase efficiency, yet users appreciate the enhanced readability.

Among use case scenarios, the medical context is frequently investigated by the scientific literature—this is one of the inspirations behind one of our research efforts being particularly focused on smart medical wearables. In the early 2000s, Wiklund [61] addressed the digital transformation of user manuals for medical devices. Morrow et al. [62] studied elderly patients diagnosed with congestive heart failure (CHF). The authors found that patients preferred instructions that were more in alignment with their cognitive abilities and personal experience. Bhutkar et al. [63] found that numerous functions of medical devices are inaccessible to users due to the difficulties related to the interpretation of the corresponding user manuals. Koster et al. [64] studied the interpretation of medical information in the Netherlands, and found that both Dutch citizens and foreigners are prone to misinterpretation; overall, merely two out of five individuals processed the information correctly. Chuang [65] focused on low-literacy medical patients and their ability to comprehend and interpret pictographs depicting medication use instructions. The authors emphasized that cooperation is needed with the potential users during the creation of user manuals, particularly since preferences may greatly differ based on age. Landreneau [66] concluded that efficient access to information may greatly assist the perioperative department and the health and safety of patients. Bowen and Reeves [67] investigated the user manuals of modal medical devices (e.g., syringe pump). The authors highlighted the potential inconsistencies of user manuals with the investigated devices. Andrade et al. [68] addressed the user manuals of medical devices, and proposed usability heuristics. A particular feature of the work is that safety-critical devices (infusion pumps) are considered. Issues with the user manual were classified by severity and approached as heuristics violations. The most frequent violations were the lack of information and clarity. Lehoux et al. [69] stressed the issue that medical experts are typically not involved in the creation of user manuals for medical devices. Note that in such cases, numerous users of such documents are medical professionals (e.g., nurses) and not just regular users. García-

Domene et al. [70] highlighted the possibility that written user manuals in the medical context shall be eliminated in the future. The work of Allwood and Kalén [71] presents the evaluation of the user manual of a patient administrative system. The test participants, who were medical professionals, reported the quality assessment in a qualitative manner (e.g., underlining difficult portions of the user manual, providing verbal comments, etc.), which was followed by listing positive and negative aspects of user manuals. The test was repeated with an improved user manual, the improvements of which were primarily based on the previous feedback. Additionally, software-related task time was measured for both tests, and it was found that on average 21% less time was required during the second test.

Warren [72] examined the cultural impact that technical documentation may have. One of the major findings was that during the creation of such documents, the relevant culture should be as important as the relevant demography. Culture and interpretation were also addressed by Webber et al. [73]. Fukuoka [74] compared the preference of American and Japanese user manual readers regarding document illustration. Li et al. [75] highlighted the differences between Chinese and English user manuals of the same products. The documents differ on the levels of both content and presentation. In a later work [76], the authors conclude that Chinese user manuals are "fuzzier" and less "rigid", highlighting the cultural differences between holistic and analytical thinking. Language and culture were also addressed by the work of Hambleton [77]. Pedraz-Delhaes et al. [78] studied the effect of user manual language quality on consumer perceptions, and found that language quality affects the perception of both the product and the manufacturer. Xu and Deng [79] investigated the effect of user manual translation. The authors found that translation to the native language of the user may improve the utilization of such documents. The work of Gil and Pym [80] provides a broad overview of translation in the context of technology.

Gök et al. [81] published a paper on the effect of user manual quality on customer satisfaction. The individuals participating in the experiment had purchased high-involvement electrical appliances, such as a dishwasher, a refrigerator, or an oven, within the last three months. The authors found a positive significant relationship between user manual quality and perceived product quality. Gemoets and Mahmood [82] had similar findings for information systems, and Smart et al. [83] addressed computer hardware. Moreover, Pedraz-Delhaes et al. [78] approached user manual quality via document language quality and came to analogous conclusions. Gemoets and Mahmood [82] empirically studied the impact of documentation quality on user satisfaction. They used five-point Likert-type scales [84] to evaluate two series of quality-related questions. One included statements (strongly disagree, disagree, neutral, agree, and strongly agree) and the other one directly addressed satisfaction (very unsatisfactory, unsatisfactory, neutral, satisfactory, and very satisfactory). Data were collected for a total of 35 questions. For both series, the authors found that the conciseness of user manuals was "moderately emphasized" by the test participants and that it was deemed a matter of "moderate priority". Guillemette [85] involved a variety of test participants with different backgrounds (e.g., banking, manufacturing, financial, education, etc.). The study investigated appropriate adjectives to describe what readers of user manuals mean by "good documentation". The most frequent (i.e., most popular) adjectives were informative, helpful, valuable, useful, logical, good, correct, and precise; however, there was no mention about being concise. The fact that document size was completely neglected was also highlighted by the author. Similarly to the study of Gemoets and Mahmood [82], the work of Schriver [86] addresses the impact of documentation quality. The survey did not utilize a uniform assessment scale; instead, each question had its own set of possible answers. One particularly interesting question was the following: "Would you be willing to pay more for a product if you knew it had a clear manual?". Of the test participants, 26.7% responded yes, 36.4% responded maybe, and 36.9% responded no. Mitchell [87] utilized both a qualitative (i.e., interviews to identify key attributes) and a quantitative (i.e., phone and mail survey to assess the previously identified attributes) approach to map document-related attributes by general importance and connection to user satisfaction. High importance and high satisfaction were assigned

to accuracy, completeness, and satisfaction. It is important to highlight that conciseness did not even make it into the top 10 list of attributes in the qualitative study. Furthermore, retrievability was assessed as low satisfaction. Smart et al. [83] also investigated the effect of user manual quality on the perception of product quality. The study covered computer hardware and the secondary product, which is the user manual itself. The variables which applied to the hardware were usability, capability, performance, reliability, installability and maintainability, and the main objective of the research was to find out how the user manual of the hardware affects these variables. The results of the telephone survey concluded that there is a direct connection between user manual quality and the perception of product quality. In essence, the authors found that there is a chance between 64% and 73% of predicting the customer's perception of product quality.

In a later work of Smart et al. [88], the authors addressed the topic of user manual format (i.e., printed versus online). The study concludes that customers get started using printed materials, and that the unavailability of the printed user manual bothers users. A subsequent study of Smart et al. [89] adds that online user manuals are preferred for task-oriented (and not feature-oriented) assistance, and that printed manuals are more helpful for those who do not know the keywords or correct terms. Mehlenbacher et al. [90] also addressed the format, and found that hard copies are significantly more popular than digital manuals. User manual format was intensely investigated in the 1980s and the 1990s [91–95], yet, note that many novel technological solutions have been introduced since then. For example, the work of De Amicis et al. [96] addresses the usage of augmented reality (AR) for user manuals.

Gellevij et al. [97] studied the effect of screen captures in manuals. The experiment compared three user manuals of the same product: one without screen captures, one with complete screen captures (i.e., the entire screen), and one with cropped screen captures. The results indicate that the use of fullscreen captures is preferable to partial ones. Herriman [98] addressed a metadiscourse on imaging in user manuals. Pavel and Zitkus [99] highlighted the importance of pedagogical instructional design (PID) in the creation of user manuals. The authors suggested that user manuals should contain live examples of the use of the product. Kovačević et al. [100] used eye-tracking technology to examine the reading of user manuals. The results highlight the importance of pictograms in such documents, as well as the impact of boldface typesetting on efficiency.

The preliminary study of van Loggem and Lundin [101] observed the interactions of test participants with a software tool unknown to them. The authors found that users tend to read the manual prior to using the software, yet they call for more extensive research to confirm this observation. A subsequent work of van Loggem [102] enquires whether users read the user manual at all. The results of the study indicates that better-educated and older users tend to read the manual. However, the results of Blackler et al. [6] contradict this finding, as the authors claim that better-educated people are less likely to read the manual. Yet, both works agree that younger individuals are the least likely to read the user manual.

Møller [103] revisited the topic of user manual usability, particularly for older users (above the age of 55). The results indicate that foreign words can be problematic for such users and that they prefer shorter manuals. This latter finding conflicts with the need for a larger font size. Glenberg and Robertson [104] investigated the indexical understanding of instructions, which may potentially increase the efficiency of processing user manuals. Ganier [105] studied the usage efficiency of user manuals for novel devices, and proposed the higher involvement of cognitive psychology concerning learning in the processes of information design. Oviedo-Trespalacios et al. [106] specifically addressed the user manuals of advanced driver assistance systems (ADASs).

The work of Earle et al. [107] investigates the user preference regarding software documentation genres. The study marks vendor-supplied tech notes as the most popular, followed by how-to videos, product help systems, and how-to articles, and the lowest preference was measured for forums (i.e., interactive Q&A websites) and tutorials (i.e., step-by-step instructions). Van Der Meij [108] compared step-by-step and guided-tour

manuals, and found that step-by-step manuals may make execution faster, but are generally not superior to the other type.

Clarke and Carroll [109] concluded that human factors should be considered during the composition of user manuals. Weiss [110] tackled the issue of the dependency related to user manuals. The work argues that such documents are not something that the user enjoys reading, and, therefore, efforts are needed to minimize engagement. Ummelen [111] studied procedural and declarative information in user manuals. The conclusion suggests that even though procedural information is used for longer, declarative information is still necessary, a point that was also investigated in subsequent works of the authors [112,113], as well as by Shachak etl al. [114]. Bédard et al. [115] proposed the concept of multi-dimensional user manuals (MUMs). The goal of the framework was to improve the quality and efficiency of information delivery, which is achieved by the use of the multi-dimensional database approach. MUM was also addressed in a different work of the authors [116] in which legal requirements and communication with end users were discussed.

Even scientific conferences and journals may be inspected from the perspective of user manuals. After all, they provide comprehensive instructions to prospective authors about paper submission. Therefore, one may perceive such pages and guides as user manuals for researchers and scientists. The works of Hoffmann et al. [117] and Schriger et al. [118] address this topic. The latter particularly investigates medical journals.

3. Methodology

In this section, the methodology for each research effort is presented. The data were collected via a series of questionnaires utilizing Likert-type scales [84], binary and multiple-choice questions, as well as other forms of qualitative and quantitative assessments. The questionnaires—containing each non-demographic question and the corresponding answer options—are provided in the appendices of this paper.

3.1. Research Alpha

The questionnaire first collected basic demographic information, such as age and gender. This was followed by the individual's connection to user manuals. As stated in Section 1, one could either be classified as a regular user (i.e., one who primarily encounters user manuals as a customer), a professional user of user manuals (i.e., one who encounters user manuals in a daily professional context), or a technical writer (i.e., one who is involved in the creative processes of user manuals). There was an option to "prefer not to say", which was also applicable to the demographic information. Additionally, following the methodology of our previous research effort [10], the highest level of education was asked as well, which was also optional to answer. However, as no research question addressed the highest level of education, this was omitted from the other three studies. In future work, research efforts could use education level as a means of extended classification (i.e., to distinguish individuals within the groups based on the connection to user manuals).

The main part of the questionnaire consisted of three multiple-choice questions—based on the approach of our earlier work [10]—aimed at the interactions with user manuals: (i) the reason for opening the document for the first time; (ii) the most common reason for such an action; and (iii) the average number of such actions. Each question was applied to a total of ten device classifications: three were based on user experience (good, neutral, and bad); two on complexity (less complex and more complex); two on device purpose (general-purpose and dedicated devices); and three on device price range (less than USD 100; between USD 100 and USD 200; and more than USD 200). Regarding the selected price ranges, note that these values were selected prior to the significant inflation of 2022 and 2023. The test participants were instructed to complete a classification only if it was applicable to their past experiences. These 30 categorical questions were extended by additional questions on personal preference and quick guides. The complete list of questions and their answer options are provided in Appendix A.

For the first question (the reason for opening the document for the first time), the answer options were the following: after purchase (i.e., prior to first use); after first use (e.g., to explore certain functionalities); if the device is not intuitive enough (e.g., if one cannot find or adequately operate a specific function); if the device has minor issues (e.g., if it is not functioning as expected or if there is a suspicion of fault); if the device has major issues (e.g., if the device is clearly malfunctioning or broken); never; other.

For the second question (the most common reason for opening the document), the answer options were the following: to explore novel functionalities (i.e., either to find out more about a specific new feature, the existence of which is already known to the individual, or to find new features that the individual is not yet aware of); to customize the device (e.g., to change the operational parameters of a service); to reset the device (i.e., to restore it to factory settings); for troubleshooting (i.e., to attempt to overcome an issue that does not require professional tools or assistance); other.

For the third question (the number of times opening the document during the complete life cycle of the device, or the average number in the case of multiple devices in a given category), the answer options were the following: 0; 1 or 2; 3 or 4; between 5 and 10; more than 10.

These 30 questions were optional in the sense that their completion relied on the subjective and objective categorization of devices. For instance, if an individual had used three smart wearables thus far, it was possible to complete three sets of questions based on user experience (if one was deemed good, one was neutral, and one was bad), yet complete only a single set based on price range (if all three belonged to the same price category).

The five questions primarily targeting quick guides were not optional, as they asked about preference, and not experience or user behavior. Therefore, these questions were answered by every single individual who participated in Research Alpha. There were questions about seeking information in figures and text, ratio preference regarding figures and text, access preference regarding mobile applications, as well as type and color preferences regarding figures.

3.2. Research Beta

A significant change compared to Research Alpha was that the option "prefer not to say" regarding the connection to user manuals was removed, which also applied to Researches Gamma and Delta. As detailed later in Section 4, nearly a quarter of all test participants chose this option, which greatly affected the analysis of the obtained data. Moreover, as explained earlier, the question related to the highest level of education was removed as well, similarly to the other two research efforts. Furthermore, as smart wearables were not distinguished or categorized—as opposed to in Research Alpha—answering the questions was not optional; every test participant answered every question.

There was a total of 18 questions in Research Beta. The first 13 questions asked about satisfaction, preference, and user behavior, while the other 5 specifically addressed devices purchased in the past 5 years. The complete list of questions and their answer options are provided in Appendix B.

On the level of methodology, every single question had 11 options. Depending on the need for a neutral option, the values ranged either from 0 to 10, or from -5 to 5. In the former, 0 was one of the extremes on the rating scale, while in the latter, 0 was the neutral option.

3.3. Research Gamma

This is the only research effort that specifically targeted a given type of smart wearables, namely, medical-purpose devices. There was a total of 18 questions in Research Gamma. The first 9 questions were usage-related binary enquiries, including context (e.g., whether the individual wears and uses smart medical wearable devices for sports and training) and medical measurement type (e.g., whether the device is used for step counting). The other 9 questions were focused on user manual interaction. In addition to general questions (i.e., questions that can be applied to any other type of smart wearable) such as the reason for

opening the document, format preference, and satisfaction, we also asked whether the individual would rely on the user manual to comprehend abnormal medical measurement values. For this question and 4 others, a five-option symmetrical scale with a neutral option in the middle was used (e.g., for user-manual-related satisfaction, the options were completely dissatisfied, dissatisfied, neutral, satisfied, and completely satisfied). The complete list of questions and their answer options are provided in Appendix C.

