

Do you like my outfit? Cromnia, a mobile assistant for blind users

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ABSTRACT

The community of visually impaired people has been very active during the last decades with initiatives devoted to raise awareness about their specific needs in the society and encourage the adoption of any innovative assistive solutions for their personal empowerment. A contextual inquiry conducted in Europe revealed that some of the major concerns to those people refer to independence of living. According to recent studies most existing remote control home automation systems miss certain specific usability and accessibility features which could address specific blind users' needs. In the present paper we present an assistive mobile app, designed to allow autonomy of blind/visually impaired users in the everyday activity of getting dressed. The user testing activities conducted so far are described and the derived results are discussed.

CCS CONCEPTS

• Human-centered computing → Interaction design • Interaction design process and methods.

KEYWORDS

Usability requirements, Universal Design, Visual Impairment, Assistive technology.

1 Introduction

The community of visually impaired people has been very active during the last decades with initiatives devoted to raise awareness about their specific needs in the society and encourage the adoption of any innovative assistive solutions for their personal empowerment [1, 6].

A cross-border contextual inquiry involving that community was performed as part of a recent European project aimed at defining

an innovation procurement roadmap for partially sighted people [11]. The survey was initially conducted in the form of a questionnaire, to be distributed on a European scale. Experts in the domain of low vision took part in the study, ranging from clinicians, to vocational rehabilitation professionals, to operators in the social care field. Then, a number of focus groups were also held in different partner countries, involving partially sighted and blind people. Among the needs that emerged, one especially inspired the present work, namely “maintaining appropriate environmental conditions” and “raising independence in personal care”. In a recent study investigating the needs of visually impaired people in the area of home automation for independent living, Leporini and Buzzi argue that most existing remote control home automation systems are generally targeted to people with physical/cognitive disabilities but miss certain specific usability and accessibility features which are necessary for blind users [8]. The purpose of our study was to design some assistive solution that would provide greater autonomy to a blind person, in everyday activities. A problem domain analysis was therefore performed to address those needs through some suitable mobile application, properly taking into account accessibility and usability requirements. A participative process started since the early stages of analysis and design, involving a group of 4 blind people from the Italian Blind Union, who volunteered to actively collaborate with the usability design team. Among the daily tasks for which higher autonomy is expected, getting dressed with a proper color match of clothes turned out to be a major concern for those people, who usually get help from their guardian. Recently, some assistive devices have been put on the market to address that need. A support to independent living is offered by OrCam *MyEye*, a lightweight text/color/face recognition device which can be mounted on a pair of glasses to help vision impaired/blind users in everyday activities, including clothes selection [132]. Another commercial tool is *Colorino*, a device which helps user with clothes selection, with washing procedure and with color combination, being able to distinguish more than 150 colors and tones, as well as shades of color [14]. However, the idea to purchase a specific tool was neglected by most of our interviewees, who observed that many people could not even afford them. Moreover, they insisted that even cheaper devices could be annoying, requiring users to bring them everywhere and check batteries status or regularly recharge them. Some software solutions, including mobile apps, are available for color and pattern detection but very few were especially conceived for blind or visually impaired users [3, 4, 5, 9]. The mobile application

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BeMyEyes is one exception but it simply relies on the use of a video call to require attendance by some remote guardian [6].

As a result of our investigation, a mobile application, named *Cromnia*, was developed, which allows users to recognize colors, patterns and color combinations, also considering the brightness level of the surrounding environment. The latter functionality has a twofold usefulness. It can be used to make sure that the scanned clothing is sufficiently illuminated but also to let the user gain awareness of the brightness of the place he/she is in.

Encouraging results were drawn from the experimental user testing, which involved a group of 6 blind people and a group of 6 partially sighted people.

The remainder of the paper is organized as follows. Section 2 summarizes the problem domain analysis activities and the resulting functional and non-functional requirements. Section 3 introduces the main features of the *Cromnia* app. Section 4 describes the usability testing activities. Section 5 concludes the paper.

2 Requirement Analysis

The problem domain analysis allowed us to get an insight into the most common issues affecting autonomy of blind people. The interviews we conducted with 10 blind people also aimed at understanding what are the problems that a visually impaired person encounters during his/her everyday activities when he/she is alone with respect to the case when he/she can rely on the sight of a companion/guardian. We found out that more meaningful responses could be achieved managing each interview in the form of an informal 'cognitive meeting', starting from more general questions and then arriving at the specific questions of interest for the analysis activity. Structuring the interview in that way we found a significant improvement in the clarity and response time of respondents, getting information directly related to the accessibility of certain applications, without making any explicit questions. For each interview an Mp3 file was generated and then cut using iMovie, in order to retain only the information considered useful for the analysis. Finally, the adequately analyzed information was reported as a form of 'Guiding Activities' in the Trello management system, in order to be easily shared with the design team. An empowerment-driven analysis method was adopted to elicit user experience (UX) requirements, as illustrated in [10, 12]. The method depicted in Fig. 1 is a transformative process which starts from a contextual investigation meant to understand users, their behavior and capacities within a given community, and to identify potential improvements in their life quality, which are expressed in terms of human needs. The key factors which may contribute to the empowerment of the target users with respect to the identified needs are considered in order to formulate clear users' empowerment goals. The goals entail a set of UX requirements which may be iteratively modified/extended and ultimately drive usability designers.

Among the daily tasks for which higher autonomy is expected, getting dressed with a proper color match of clothes turned out to

be one of the major concerns for those people, who usually rely on their guardian's advice.

As a result of the analysis phase the following functional requirements were established:

- Ambient light detection,
- Framed color detection,
- Framed texture detection,
- Appropriate color combination.

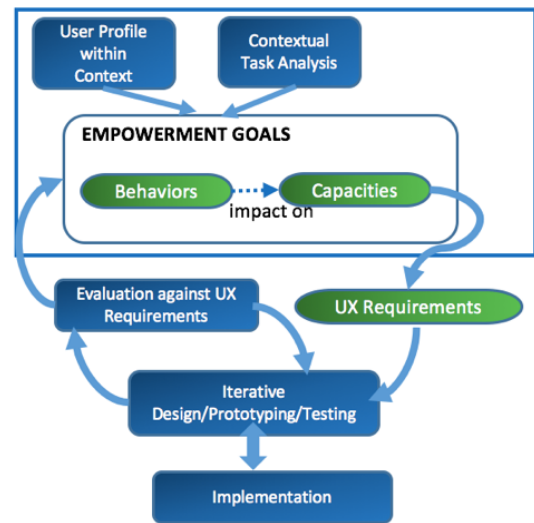


Figure 1: Empowerment-driven Requirements Engineering process.

The associated non-functional requirements, also related to usability and accessibility, were:

- Full integration with the device voice synthesizing tool;
- Simple and immediate notification system;
- Adaptive fonts and label size with respect to the type of disability studied;
- Real-time response.

3 The Cromnia App

Cromnia is a mobile app designed and developed for Apple iOS platform, which is the most widely used by the community of blind/visually impaired people. The graphical interface design took into account general usability guidelines and was iteratively assessed by an automatic usability evaluation tool [2]. Besides, Apple best practices for the design of accessible applications for blind users were considered so as to ensure consistency with consolidated interaction modalities, e.g., integrating Voiceover and implementing accessibility rules, ensuring ease of use by the end user. The application has a very simple interface. *Cromnia* consists in a single interface that looks like the interface of iOS systems stock camera.

Four different recognition modalities can be set when the app is accessed, namely:

- The *viewfinder* modality for continuous real-time recognition of colors (Fig 2.a)
- The *brightness detector*, to detect the brightness level of the environment (Fig 2.b).
- The *scanner*, to recognize the color and the texture of the cloth in the frame (Fig 2.c).
- The *color combination analyzer*, to verify the appropriateness of color matching between the last two recognized clothes. (Fig 2.d)

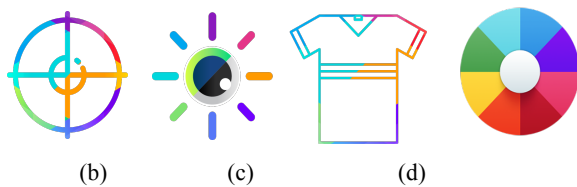


Figure 2: Cromnia recognition modalities.