3.4. Research Delta

In Research Delta, the questionnaire targeted time efficiency (i.e., the time needed to find something in the user manual), perseverance (i.e., the time after which the individual gives up on the user manual), alternate actions (i.e., when the individual is unable to find help in the user manual), and user satisfaction. There was a total of 20 questions. Time efficiency was addressed by 4 questions for 4 primary reasons of user manual access (exploration, customization, reset, and troubleshooting). There were 4 possible answers for each: under a minute; between 1 and 5 min; between 5 and 10 min; over 10 min. Perseverance was measured for the same primary reasons, with the same answer options. The primary reasons were also applied to alternate actions with 6 different options (e.g., asking a friend or relative). User satisfaction was rated on a scale from 0 to 10—where 0 corresponded to very unsatisfied, and 10 to very satisfied—along 6 aspects of subjectively perceived document quality: overall satisfaction, time efficiency, language, structure, visualization, and length. One additional question collected data on language preference (i.e., between simplified and technical language) on a scale from -5 to 5 (similarly to the scale utilized in Research Beta) and one addressed the potential reasons for unsuccessful user manual usage (i.e., if the individual is unable to find the relevant information). The complete list of questions and their answer options are provided in Appendix D.

4. Results

In this section, the obtained results for each research effort are presented. The analysis of the data is based on the classification of test participants (i.e., regular users, professional users, and technical writers). The presentation of the data follows this order, extended with the overall results. Therefore, distributions and the mean values are shown in the following order: overall, regular users, professional users, and technical writers.

4.1. Research Alpha

A total of 1208 test participants completed the research questionnaire. Of these, 541 (44.78%) were male, 648 (53.64%) were female, 4 (0.33%) were other, and 15 (1.24%) preferred not to answer. The recruited individuals were in the age range between 18 and 60, and the average age was 36. Regarding the highest level of education, 119 (9.85%) finished elementary school, 257 (21.27%) had a high school diploma, 622 (51.49%) went to college, 130 (10.76%) had a higher university degree, and 80 (6.62%) had a Ph.D. degree. As for the connection to user manuals, 426 (35.26%) were regular users, 267 (22.1%) were professional users, 220 (18.21%) were technical writers, and 295 (24.42%) preferred not to answer. This latter group was technically a combination of the different classifications with an unknown distribution. They were relevant to the overall analysis, but they did not form a separate, individual category.

The three primary questions (the reason for opening the document for the first time; the most common reason for opening the document; the number of times opening the document during the complete life cycle of the device, or the average number in the case of multiple devices in a given category) are denoted as Q1, Q2, and Q3 in this analysis, respectively. The results were analyzed via Pearson's chi-squared test. The goodness of fit was assessed, with DoF $= 6$ for Q1 and DoF $= 4$ for Q2 and Q3. As not every single individual completed all the questions, the inputs varied in size, and thus, the analysis was applied to the percentage-based distribution of the questionnaire options. In Research Alpha, the overall results and the different classifications are separately presented; however,

note that the overall results are not exclusively based on the classifications, as they contain the data with the unknown categorical distribution as well. Regarding devices, the vast majority of the test participants owned multiple smart wearables. Therefore, achieving balance in terms of input sizes was less challenging.

4.1.1. User Experience

The input sizes for positive, neutral, and negative user experiences were 1167, 1108, and 1052, respectively. The results for Q1 are presented in Figure 1. The most dominant behavior is that user manuals are first accessed after the purchase of the device. In comparison, it is rather less likely that the first encounter is due to some sort of an issue. This behavior is in alignment with Q2 and Q3, as shown in Figures 2 and 3, respectively, declaring exploration as the dominant reason, and 1 or 2 as the most common numbers of total access times. These trends are generally applicable to the analysis of the other influence factors as well. However, for the category of professional users, opening user manuals for the first time after the first use of the device is similarly frequent.

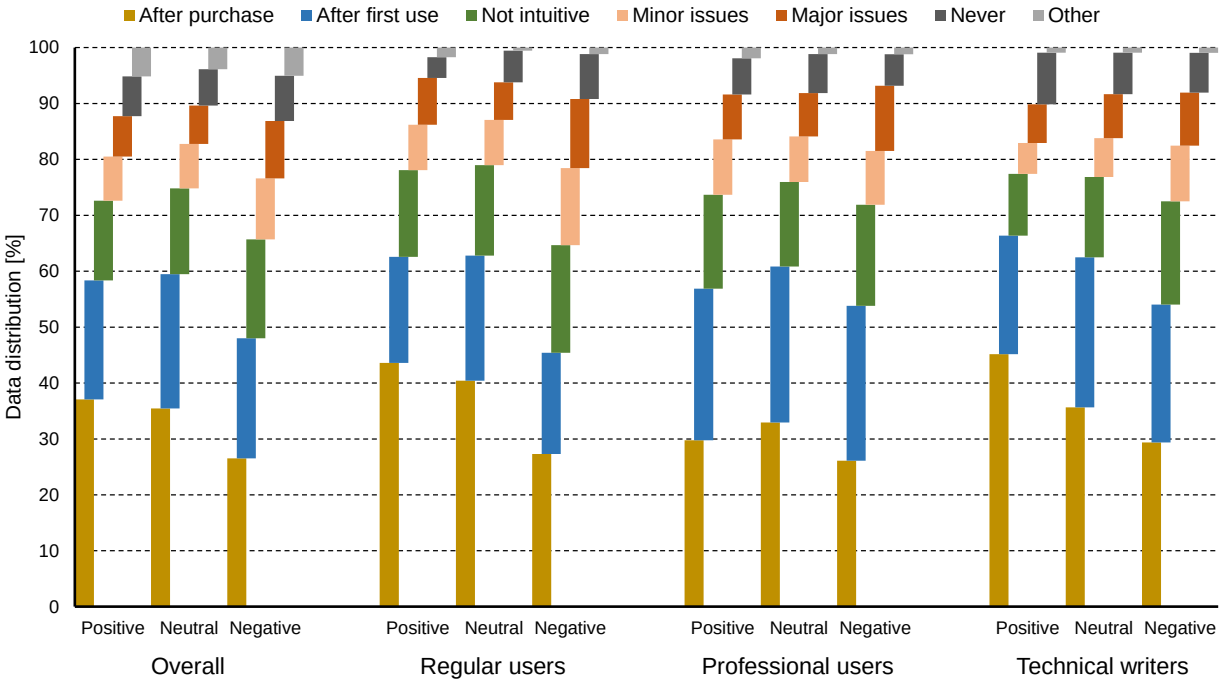

Figure 1. Obtained results for Research Alpha: user experience (Q1).

As mentioned earlier, the overall results contain data from test participants the category of whom is not declared. The potential impact of this is well demonstrated by Figure 1. While the "other" option for Q1 was below 2% for the different classifications, it was nearly 12% for those with unknown distribution, resulting in approximately 5% of the overall results.

Regarding the influence factor itself, major issues with the device that have a negative user experience are more common, as well as the action of troubleshooting. In these cases, the aforementioned most frequent behaviors are less dominant, yet the relations in the data distribution are still maintained.

To understand the significance of these differences, and thus, the impact of the influence factor, a statistical analysis is used to compare devices with positive, neutral, and negative user experiences. The results are summarized in Table 1. The p values that are below 0.05 are highlighted, indicating statistically significant differences.

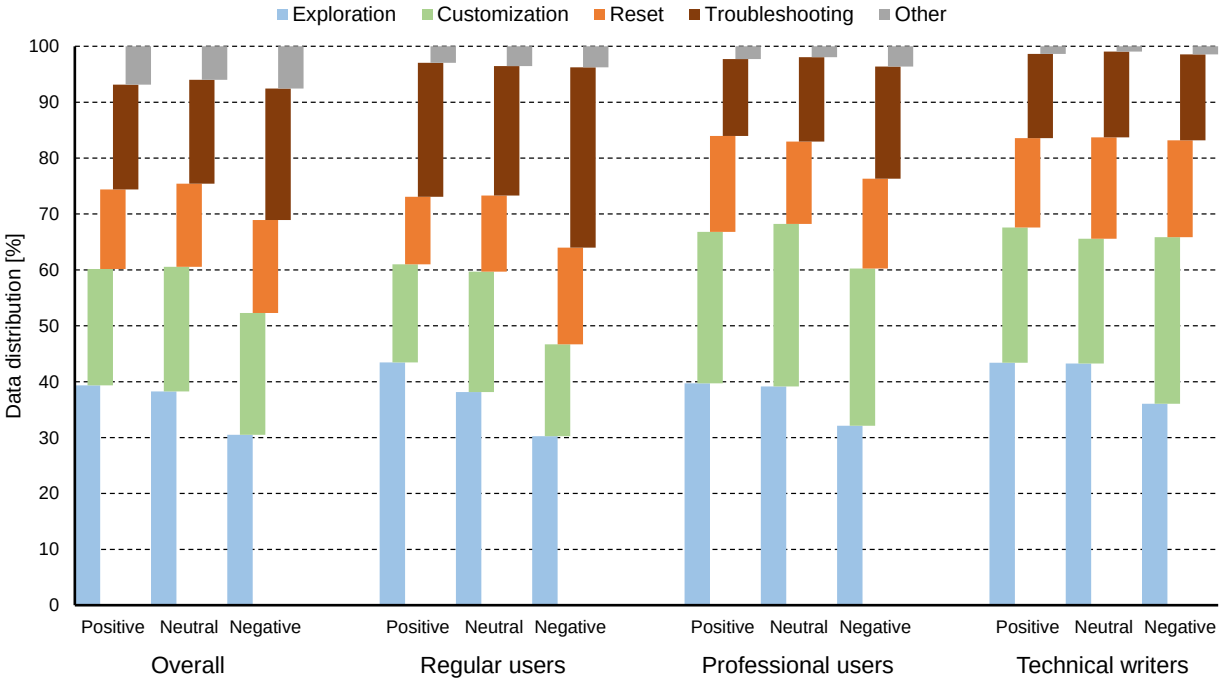

Figure 2. Obtained results for Research Alpha: user experience (Q2).

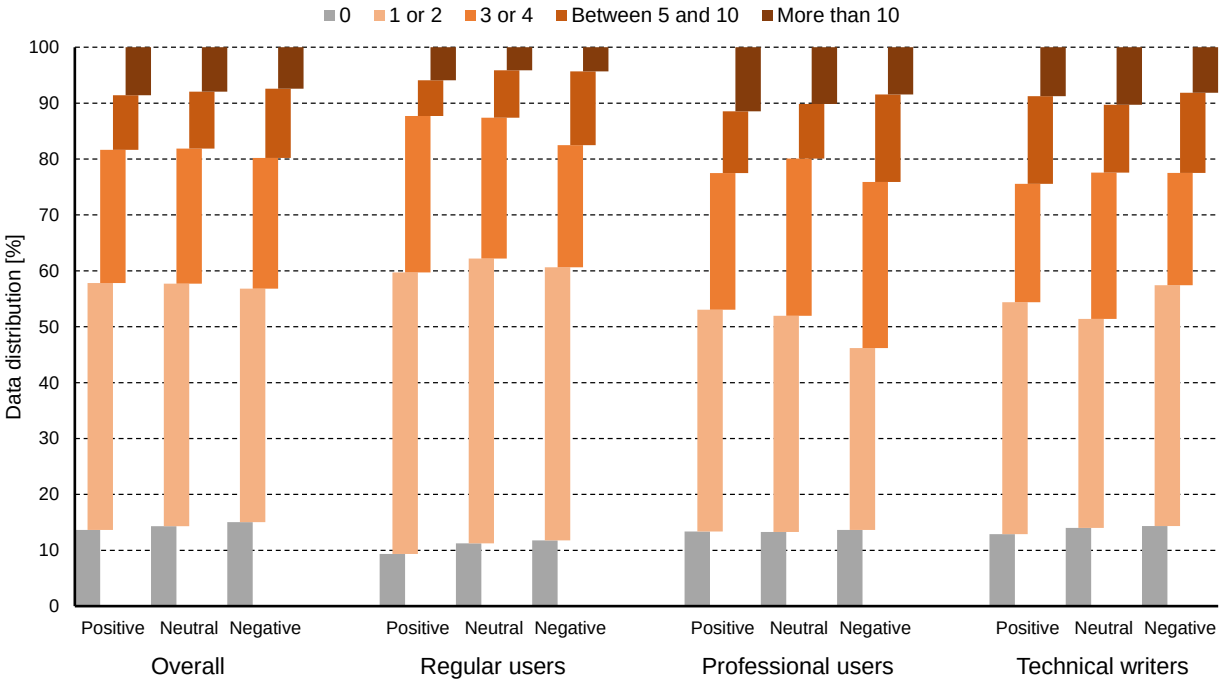

Figure 3. Obtained results for Research Alpha: user experience (Q3).

Statistically significant differences can be found mostly in the category of regular users, as well as in the Q1 data of technical writers when comparing positive and negative user experience. In this latter case, the after-purchase first access dropped from over 45% to below 30%, while most of the other options greatly increased. In the case of regular users, these tendencies apply to the comparison of neutral and negative user experience. For Q2, exploration is replaced by troubleshooting as the primary reason for accessing the user manuals of devices with negative user experience. Regarding Q3, having a total access

number between 5 and 10 (instead of 3 or 4) gradually increased with the decline in user experience, but the resulting differences are not statistically significant.

Table 1. Statistical analysis of Research Alpha: user experience (Q1–Q3).

Comparison	Overall	Regular Users	Professional Users	Technical Writers
Q1				
Positive/Neutral	0.99	0.77	0.97	0.51
Positive/Negative	0.38	*0.01*	0.88	*0.02*
Neutral/Negative	0.41	*0.03*	0.65	0.7
Q2				
Positive/Neutral	0.99	0.77	0.95	0.97
Positive/Negative	0.43	*0.05*	0.32	0.62
Neutral/Negative	0.48	0.13	0.41	0.45
Q3				
Positive/Neutral	0.99	0.76	0.93	0.61
Positive/Negative	0.9	0.12	0.29	0.98
Neutral/Negative	0.97	0.62	0.38	0.51

Italics is used to highlight statistically significant differences ($p < 0.05$)

4.1.2. Device Complexity

The input sizes for less complex and more complex devices were 1048 and 1037, respectively. The results for Q1 are presented in Figure 4. For more complex devices, regular users reported that the user manual is more likely to be accessed prior to first use. However, as shown in Table 2, such a difference in the distribution of options is not statistically significant, unlike for Q2 and Q3, the results of which are shown in Figures 5 and 6, respectively.