At the top there is the information related to the framed clothes, which is also communicated through voice synthesis. In spite of a number of existing color recognition algorithms, a simplifying algorithm was developed to associate one color to an interval of RGB values (e.g., red is the color associated from RGB [R=255, G=064, B=064] to RGB [R=161, G=031, B=018]). Such a simplification was necessary to address the specific needs of visually impaired people.

As for the texture recognition feature, it relies on the use of a convolutional neural network. We adopted the TensorFlow open source machine learning framework to build an initial neural network creating specific datasets of textures and then training the network up to 10000 steps. As a result of the training phase, the neural network is capable of recognizing simple pattern like vertical stripes, horizontal stripes, squares, polka dots, rhombs, triangles and solid colors and also complex patterns like drawings. Finally, the surrounding brightness is calculated using a real-time analysis algorithm of grayscale obtained by converting the camera image. The combination of these analyses is then communicated, through the use of speech synthesis, with a completely accessible notification system to the user.

To illustrate the use of the application, let us consider the following scenario.

Pasquale, a native blind 35 man, has to dress up for an appointment with a friend he wishes to impress for his outfit. He uses Cromnia to decide what to wear. He puts a set of possible clothes on his bed and starts using the app. He detects the switch button through the VoiceOver feature and enters the viewfinder modality to scan the clothes. A vocal assistant informs Pasquale about the color of the current target as he directs the camera on the clothes. He checks for brightness in the room and discovers it is sufficient to get a reliable response. Then he switches to the scanner mode and gets information about the color and pattern of each cloth. He presses the color combination button and the assistant informs him that the last two scanned clothes form a bad

color matching, so Pasquale tries a new one, and this time he gets approval.

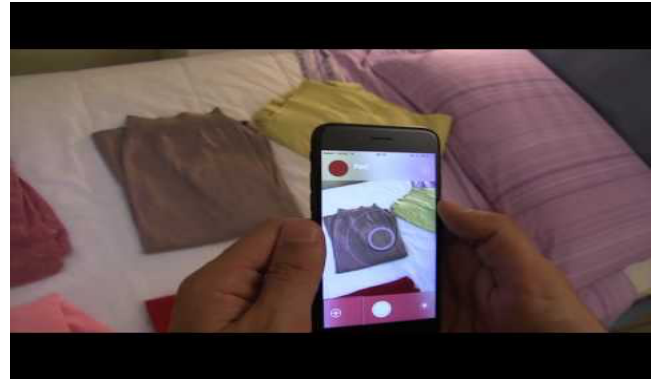


Figure 3: Scanning clothes with Cromnia.

4 Usability Testing

A comparative user study was conducted to evaluate usability of *Cromnia* with respect to existing day-to-day methods adopted to get dressed. We were especially interested in evaluating efficiency as well as degree of acceptance and empowerment perception.

We recruited 12 visually impaired participants, 10 males, from the Italian Blind Union. Participants' age ranged from 27 to 72 (M=45.8, SD=11.7), half of them being totally blind, and the others partially sighted. All the participants knew how to use a smartphone. Three participants had never used a smartphone as an aid. All the participants were volunteers. Figure 4 illustrates some participants performing their tasks.

The experimental tasks focused on

- Color and texture recognition from one cloth;
- Checking the combination of two items of clothing.

To perform the experiment, the zonal section of Italian Blind Union provided one of their laboratories. The laboratory was chosen in order to have an optimal light condition for the type of tests to be performed. The laboratory was equipped in order to recreate the typical home environment.

The equipment used consisted of:

- 1 device (Apple iPhone 8) with *Cromnia* app preinstalled.
- 1 chronometer to measure task completion time.
- 1 empty chest of drawers in which participants must arrange clothes provided.
- 1 basket to fill with clothes during the experiment to complete the selections.
- 1 set of different clothing, consisting of 18 different garments:
 - 6 t-shirts.
 - 6 pullovers.
 - 6 pants.