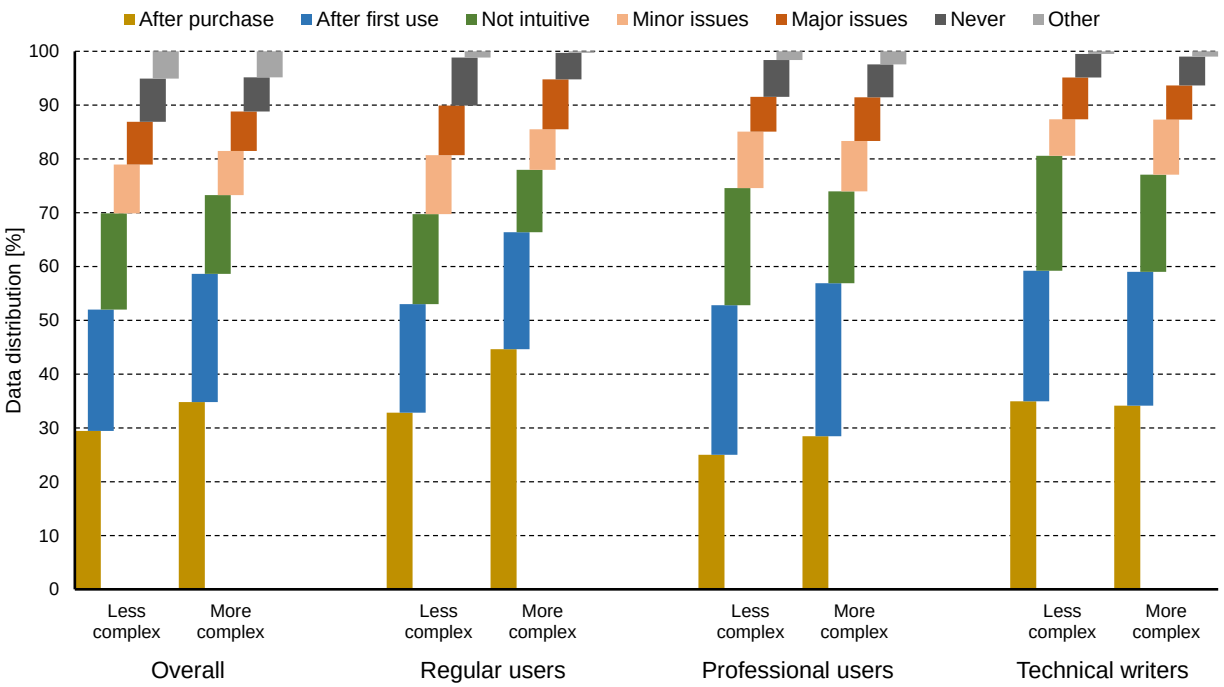

Figure 4. Obtained results for Research Alpha: device complexity (Q1).

Figure 5 demonstrates that for regular users, a higher device complexity comes with a greater need for exploration. This effect is not present in the data of the other classifications. Regarding Q3, the average access number for more complex devices is significantly higher, as shown in Figure 6. It is particularly notable that the number for the complete lack of user manual access is roughly half for such devices.

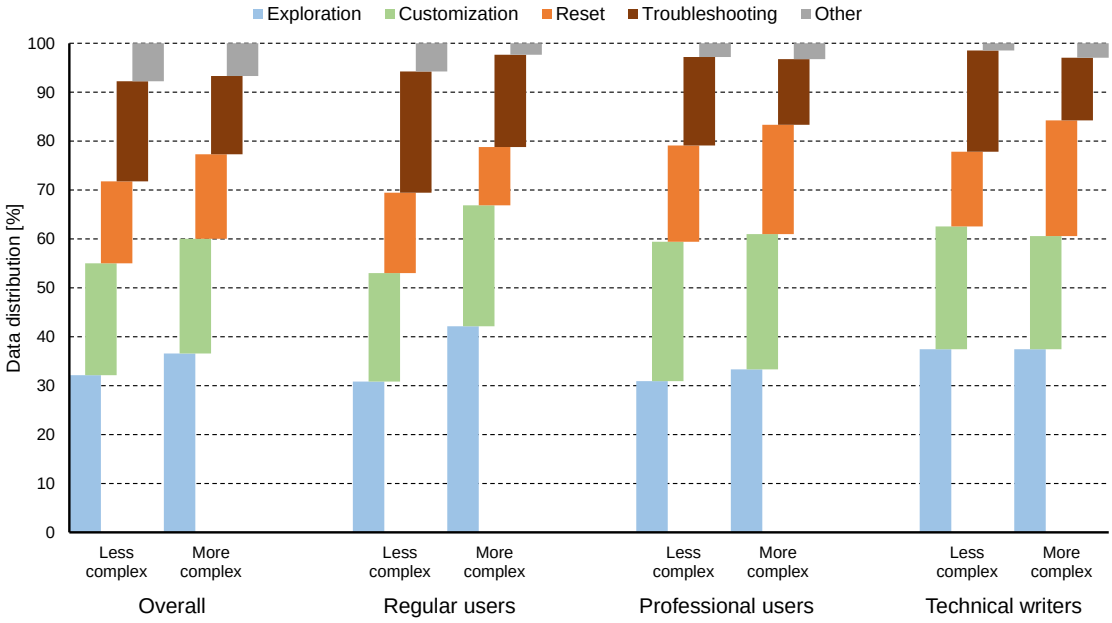

Figure 5. Obtained results for Research Alpha: device complexity (Q2).

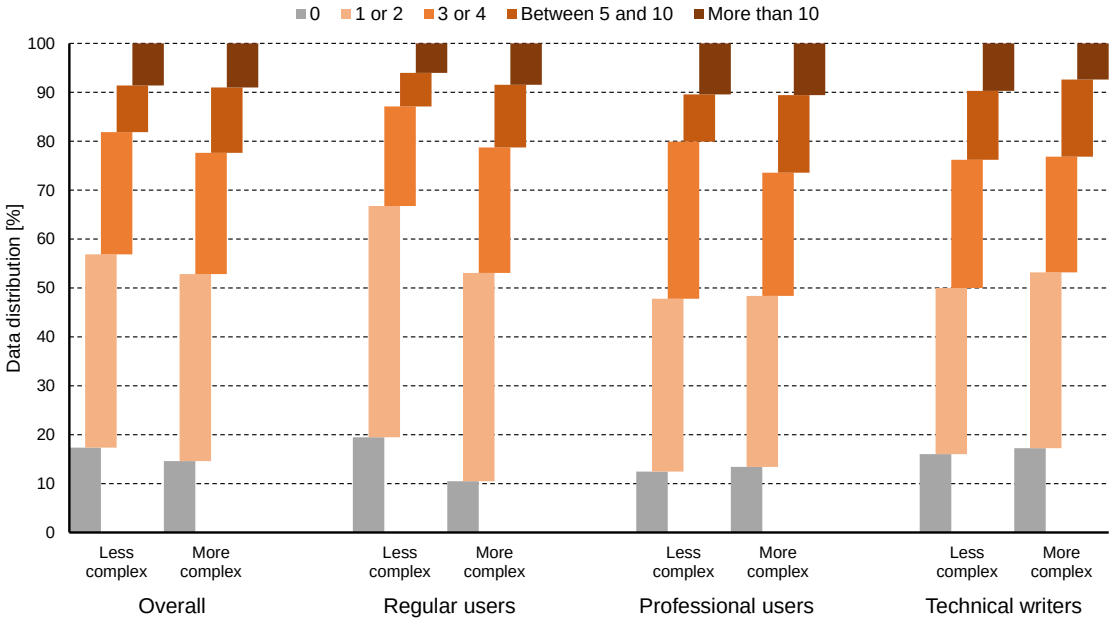

Figure 6. Obtained results for Research Alpha: device complexity (Q3).

4.1.3. Device Purpose

The input sizes for general-purpose and dedicated devices were 1029 and 1013, respectively. The results for Q1 are presented in Figure 7. The tendencies are similar to the case of complexity, where the data of dedicated devices correspond to those of more complex devices. This is applicable to Q2 and Q3 as well, depicted in Figures 8 and 9. However, as shown in Table 3, none of these differences reach statistical significance.

Table 2. Statistical analysis of Research Alpha: device complexity (Q1–Q3).

Comparison	Overall	Regular Users	Professional Users	Technical Writers
Q1 Less complex/ More complex	0.91	0.12	0.86	0.83
Q2 Less complex/ More complex	0.76	*0.05*	0.74	0.07
Q3 Less complex/ More complex	0.77	*0.02*	0.31	0.86

Italics is used to highlight statistically significant differences ($p < 0.05$)

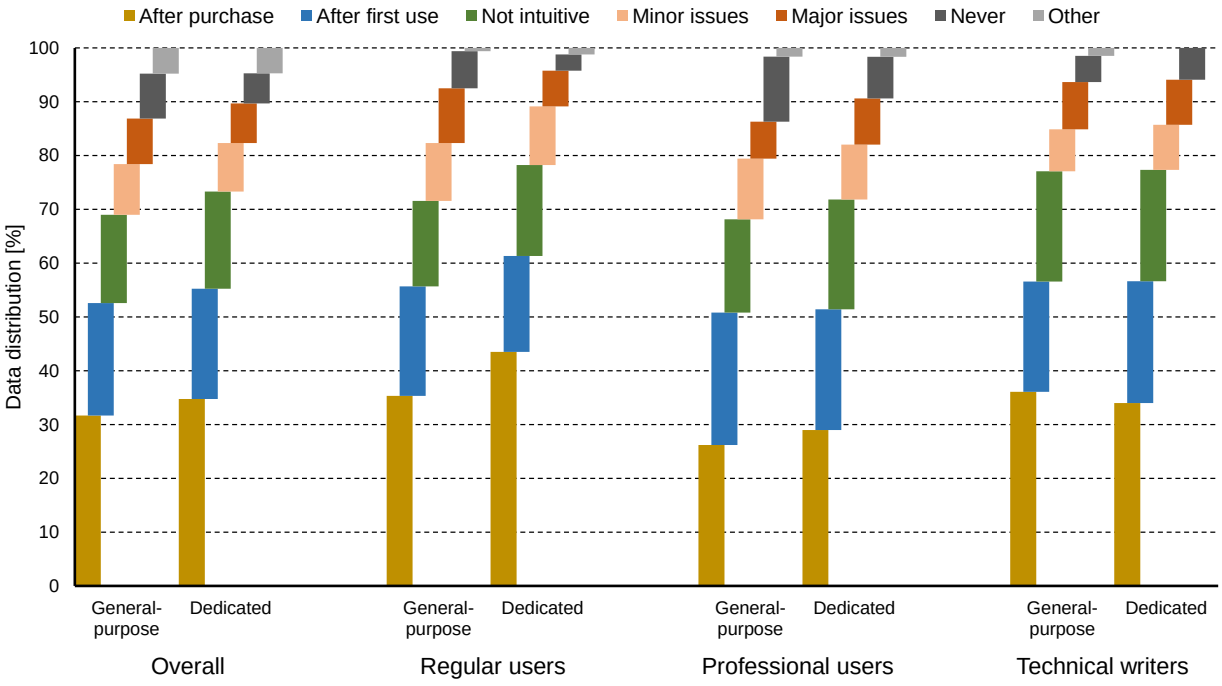

Figure 7. Obtained results for Research Alpha: device purpose (Q1).

4.1.4. Price Range

The input sizes for the three price ranges (less than USD 100; between USD 100 and USD 200; more than USD 200) were 1012, 1006, and 1013, respectively. The results for Q1, Q2, and Q3 are presented in Figure 10, Figure 11, and Figure 12, respectively, and the results of the statistical analysis are provided in Table 4. The obtained data indicate that the price of the device does not have any profound effect on the engagement with user manuals. The number of access times increases for regular users with device price, yet generally, there are no clear tendencies, and none of the differences in the comparisons show statistical significance. The lowest p value is 0.43, with all the rest at 0.5 or above.

4.1.5. Other Questions

As explained in Section 3, the five additional questions were not optional, and therefore, the input size for each was 1208. Overall, 54.64% of the test participants chose figures as the primary source of information. This value for the classifications of regular users, professional users, and technical writers, was 60.8%, 49.44%, and 50%, respectively. Regarding figures, 38.08% preferred conceptual figures over photos and screenshots. For the classifications, this was 34.04%, 41.95%, and 42.73%, respectively. Color figures were preferred by 71.52%, and for the classifications, this was 78.4%, 68.54%, and 62.27%, respectively. As for

access to mobile applications, 45.03% preferred QR codes, 35.6% preferred a direct link to the application store, and 19.37% had an alternate preference. These values deviated less than 2% for the different classifications of test participants.

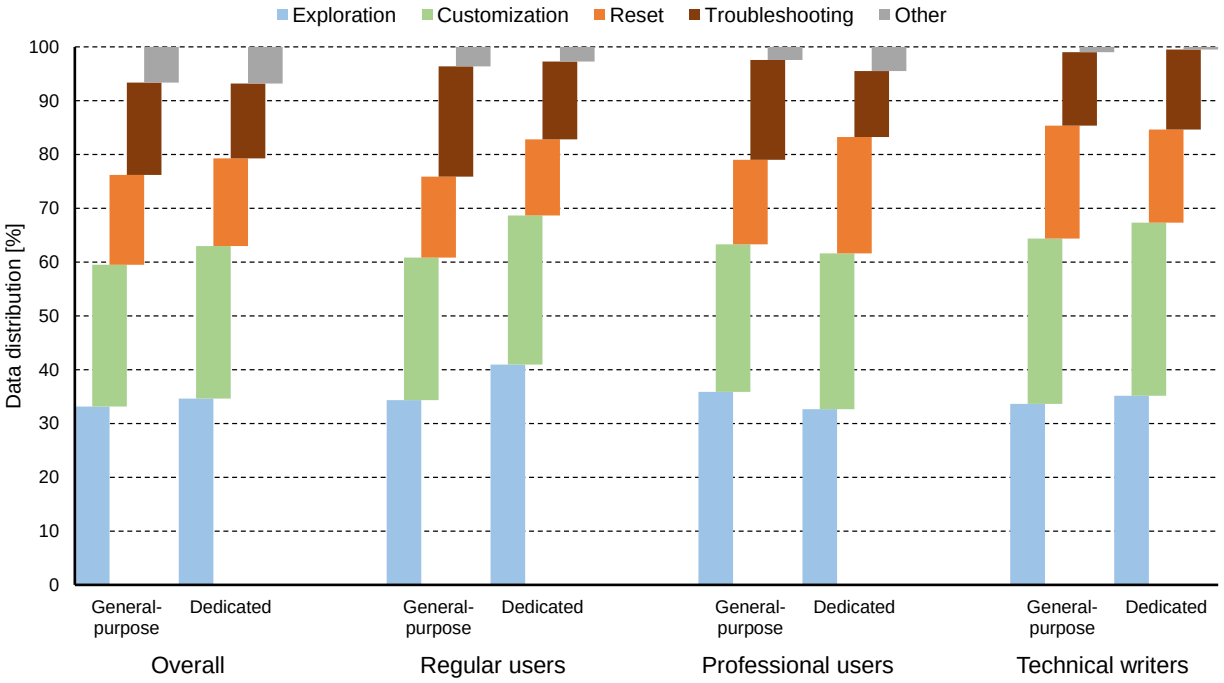

Figure 8. Obtained results for Research Alpha: device purpose (Q2).

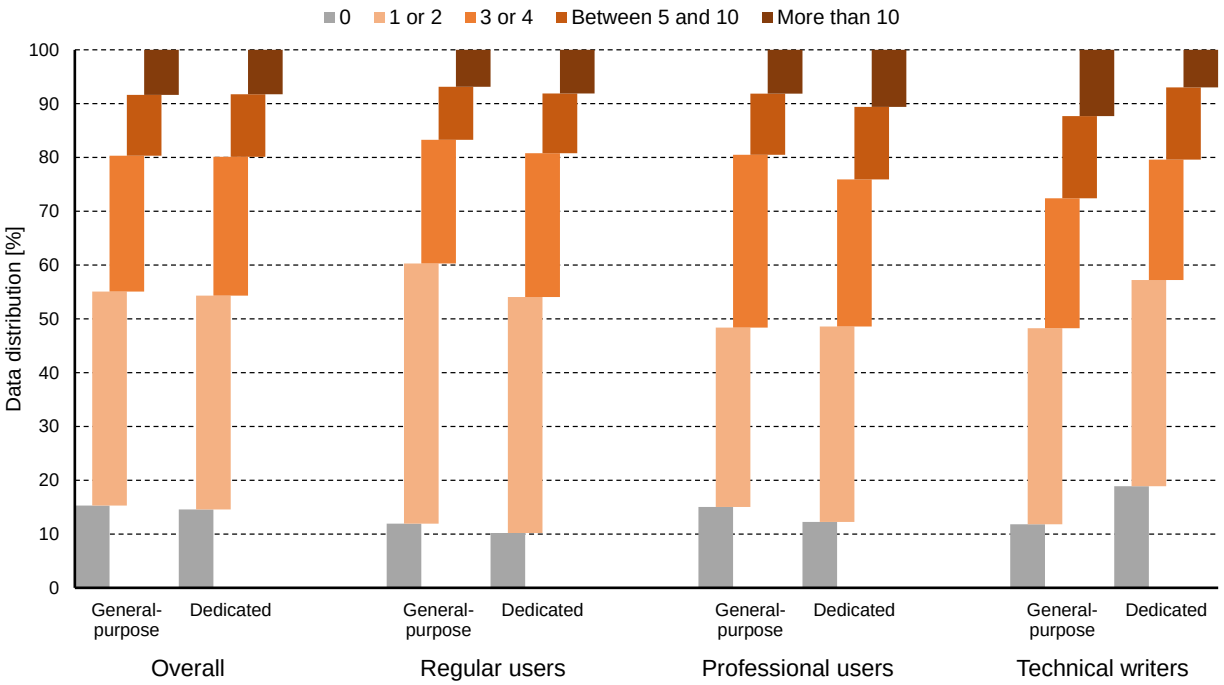

Figure 9. Obtained results for Research Alpha: device purpose (Q3).

Table 3. Statistical analysis of Research Alpha: device purpose (Q1–Q3).

Comparison	Overall	Regular Users	Professional Users	Technical Writers
Q1 General-purpose/ Dedicated	0.94	0.32	0.76	0.74
Q2 General-purpose/ Dedicated	0.92	0.46	0.19	0.87
Q3 General-purpose/ Dedicated	0.99	0.8	0.63	0.15

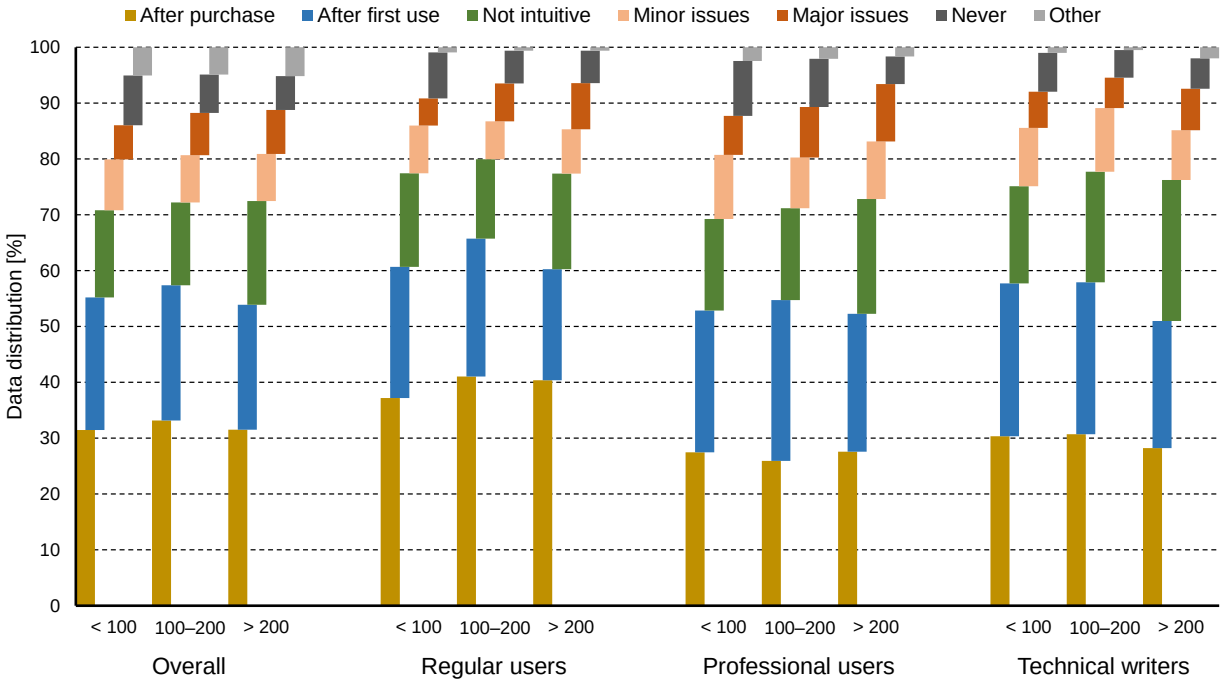

Figure 10. Obtained results for Research Alpha: price range (Q1).

The preferred text-to-figure ratio is shown in Figure 13. While we can see a rather balanced preference in the case of regular users, nearly 30% of technical writers would prefer to have text-only user manuals. For professional users, the distribution is halfway between the other classifications.

4.2. Research Beta

A total of 1105 test participants completed the research questionnaire. Of these, 531 (48.05%) were male, 571 (51.67%) were female, and 3 (0.27%) were other. The recruited individuals were in the age range between 18 and 70, and the average age was 35. As for the connection to user manuals, 500 (45.25%) were regular users, 335 (30.32%) were professional users, and 270 (24.43%) were technical writers.

The results obtained via rating scales between −5 and 5 are shown in Figure 14. As declared in the beginning of this section, the classifications are presented in the following order: overall, regular users, professional users, and technical writers. Again, in each data series, the first point represents the overall rating, followed by regular users, professional users, and the fourth point indicates the values associated with technical writers. The mean scores are visualized with 0.95 confidence intervals. Generally, the means of the

obtained data reside in the interval between −1 and 1, so there was no dominant opinion in either direction.

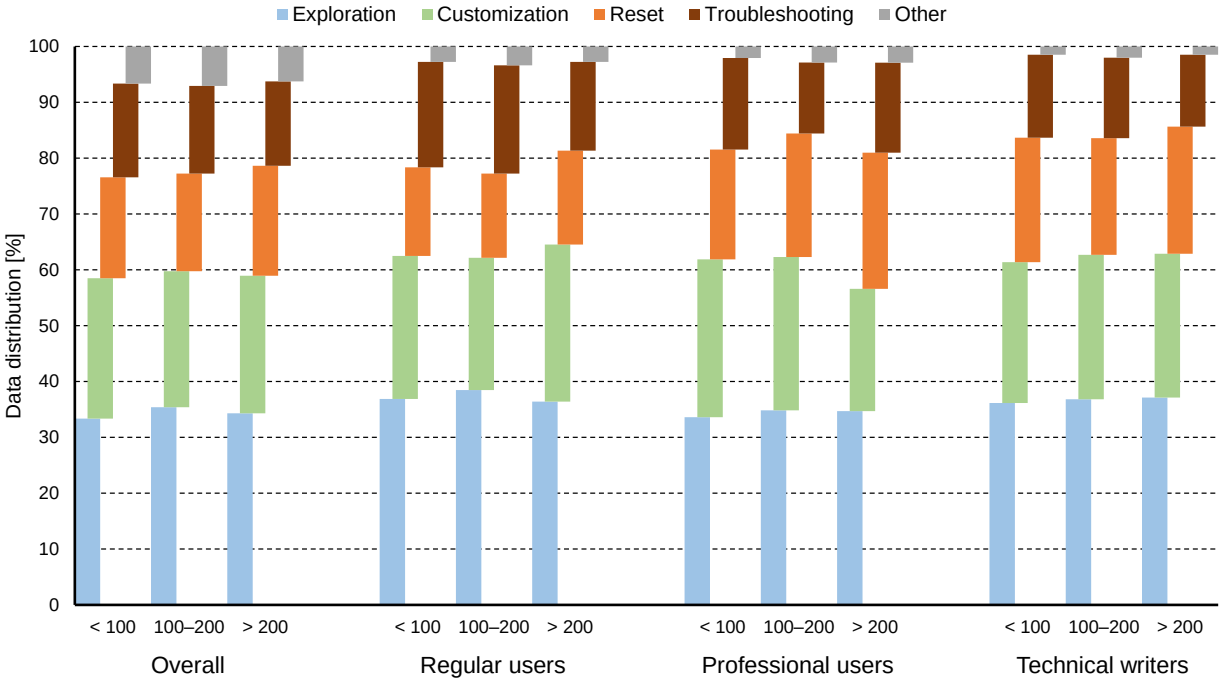

Figure 11. Obtained results for Research Alpha: price range (Q2).

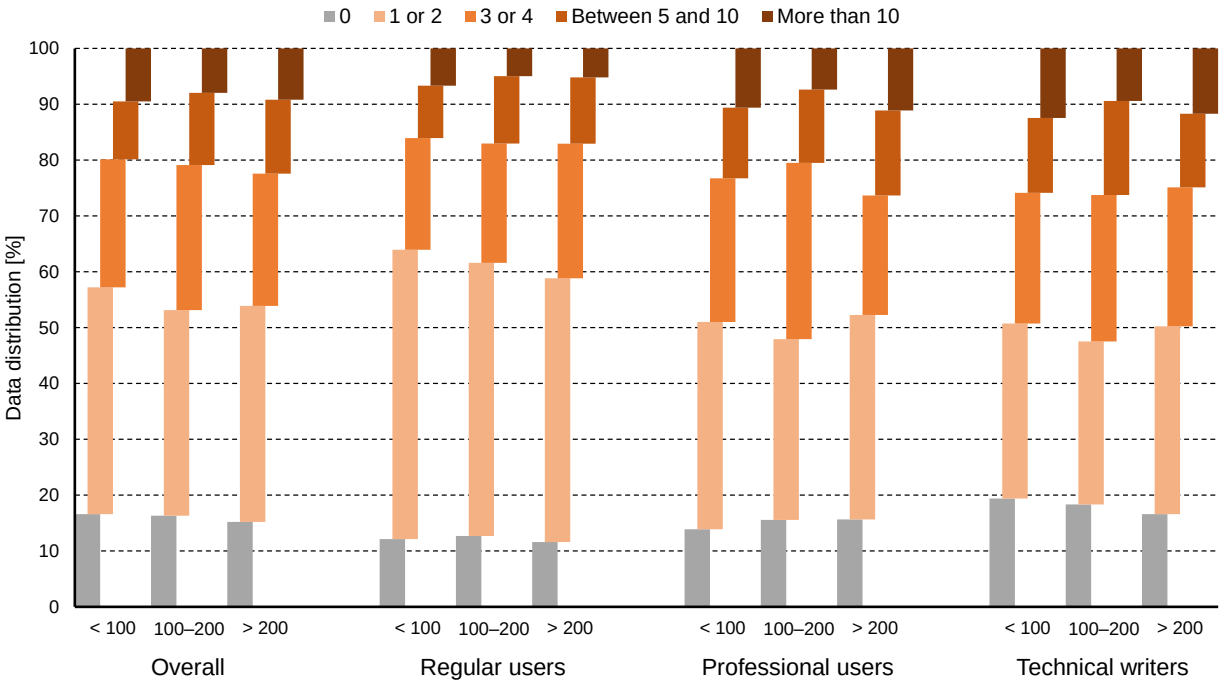

Figure 12. Obtained results for Research Alpha: price range (Q3).

Table 4. Statistical analysis of Research Alpha: price range (Q1–Q3).

Comparison	Overall	Regular Users	Professional Users	Technical Writers
Q1				
<100/100–200	0.99	0.83	0.93	0.95
<100/>200	0.91	0.73	0.43	0.51
100–200/>200	0.98	0.91	0.67	0.5
Q2				
<100/100–200	0.99	0.98	0.81	0.99
<100/>200	0.98	0.96	0.57	0.99
100–200/>200	0.99	0.98	0.81	0.99
Q3				
<100/100–200	0.81	0.83	0.52	0.71
<100/>200	0.92	0.71	0.83	0.95
100–200/>200	0.81	0.83	0.52	0.71

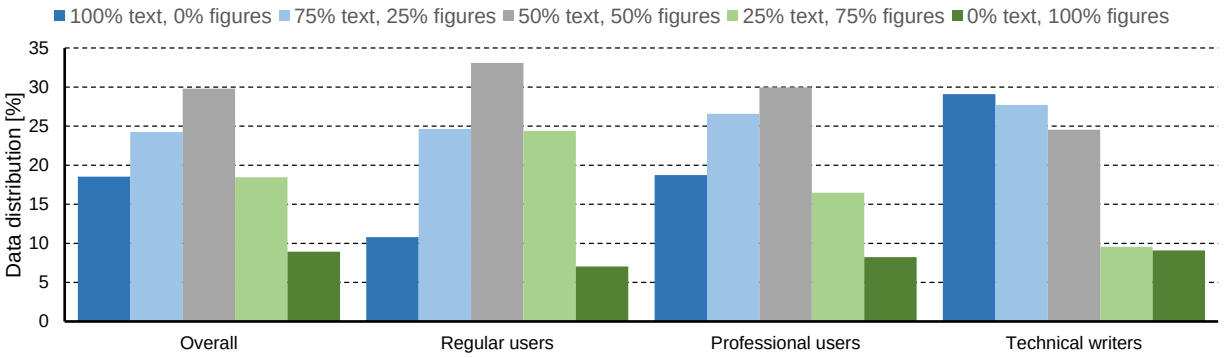

Figure 13. Obtained results for Research Alpha: preferred text-to-figure ratio.

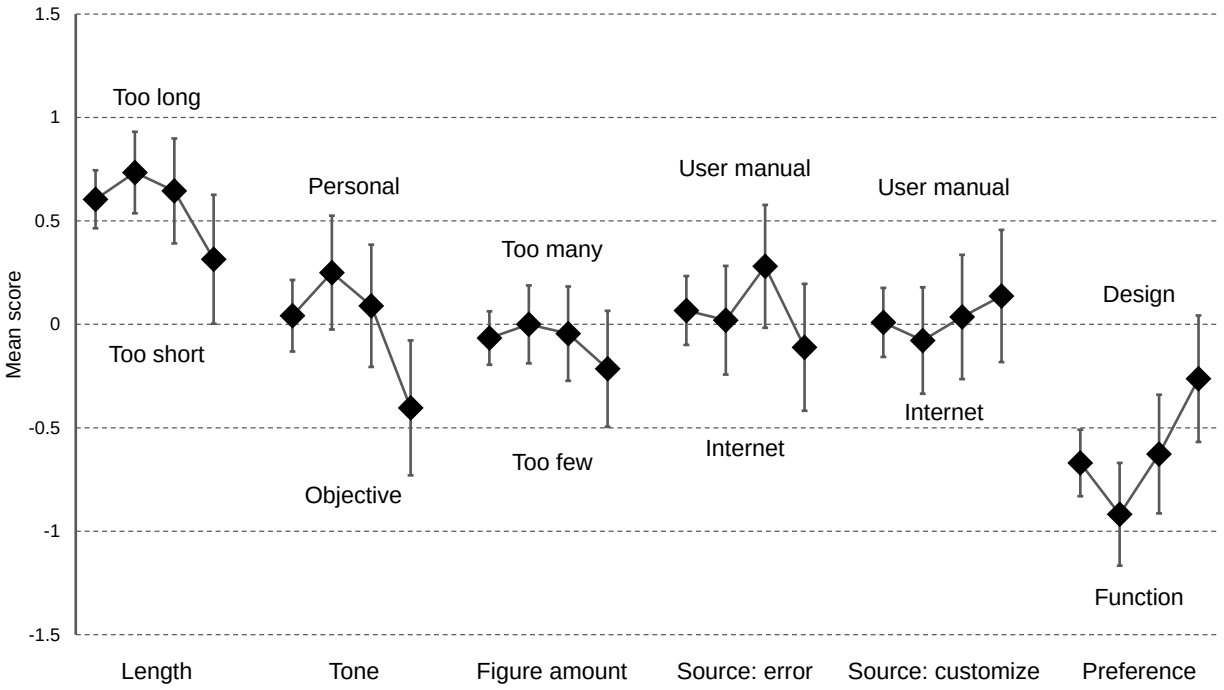

Figure 14. Obtained results for Research Beta: rating scales between −5 and 5.

In most of the questions, the responses provided by regular users and professional users did not deviate much—the only exception is the information source in case of device

error. However, the results of the technical writers deviated more, specifically compared to the regular users. In fact, some of these differences are statistically significant. This rating pattern is applicable to the vast majority of the questions within this research effort.

User manual length was assessed to be too long in general, yet it should be noted again that the mean values are between 0 and 1 on a scale running from −5 to 5. The closest to a balanced opinion were the results of technical writers. Regular and professional users preferred a more personal tone, while technical writers shifted towards a more objective style of writing. The difference between regular users and technical writers for this question is statistically significant. Regular and professional users had a near-zero mean score for figure amount, while technical writers reported that there are too few figures. In case of device error, professional users rely on the user manual more instead of the internet, yet this preference is balanced for customization. About the device itself, all means are in favor of function, yet regular users prefer it even more compared to the other classifications, and the difference between regular users and technical writers is statistically significant.

The results obtained via rating scales between 0 and 10 are shown in Figure 15. All the means fit into the interval between 4 and 6. Finding and understanding information was reported to be the easiest by regular users, and the most difficult by technical writers. In the case of the latter question, the difference is statistically significant. Figure quality was rated the highest by regular users, and the lowest by technical writers. Regarding the investigated negative and positive effects, the greatest impact was reported by regular users, and the lowest by technical writers. Two of these differences are statistically significant. As for the lack of printed user manuals, technical writers found it to be significantly more acceptable than regular users.

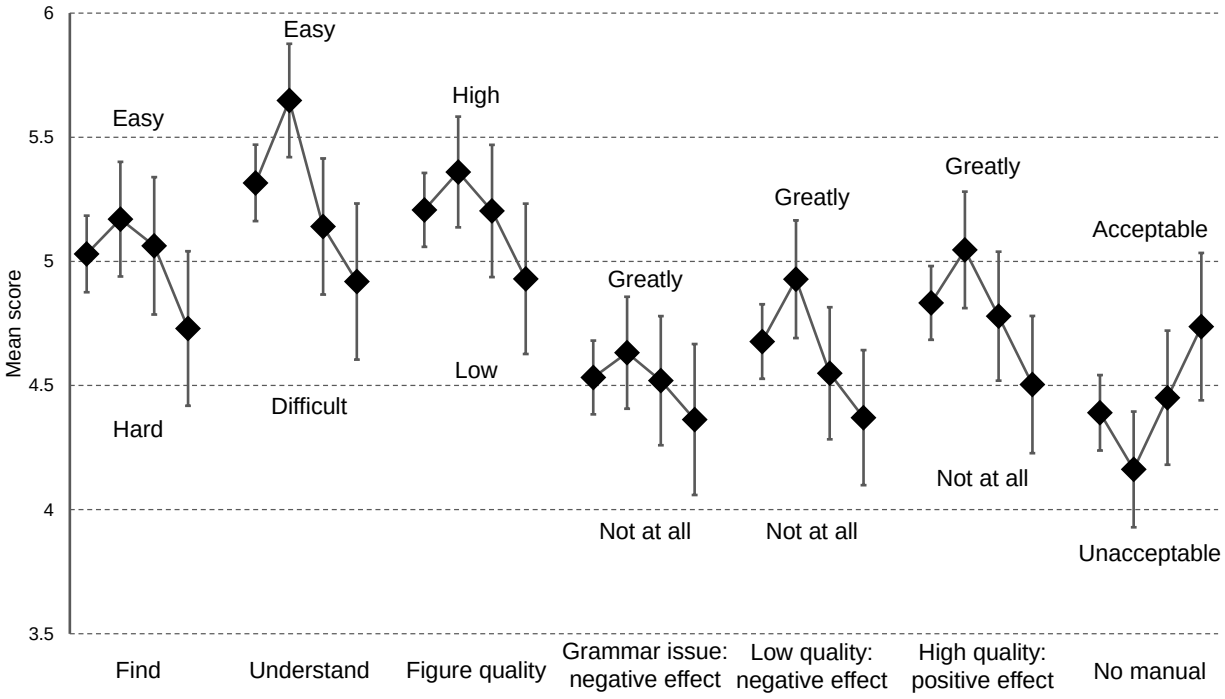

Figure 15. Obtained results for Research Beta: rating scales between 0 and 10.

The results obtained via rating scales between 0 and 10 regarding the assessment of devices purchased in the past 5 years are reported in Figure 16. All the means fit into the interval between 5 and 5.5. Generally, the previously introduced tendencies are applicable to this analysis as well. In this context, regular users were the most satisfied, while technical writers were the least satisfied. This extends to the assessment of the intuitive design of smart wearables. However, none of the differences are statistically significant.

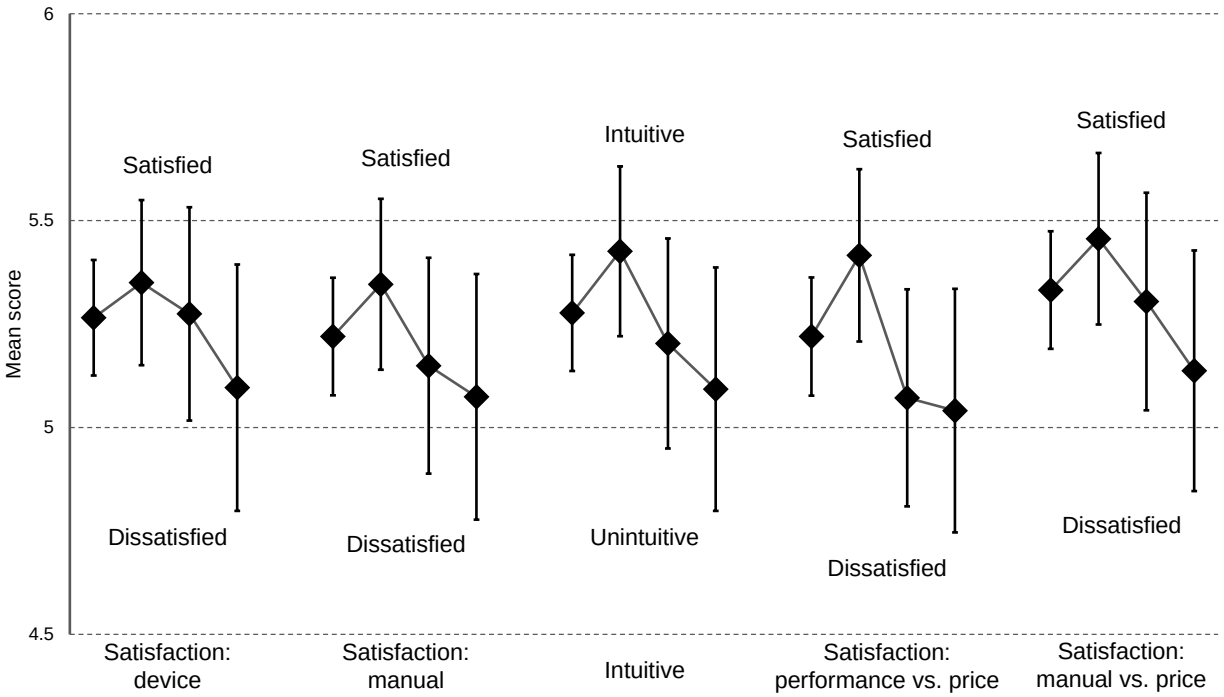

Figure 16. Obtained results for Research Beta: assessment of devices purchased in the past 5 years, rated between 0 and 10.

4.3. Research Gamma

A total of 342 test participants completed the research questionnaire. Of these, 174 (50.88%) were male, 166 (48.54%) were female, and 2 (0.58%) were other. The recruited individuals were in the age range between 18 and 88, and the average age was 32. As for the connection to user manuals, 172 (50.29%) were regular users, 88 (25.73%) were professional users, and 82 (23.98%) were technical writers.

The data distribution of binary answers regarding wearing and using smart medical wearable devices is shown in Figure 17. Roughly 60% of the test participants reported wearing their smart medical wearable to bed, which is the lowest among the three specified contexts. However, it is notable that only around 45% use the device for sleep monitoring. This opens up research questions regarding the motivations for wearing such a device in bed, other than sleep monitoring.

Regarding the other four functions of smart medical wearables, the highest values were reported for blood oxygen measurement. As data collection began in the first years of the COVID-19 pandemic, it is not surprising that more than 83% of the test participants used their devices for such a function. After all, it was a concern whether wearing a face mask for extended periods of time would affect the individual's blood oxygen level. The physiological impacts of wearing masks were addressed by many within the scientific community. For example, Hamouda et al. [119] concluded no significant effect on the blood oxygen saturation, while Liu et al. [120] measured a notable difference for KN95 masks. Due to the presence of both perspectives, the concern of individuals is understandable. As for the different classifications, the data indicate that technical writers are more active in wearing and using such devices, while professional users are less active in certain contexts.

Figure 18 shows the distribution for the most common reasons for accessing the user manual among the classifications. It is noteworthy that the exploration of novel functionalities was over 29% for regular users, while only 17% for technical writers. Instead, resetting the device was the leading reason for technical writers at 29.27%, which was only 16.28% and 15.9% for regular and professional users, respectively.

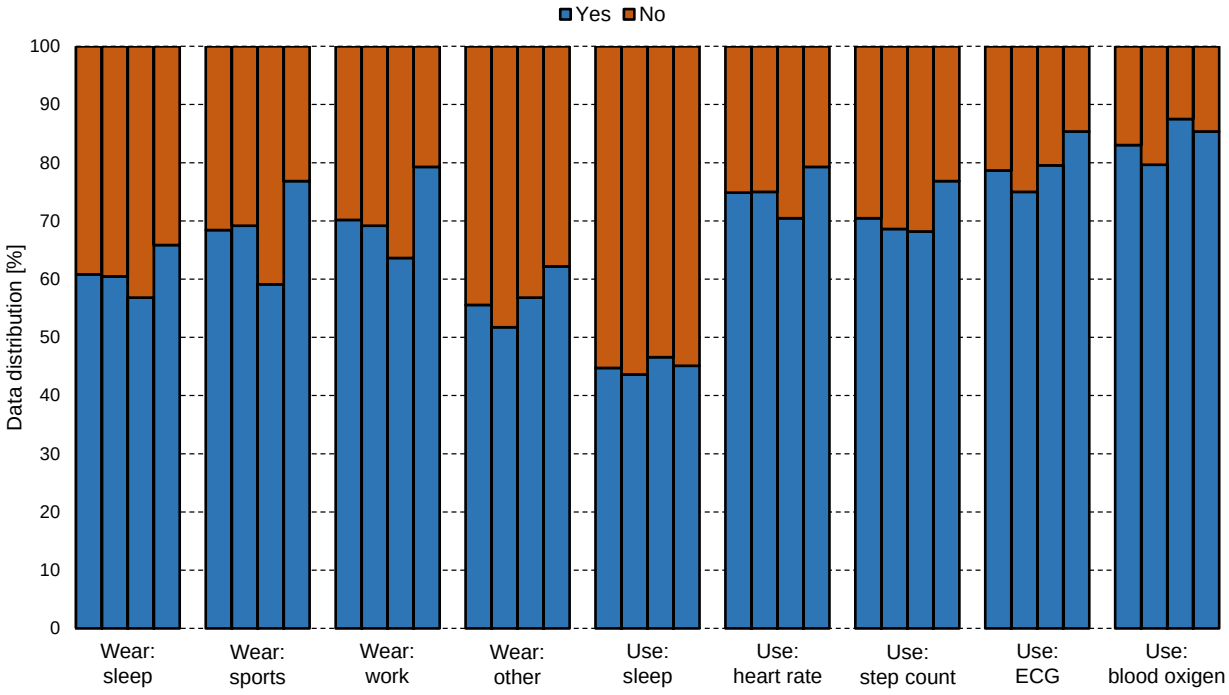

Figure 17. Obtained results for Research Gamma: wearing and using smart medical wearable devices.

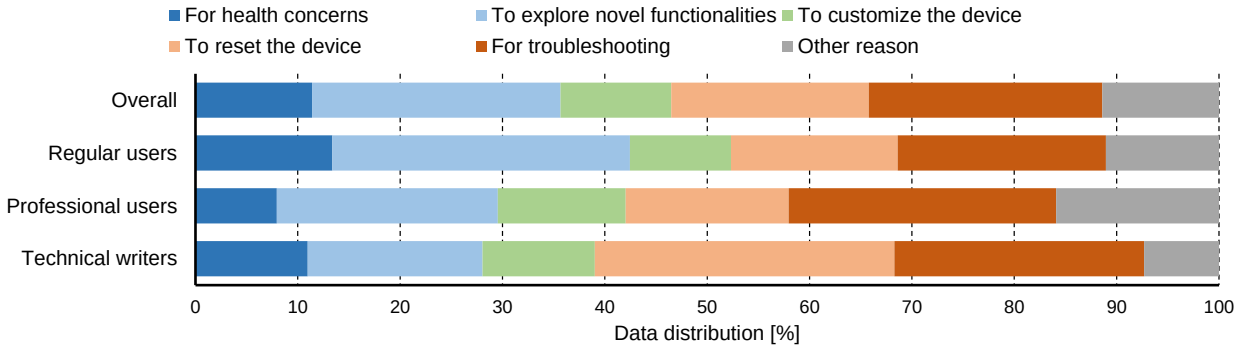

Figure 18. Obtained results for Research Gamma: most common reason for accessing the user manual.

Regarding format preference, 20.76% preferred printed manuals, 31.58% selected PDF, and 28.36% and 19.3% chose static and interactive HTML, respectively. The greatest difference was measured for the HTML types, particularly between professional users and technical writers. For professional users, 23.86% and 27.27% preferred static and interactive HTML, respectively, while these values were 32.93% and 12.2% for technical writers.

As for seeking information in user manuals, precisely one-third chose figures, and two-thirds selected text. The only somewhat notable deviation was registered for technical writers, for whom these values were 29.27% and 70.73%.

On average, the test participants accessed their devices 2.77 times. For the classifications, this value was 2.71, 2.89, and 2.77, respectively, and the difference between them is not statistically significant. Note that test participants could provide any non-negative integer for this question. Zero was only provided by a single individual, but in that specific case, the test participant could still provide valid answers for the other questions, as this was a self-estimated average value (i.e., had multiple devices, most manuals of which were not accessed at all). The highest value was 10, which was reported by 1.75% of the test participants. The common value for all classifications was 1, reported by precisely one-third of the test participants. This was followed by 3 (20.18%), 4 (16.96%), 2 (13.74%), and 5 (13.16%).

The obtained results for the questions with five-point assessment scales are reported in Figure 19. In the figure, −2 corresponds to completely unintuitive, very difficult, very dissatisfied, very unlikely, and completely unacceptable, and the other numbers follow this logic, in accordance with Appendix C.

Regarding the intuitive nature of smart medical wearables, 61% of the test participants rated the devices to be either intuitive or completely intuitive, while only 13.74% of the responses were registered on the other end of the scale. These values for regular users were 56.4% and 15.7%, and they were 67.07% and 10.97% for technical writers. For the ease of finding information, a similar distribution can be seen, but the deviations between the classifications are lesser in extent. Regarding satisfaction with the user manual, regular users expressed a lower rate of satisfaction, and utilized the neutral option more (26.74%), while the same option is lower for technical writers (18.29%). Overall, 65.79% of the test participants found it either likely or very likely that they would access the user manual if an abnormal medical value was measured, which signifies the importance of user manuals in the investigated context. Finally, 48.78% of the technical writers would deem it completely acceptable to have smart medical wearables shipped without printed user manuals, while the corresponding values for regular and professional users were 37.2% and 34.09%. Moreover, only 14.63% of technical writers found the concept to be unacceptable or completely unacceptable.

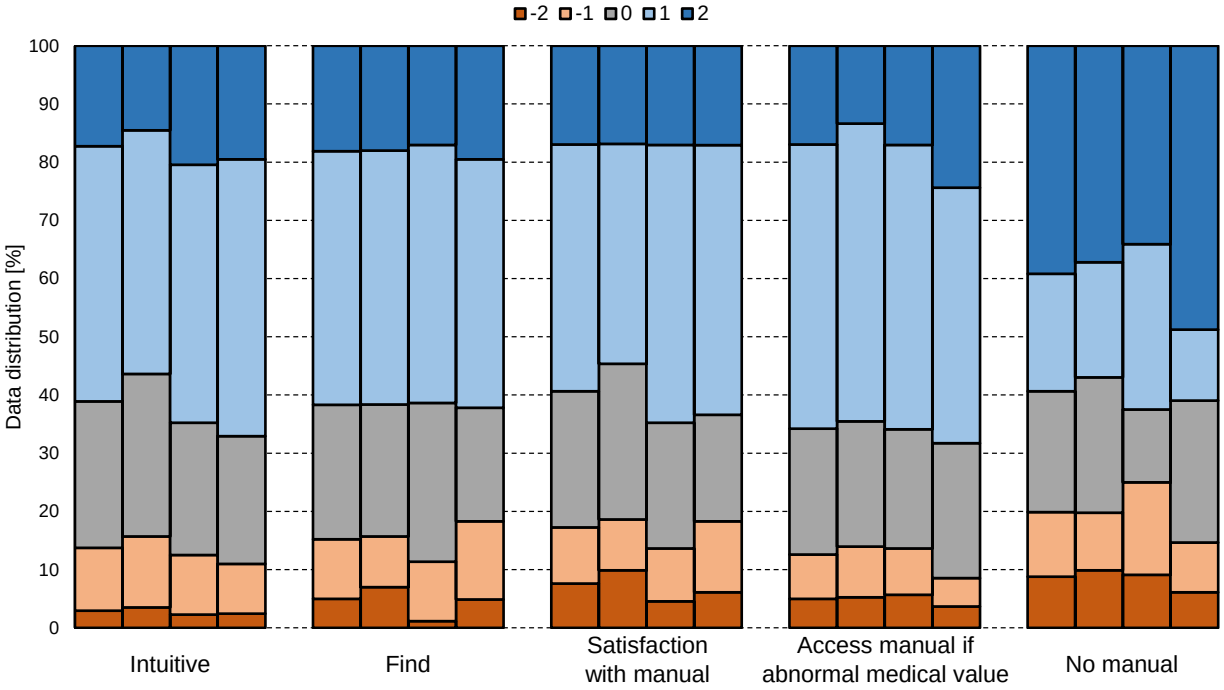

Figure 19. Obtained results for Research Gamma: five-point assessments of smart medical wearables.

It is also interesting to see that if we average out the corresponding numerical values of these latter ratings on accepting the lack of a printed manual, those who favor PDF as user manual format have the highest value at 0.96, while the same for interactive HTML preference is only 0.33. If we compare them with a two-tailed t-test, the difference is statistically significant ($p < 0.01$). For printed and static HTML user manuals, these values are 0.69 and 0.66, respectively.

4.4. Research Delta

A total of 2556 test participants completed the research questionnaire. Of these, 1303 (50.98%) were male, 1241 (48.55%) were female, and 12 (0.47%) were other. The recruited individuals were in the age range between 18 and 79, and the average age was 32. As for

the connection to user manuals, 1648 (64.48%) were regular users, 812 (31.77%) were professional users, and 96 (3.76%) were technical writers.

The average time for task completion is summarized in Figure 20. The obtained data indicate that exploration is generally a faster task, while the other three tasks show similar distributions. It is notable that roughly 27% of the test participants require at least 10 min for task completion, regardless of task type. The overall rate of those that complete the task in under a minute is around 6% of the test population. Regarding classifications, regular and professional users have similar data distributions. However, technical writers complete the tasks faster on average. For exploration, while 42.29% of regular users and 41.63% of professional users complete the task in under 5 min, the same for technical writers is 56.25%. This difference is even greater for customization. The corresponding values for regular users, professional users, and technical writers are 30.03%, 29.68%, and 63.54%, respectively. Moreover, only 11.46% of technical writers need 10 min or more for customization, while the same values for regular and professional users are 26.09% and 29.31%, respectively.

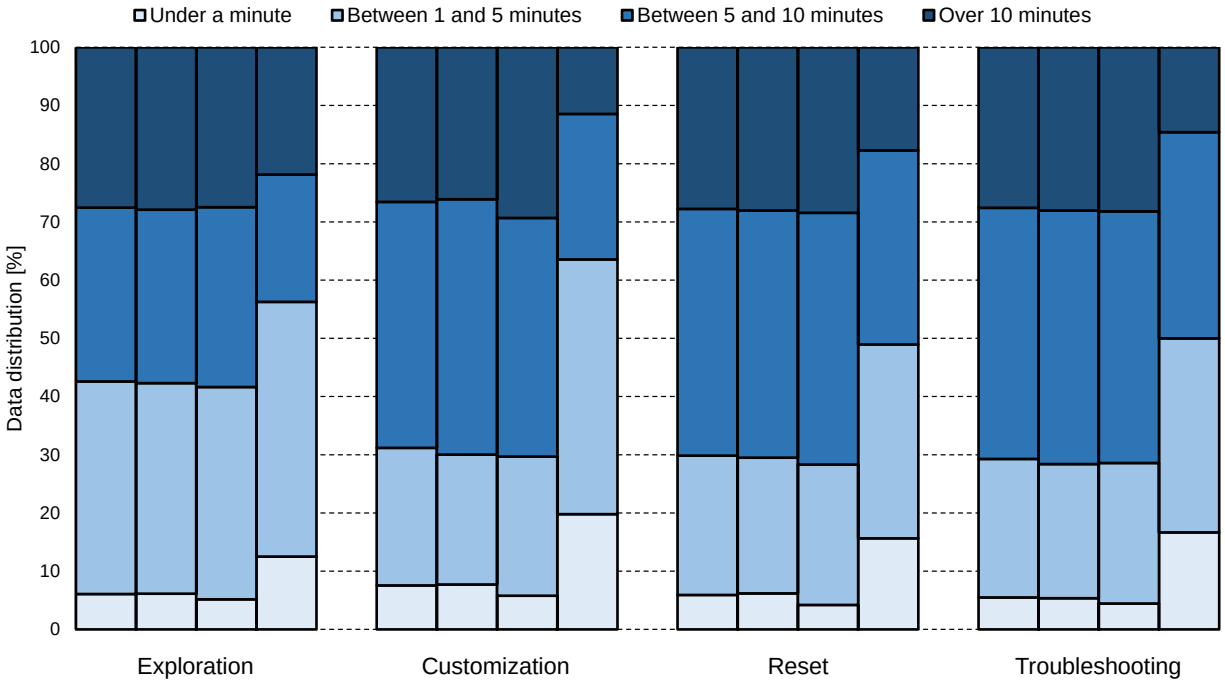

Figure 20. Obtained results for Research Delta: average time for task completion.

Figure 21 shows the average time intervals before the users give up the completion of a task. Similar tendencies can be seen as in the case of task completion times. However, exploration does not show a notable deviation in the overall distribution, and none of the different classifications deviate significantly between tasks. The obtained data indicate that even though technical writers complete the tasks faster, they also abandon the tasks faster if they do not succeed. For example, in the case of exploration, 4.49% of regular users and 4.93% of professional users give up task completion in under a minute, while the same for technical writers is 13.54%.

The distribution of alternate actions is shown in Figure 22. These are the actions that users take if they are unable to find what they are looking for in the user manual. Generally, the most common action is to search on the internet, followed by contacting customer support. While the rate for attempting exploration without the proper support is roughly the same as giving it up entirely, the same is not applicable to the other tasks, particularly for troubleshooting. In the case of the latter, 17.95% of the overall test population would rather attempt troubleshooting without the necessary information, while only 2.93% would

leave the device in its state. It should also be highlighted that for most tasks, technical writers are more likely to rely on the internet, and less likely to contact customer support.

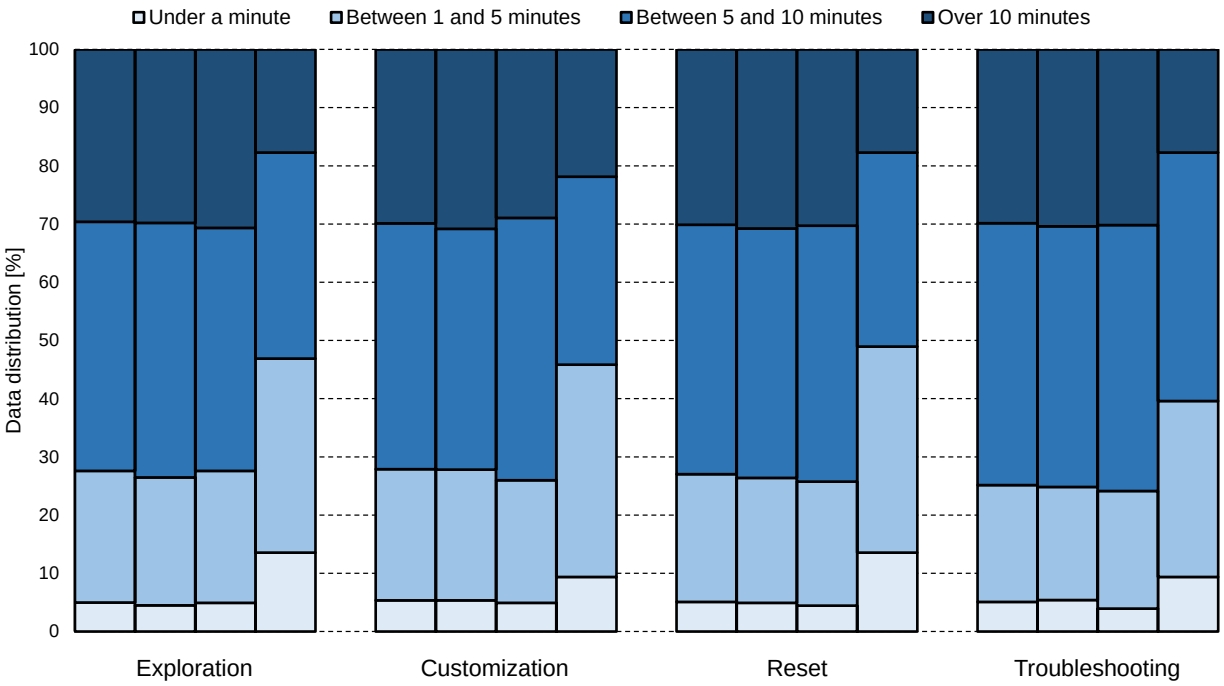

Figure 21. Obtained results for Research Delta: average time before giving up on a task.

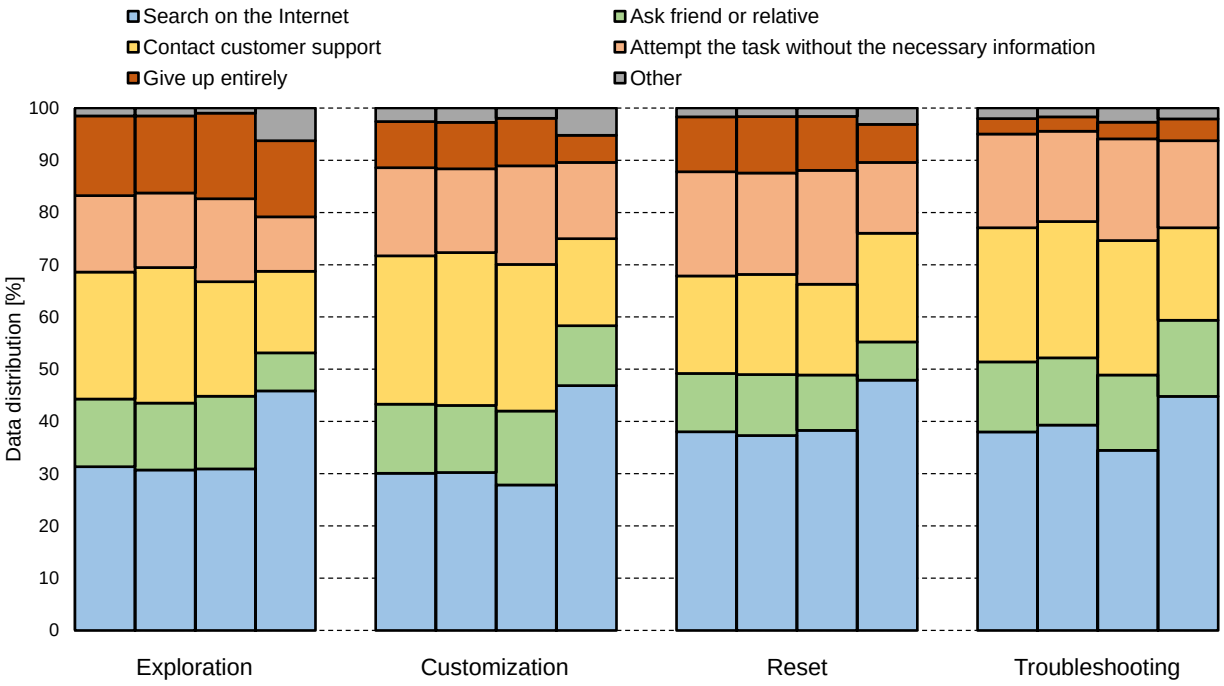

Figure 22. Obtained results for Research Delta: distribution of alternate actions.

In terms of document language, 61.58% of the test participants would prefer a simplified writing style, 23.51% would prefer a more technical phrasing, and 14.9% did not register a preference in either direction. The mean overall value is −1.27, where the negative half of the rating scale favors simplified writing. The means for regular users, professional

users, and technical writers are −1.36, −1.13, and −0.96, respectively. The differences between the classifications are not statistically significant.

The obtained results for the reason for unsuccessful task completion are highly distributed among the answer options. Overall, 27.82% of the test participants deemed the technical language to be too complicated, 20.74% blamed the structure of the user manual, 23.98% suggested the content-wise incomplete nature of the document, 24.33% stated the relevant information is presented implicitly—instead of explicitly—and 3.13% reported that it is due to other reasons. The data for regular and professional users deviate less than 2% from the overall distribution. For technical writers, these values are 30.21%, 15.63%, 20.83%, 23.96%, and 9.37%, respectively. This means that technical writers criticize the complicated technical language more, and the structure and the completeness of the user manual less. Furthermore, more of them (nearly 10%) referred to a reason that was not listed in the questionnaire.

The mean scores on user satisfaction are summarized in Figure 23. For every aspect, similar rating patterns were achieved. The overall means are between 4.75 and 4.9 on the scale between 0 and 10, and the means of the regular and professional users do not deviate significantly. For technical writers, higher levels of satisfaction were registered in every single case. Statistically significant differences were measured for language between regular users and technical writers, as well as between technical writers and the other classifications for structure, figures, and length.

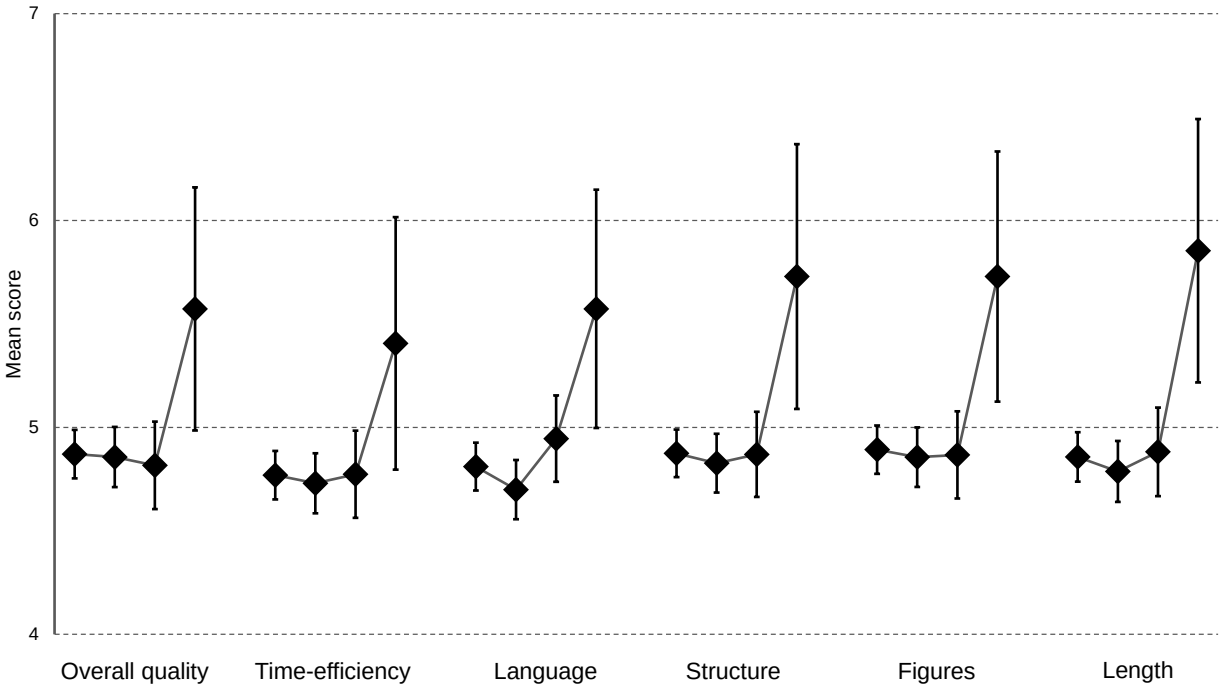

Figure 23. Obtained results for Research Delta: user satisfaction.

5. Discussion

In this section, we discuss the implications and limitations of our work. Furthermore, we cover additional points of discussion that are scientifically relevant to the addressed topics.

Table 4 shows that the price of the smart wearable device does not have a significant impact on the engagement with the user manual. This means that high-end devices do not require a different, more sophisticated way of working among technical writers. Therefore, the user manuals of cheaper and more expensive devices may be treated equally. As seen in Figure 15, the quality of the user manual may affect how regular users perceive the device. Hence, regardless of device price category, user manuals must adhere to high quality standards. Additionally, this also implies that the personal assessment of

cheaper, low-end devices may be compensated for by exceptionally written user manuals. In 2019, Gök et al. [81] already highlighted the correlation between user manual quality and perceived product quality.

Figure 13 indicates that regular users are rather balanced in their preference towards the ratio of text and figures in user manuals. This implies a positive feedback regarding the best practice in the industry. Although technical writers prefer text more, note that they constitute a rather small population portion within society (i.e., not every second person is a technical writer), and thus, their preference has a lower impact on the whole picture.

In Figure 15, we can see that technical writers find it more difficult to find what they are looking for in the user manual. However, Figure 20 indicates that technical writers complete search-related tasks faster. One may perceive this as a contradiction. Yet, if we take into consideration the findings presented in Figure 21—that technical writers also give up sooner—then this phenomenon can be explained by the differences in actual success rate. A limitation of this work is that the success rate of search-related tasks was not measured explicitly.

Figure 15 also shows that user manual quality has a significantly smaller impact on the technical writers' perception of the device. This implies that technical writers separate the user manual and the device more, due to their professional background and expertise.

Figure 22 highlights that technical writers are less likely to contact customer support for help with certain tasks. This can be explained by the fact that it is a rather frequent scenario that customer support also relies on the very same user manual. Hence, if a technical writer cannot efficiently find the information, then it is possible to have less faith in customer support to do the same. Technical writers prefer to look up the information on the internet, which is also in alignment with the case of device error, as presented in Figure 14.

As shown by both Figures 15 and 19, technical writers accept the lack of printed user manuals the most. As stated earlier, the difference between this and the corresponding mean opinion of regular users is statistically significant. This can be partially explained by the fact that designing user manuals for the printed format can be significantly more challenging compared to digital user manuals. This is particularly applicable to printed documents that are small in size. A small page size implies serious constraints for imaging, as well as for editing. For example, every single word in the figures of a small printed user manual must be easily readable.

In Research Alpha, it was found that for smart wearables in general, 54.64% of the test participants chose figures as the primary source of information. However, in Research Gamma, we found that the same value for smart medical wearables was only 33.33%. This may be explained by the difficulties and unlikely nature of illustrating complex medical information and phenomena in an easy-to-understand manner. However, the magnitude of this difference requires thorough investigation in the future to explore all the underlying reasons.

According to the results of Research Alpha, the number of times the user manual was accessed for more complex (Figure 6) and dedicated (Figure 9) devices was five or more for roughly 45% of the test population. Yet for smart medical wearables, the corresponding value was only 15.5%. This is also a difference that demands further investigation. What can be concluded from the obtained data is that for more complex (Figure 5) and dedicated (Figure 8) devices, the combined distribution for reset and troubleshooting was a little over 30%, while it was 42.11% for smart medical devices (Figure 18). This means that a higher portion of the test participants experienced issues (e.g., device malfunction), the solutions to which may have required multiple instances of user manual access.

6. Conclusions

In this paper, we presented four research efforts on the influence factors of user manual engagement for smart wearable devices. The obtained results for the first study conclude that the user experience and the complexity of the smart wearable device may significantly

affect user manual engagement for regular users, as well as for technical writers in certain contexts. However, we found that the purpose of the device (i.e., general-purpose or dedicated) and its price range do not affect such actions. Additionally, the data indicate that technical writers prefer text over figures in user manuals. In the second study, we found statistically significant differences between regular users and technical writers for the preferred writing tone, the preference between design and function, the difficulty of understanding technical content, the impact of user manual quality on the corresponding device, and the acceptance rate of omitting printed user manuals from the shipped products. In the third study, we specifically investigated smart medical wearables. The data show that due to the recent pandemic, the measurement of blood oxygen saturation is the most common among users. We conclude that nearly two-thirds of the test participants would rely on the user manual if an abnormal medical value was registered, and that those who prefer PDF manuals are the most likely to accept the lack of a printed user manual. The data of the fourth study indicate that technical writers are faster in completing search-related tasks in user manuals, yet they are also more likely to abandon such tasks in shorter time frames. Generally, technical writers are more satisfied with the user manuals of smart wearable devices, and the differences between their ratings and those who belong to the other classifications are significant for many aspects of document quality.

Regarding the potential future continuations of this work, studying user behavior could provide a better understanding of use case scenarios, such as the case of wearing a smart medical wearable to bed without using the sleep monitoring function, as well as the direct assessment of the success rate of search-related tasks for different user classifications. Beyond smart medical wearables, other dedicated devices should be investigated as well, such as smartwatches specifically designed for diving. Furthermore, it should be emphasized that numerous contributions of the scientific literature on user manuals were published in the last century. Repeating certain research efforts could highlight differences in modern contexts. For example, user patience may be different today then it was decades ago, which may significantly impact the engagement with user manuals.

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Abbreviations

The following abbreviations are used in this manuscript:

ADAS	Advanced driver assistance system
AR	Augmented reality
CHF	Congestive heart failure
MUM	Multi-dimensional user manual
PID	Pedagogical instructional design
VMS	Variable message sign

Appendix A. Questions and Answers of Research Alpha

1. Q: In the case of devices with a good user experience, when do you first open the user manual?
   A: After purchase/After first use/If the device is not intuitive enough/If the device has minor issues/If the device has major issues/Never/Other
2. Q: In the case of devices with a good user experience, why do you usually open the user manual?
   A: To explore novel functionalities/To customize the device/To reset the device/For troubleshooting/Other
3. Q: In the case of devices with a good user experience, during the complete life cycle of the device, how many times do you usually use the user manual?
   A: 0/1 or 2/3 or 4/Between 5 and 10/More than 10
4. Q: In the case of devices with a neutral user experience, when do you first open the user manual?
   A: After purchase/After first use/If the device is not intuitive enough/If the device has minor issues/If the device has major issues/Never/Other
5. Q: In the case of devices with a neutral user experience, why do you usually open the user manual?
   A: To explore novel functionalities/To customize the device/To reset the device/For troubleshooting/Other
6. Q: In the case of devices with a neutral user experience, during the complete life cycle of the device, how many times do you usually use the user manual?
   A: 0/1 or 2/3 or 4/Between 5 and 10/More than 10
7. Q: In the case of devices with a bad user experience, when do you first open the user manual?
   A: After purchase/After first use/If the device is not intuitive enough/If the device has minor issues/If the device has major issues/Never/Other
8. Q: In the case of devices with a bad user experience, why do you usually open the user manual?
   A: To explore novel functionalities/To customize the device/To reset the device/For troubleshooting/Other
9. Q: In the case of devices with a bad user experience, during the complete life cycle of the device, how many times do you usually use the user manual?
   A: 0/1 or 2/3 or 4/Between 5 and 10/More than 10
10. Q: In the case of less complex devices, when do you first open the user manual?
    A: After purchase/After first use/If the device is not intuitive enough/If the device has minor issues/If the device has major issues/Never/Other
11. Q: In the case of less complex devices, why do you usually open the user manual?
    A: To explore novel functionalities/To customize the device/To reset the device/For troubleshooting/Other
12. Q: In the case of less complex devices, during the complete life cycle of the device, how many times do you usually use the user manual?
    A: 0/1 or 2/3 or 4/Between 5 and 10/More than 10
13. Q: In the case of more complex devices, when do you first open the user manual?
    A: After purchase/After first use/If the device is not intuitive enough/If the device has minor issues/If the device has major issues/Never/Other
14. Q: In the case of more complex devices, why do you usually open the user manual?
    A: To explore novel functionalities/To customize the device/To reset the device/For troubleshooting/Other
15. Q: In the case of more complex devices, during the complete life cycle of the device, how many times do you usually use the user manual?
    A: 0/1 or 2/3 or 4/Between 5 and 10/More than 10

16. Q: In the case of general-purpose devices, when do you first open the user manual?
    A: After purchase/After first use/If the device is not intuitive enough/If the device has minor issues/If the device has major issues/Never/Other
17. Q: In the case of general-purpose devices, why do you usually open the user manual?
    A: To explore novel functionalities/To customize the device/To reset the device/For troubleshooting/Other
18. Q: In the case of general-purpose devices, during the complete life cycle of the device, how many times do you usually use the user manual?
    A: 0/1 or 2/3 or 4/Between 5 and 10/More than 10
19. Q: In the case of dedicated devices, when do you first open the user manual?
    A: After purchase/After first use/If the device is not intuitive enough/If the device has minor issues/If the device has major issues/Never/Other
20. Q: In the case of dedicated devices, why do you usually open the user manual?
    A: To explore novel functionalities/To customize the device/To reset the device/For troubleshooting/Other
21. Q: In the case of dedicated devices, during the complete life cycle of the device, how many times do you usually use the user manual?
    A: 0/1 or 2/3 or 4/Between 5 and 10/More than 10
22. Q: In the case of devices that cost less than USD 100 , when do you first open the user manual?
    A: After purchase/After first use/If the device is not intuitive enough/If the device has minor issues/If the device has major issues/Never/Other
23. Q: In the case of devices that cost less than USD 100 , why do you usually open the user manual?
    A: To explore novel functionalities/To customize the device/To reset the device/For troubleshooting/Other
24. Q: In the case of devices that cost less than USD 100 , during the complete life cycle of the device, how many times do you usually use the user manual?
    A: 0/1 or 2/3 or 4/Between 5 and 10/More than 10
25. Q: In the case of devices that cost between USD 100 and USD 200 , when do you first open the user manual?
    A: After purchase/After first use/If the device is not intuitive enough/If the device has minor issues/If the device has major issues/Never/Other
26. Q: In the case of devices that cost between USD 100 and USD 200 , why do you usually open the user manual?
    A: To explore novel functionalities/To customize the device/To reset the device/For troubleshooting/Other
27. Q: In the case of devices that cost between USD 100 and USD 200 , during the complete life cycle of the device, how many times do you usually use the user manual?
    A: 0/1 or 2/3 or 4/Between 5 and 10/More than 10
28. Q: In the case of devices that cost more than USD 200 , when do you first open the user manual?
    A: After purchase/After first use/If the device is not intuitive enough/If the device has minor issues/If the device has major issues/Never/Other
29. Q: In the case of devices that cost more than USD 200 , why do you usually open the user manual?
    A: To explore novel functionalities/To customize the device/To reset the device/For troubleshooting/Other
30. Q: In the case of devices that cost more than USD 200 , during the complete life cycle of the device, how many times do you usually use the user manual?
    A: 0/1 or 2/3 or 4/Between 5 and 10/More than 10
31. Q: Do you primarily seek information in figures or in text?
    A: In figures/In text

32. Q: Regarding figures, what do you prefer in a quick guide?
    A: Conceptual figures/Photos or screenshots
33. Q: What kind of figures do you prefer in a quick guide?
    A: Colored figures/Black and white figures
34. Q: If a mobile application is available, what form of access do you prefer?
    A: QR code/Direct link to application store/None of the above
35. Q: What ratio between text and figures do you prefer in a quick guide?
    A: 100% text, 0% figures/75% text, 25% figures/50% text, 50% figures/25% text, 75% figures/0% text, 100% figures

Appendix B. Questions and Answers of Research Beta

1. Q: How satisfied are you with the length of user manuals?
   A: −5 (Too short)/−4/−3/−2/−1/0/1/2/3/4/5 (Too long)
2. Q: If you used the user manual, how easily could you find that you searched for?
   A: 0 (Hard to find)/1/2/3/4/5/6/7/8/9/10 (Easy to find)
3. Q: Do you prefer text with objective/neutral tone or personal/friendly tone?
   A: −5 (Objective/neutral tone)/−4/−3/−2/−1/0/1/2/3/4/5
   (Personal/friendly tone)
4. Q: How easy is it to understand the text in user manuals?
   A: 0 (Difficult to understand)/1/2/3/4/5/6/7/8/9/10 (Easy to understand)
5. Q: What do you think about the amount of figures/pictures in user manuals?
   A: −5 (Too few)/−4/−3/−2/−1/0/1/2/3/4/5 (Too many)
6. Q: What do you think about the quality and usefulness of figures/pictures in user manuals?
   A: 0 (Low quality, useless)/1/2/3/4/5/6/7/8/9/10 (High quality, useful)
7. Q: If you encounter a grammatical/spelling/punctuation error in user manuals, how much does it negatively affect your opinion about the user manuals?
   A: 0 (Not at all)/1/2/3/4/5/6/7/8/9/10 (Greatly affects my opinion)
8. Q: How much does the low overall quality of the user manual negatively affect your opinion about the device?
   A: 0 (Not at all)/1/2/3/4/5/6/7/8/9/10 (Greatly affects my opinion)
9. Q: How much does the high overall quality of the user manual positively affect your opinion about the device?
   A: 0 (Not at all)/1/2/3/4/5/6/7/8/9/10 (Greatly affects my opinion)
10. Q: Would it be a problem for you if no printed user manual was provided for your device?
    A: 0 (Unacceptable)/1/2/3/4/5/6/7/8/9/10 (Completely acceptable)
11. Q: What is your primary source of help if you encounter an error with your device?
    A: −5 (Internet)/−4/−3/−2/−1/0/1/2/3/4/5 (User manual)
12. Q: What is your primary source of help if you wish to customize your device?
    A: −5 (Internet)/−4/−3/−2/−1/0/1/2/3/4/5 (User manual)
13. Q: What is more important to you regarding your device?
    A: −5 (Functionality)/−4/−3/−2/−1/0/1/2/3/4/5 (Design or appearance)
14. Q: Regarding the devices purchased in the past 5 years, how satisfied were you with them?
    A: 0 (Completely dissatisfied)/1/2/3/4/5/6/7/8/9/10 (Completely satisfied)
15. Q: Regarding the devices purchased in the past 5 years, how satisfied were you with the user manuals?
    A: 0 (Completely dissatisfied)/1/2/3/4/5/6/7/8/9/10 (Completely satisfied)
16. Q: Regarding the devices purchased in the past 5 years, how intuitive were the devices?
    A: 0 (Completely unintuitive)/1/2/3/4/5/6/7/8/9/10 (Completely intuitive)

17. Q: Regarding the devices purchased in the past 5 years, how satisfied were you with the performance of the devices compared to their prices?
    A: 0 (Completely dissatisfied)/1/2/3/4/5/6/7/8/9/10 (Completely satisfied)
18. Q: Regarding the devices purchased in the past 5 years, how satisfied were you with the user manuals of the devices compared to the prices of the devices?
    A: 0 (Completely dissatisfied)/1/2/3/4/5/6/7/8/9/10 (Completely satisfied)

Appendix C. Questions and Answers of Research Gamma

1. Q: Do you wear and use smart medical wearable devices for sleeping?
   A: Yes/No
2. Q: Do you wear and use smart medical wearable devices for sports and training?
   A: Yes/No
3. Q: Do you wear and use smart medical wearable devices during work?
   A: Yes/No
4. Q: Do you wear and use smart medical wearable devices for other activities?
   A: Yes/No
5. Q: Do you use smart medical wearable devices for sleep monitoring?
   A: Yes/No
6. Q: Do you use smart medical wearable devices for heart rate monitoring?
   A: Yes/No
7. Q: Do you use smart medical wearable devices for step counting?
   A: Yes/No
8. Q: Do you use smart medical wearable devices for ECG monitoring?
   A: Yes/No
9. Q: Do you use smart medical wearable devices for blood oxygen measurement?
   A: Yes/No
10. Q: Why do you usually open the user manual?
    A: For health concerns/To explore novel functionalities/To customize the device/To reset the device/For troubleshooting/Other reason
11. Q: What user manual format do you prefer?
    A: Printed/PDF/Static HTML/Interactive HTML
12. Q: Where do you primarily seek information in the user manual?
    A: In figures/In texts
13. Q: How intuitive do you find your smart medical wearable devices?
    A: Completely unintuitive/Unintuitive/Neutral/Intuitive/Completely intuitive
14. Q: During the complete life cycle of the device, how many times do you access the user manual?
    A: [Zero or positive integer]
15. Q: How easily do you find what you're looking for in the user manual?
    A: Completely difficult/Difficult/Neutral/Easy/Completely easy
16. Q: How satisfied are you in general with the user manuals of smart medical wearable devices?
    A: Completely disstatisfied/Dissatisfied/Neutral/Satisfied/Completely satisfied
17. Q: If you encounter any abnormal medical value/measurement, how likely is it that you access the user manual for medical information?
    A: Completely unlikely/Unlikely/Neutral/Likely/Completely likely
18. Q: Do you find it acceptable to purchase a smart medical wearable device without a printed user manual?
    A: Completely unacceptable/Unacceptable/Neutral/Acceptable/Completely acceptable

Appendix D. Questions and Answers of Research Delta

1. Q: How much time does it usually take you to find what you're looking for in the user manual in the case of exploring novel functionalities?
   A: Under a minute/Between 1 and 5 min/Between 5 and 10 min/Over 10 min
2. Q: How much time does it usually take you to find what you're looking for in the user manual in the case of customizing the device?
   A: Under a minute/Between 1 and 5 min/Between 5 and 10 min/Over 10 min
3. Q: How much time does it usually take you to find what you're looking for in the user manual in the case of resetting the device?
   A: Under a minute/Between 1 and 5 min/Between 5 and 10 min/Over 10 min
4. Q: How much time does it usually take you to find what you're looking for in the user manual in the case of troubleshooting?
   A: Under a minute/Between 1 and 5 min/Between 5 and 10 min/Over 10 min
5. Q: After how much time on average do you give up looking for information in the user manual in the case of exploring novel functionalities?
   A: Under a minute/Between 1 and 5 min/Between 5 and 10 min/Over 10 min
6. Q: After how much time on average do you give up looking for information in the user manual in the case of customizing the device?
   A: Under a minute/Between 1 and 5 min/Between 5 and 10 min/Over 10 min
7. Q: After how much time on average do you give up looking for information in the user manual in the case of resetting the device?
   A: Under a minute/Between 1 and 5 min/Between 5 and 10 min/Over 10 min
8. Q: After how much time on average do you give up looking for information in the user manual in the case of troubleshooting?
   A: Under a minute/Between 1 and 5 min/Between 5 and 10 min/Over 10 min
9. Q: What do you usually do when you're unable to find what you're looking for in the user manual, in the case of exploring novel functionalities?
   A: Search on the Internet/Ask friend or relative/Contact customer support/Attempt the task without the necessary information/Give up entirely/Other
10. Q: What do you usually do when you're unable to find what you're looking for in the user manual in the case of customizing the device?
    A: Search on the Internet/Ask friend or relative/Contact customer support/Attempt the task without the necessary information/Give up entirely/Other
11. Q: What do you usually do when you're unable to find what you're looking for in the user manual in the case of resetting the device?
    A: Search on the Internet/Ask friend or relative/Contact customer support/Attempt the task without the necessary information/Give up entirely/Other
12. Q: What do you usually do when you're unable to find what you're looking for in the user manual in the case of troubleshooting?
    A: Search on the Internet/Ask friend or relative/Contact customer support/Attempt the task without the necessary information/Give up entirely/Other
13. Q: What do you prefer in terms of document language?
    A: −5 (Simplified)/−4/−3/−2/−1/0 (No preference)/+1/+2/+3/+4/+5 (Technical)
14. Q: If you're unable to find what you're looking for in the user manual, what do you think the reason might be?
    A: Too complicated technical language/Illogical structuring/Incomplete user manual (does not contain the information at all)/Implicit information (does not contain the information explicitly)/Other
15. Q: On average, how satisfied are you with the user manuals?
    A: 0 (Very unsatisfied)/1/2/3/4/5/6/7/8/9/10 (Very satisfied)
16. Q: On average, how satisfied are you with the time efficiency of user manuals (i.e., how fast do you find what you're looking for)?
    A: 0 (Very unsatisfied)/1/2/3/4/5/6/7/8/9/10 (Very satisfied)

17. Q: On average, how satisfied are you with the language of the user manuals?
    A: 0 (Very unsatisfied)/1/2/3/4/5/6/7/8/9/10 (Very satisfied)
18. Q: On average, how satisfied are you with the structure of the user manuals?
    A: 0 (Very unsatisfied)/1/2/3/4/5/6/7/8/9/10 (Very satisfied)
19. Q: On average, how satisfied are you with the visualization (i.e., figures and images) of the user manuals?
    A: 0 (Very unsatisfied)/1/2/3/4/5/6/7/8/9/10 (Very satisfied)
20. Q: On average, how satisfied are you with the length of the user manuals?
    A: 0 (Very unsatisfied)/1/2/3/4/5/6/7/8/9/10 (Very satisfied)

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