The evaluation was set up as a within-subjects design where all participants performed the required tasks with and without the use of *Cromnia*.

The experiment started with a presentation session, explaining the purpose of the experiment to all participants. Before starting the experiment, the participants were asked to respond to a demographic questionnaire asked to sign a form for the treatment of data provided during the experiment. Then the participants were introduced individually to the laboratory environment, thus enabling them to become familiar with it. Participants were then shown the app *Cromnia* on the laboratory device, thus enabling them to become familiar with the equipment and make a quick 10 minutes training phase with regard to the use of the app. The training included:

- Unlocking the laboratory device.
- Exploring the home interface of the laboratory device unlocked (identification of individual applications present by default on the main interface, until the discovery of the *Cromnia* icon, located in the lower right corner).
- Opening the application and listening to the app tutorial, which runs automatically with the first access.
- Exploring the interface of the App *Cromnia*.
- Checking for brightness level in the room
- Finding a label that reproduces the pattern and color of the garment detected (located in upper and central area of the interface).
- Finding the button designed for reading the clothing item (button located at the bottom center of the application).
- Finding the button for switching to viewfinder mode for continuous and exclusive reading of the framed color (located in the lower left corner).
- Acquisition of colors and patterns of clothing. For this testing phase all participants performed their tasks with the same set of clothes to train:
 - 1 yellow t-shirt with a black drawing.
 - 1 black t-shirt with a white drawing.
 - 1 violet pullover with white yellow stripes



Figure 4: Participants performing the experimental tasks

Then the set of clothes used for the experiment were described to participants, who were given the opportunity to become familiar with them. We were careful to provide any necessary information about the characteristics of the experimental clothing. Finally, participants were asked to put into drawers the clothing items in the order they preferred provided that they kept in mind their positions.

One of the task was: *find 3 clothes which are communicated by the investigator*. The task was repeated 6 times by each participant with random clothing. The tasks were divided into 3 repetitions with the *Cromnia* method and 3 repetitions with the day-to-day method. For each series of repetitions, a different set of clothes was used, so that the choice of the set could not influence the results. To further reduce biases, 2 sets of different clothes, each consisting of 4 t-shirts, 4 pullovers and 4 pants, chosen out of the totality of the clothing available for the experiment.

	T-shirt - M	Pullover - N	Pant - P
1	Yellow t-shirt with white stripes	Red solid pullover	Light blue solid jeans
2	Black t-shirt with white drawing	Violet solid pullover	Dark blue solid jeans
3	Blue t-shirt with a solid color	Blue solid pullover	Black solid pants
4	Blue t-shirt with red drawing	Black solid pullover	Brown solid pants
5	White t-shirt with violet drawing	Green solid pullover	Gray solid pants
6	White t-shirt with blue stripes	Green pullover with gray drawing	Dark blue jeans with white drawing

	T-shirt - M	Pullover - N
T-shirt	M1, M2, M3, M4	M3, M4, M5, M6
Pullover	N1, N2, N3, N4	N3, N4, N5, N6
Pants	P1, P2, P3, P4	P3, P4, P5, P6

To facilitate the balancing of repetitions and prevent their order might influence the results, participants were divided into two blocks, depending on the order of repetitions:

- Block A: Participants who make first 3 repetitions with the day-to-day method and then 3 repetitions with the *Cromnia* method.
- Block B: Participants who make first 3 repetitions with the *Cromnia* method and then 3 repetitions with the day-to-day method.

	Block	Rep.1	Rep.2	Rep.3	Rep.4	Rep.5	Rep.6
1	A	M1 N1 P4	M4 N3 P2	M2 N4 P4	M5 N1 P4	M1 N5 P6	M3 N3 P3
2	B	M4 N3 P1	M1 N2 P2	M2 N3 P4	M5 N6 P6	M6 N4 P3	M3 N6 P4

3	A	M3 N4 P3	M2 N2 P1	M3 N4 P2	M4 N6 P4	M6 N4 P6	M5 N6 P4
4	B	M1 N2 P4	M3 N4 P2	M2 N1 P1	M4 N3 P6	M3 N4 P3	M5 N3 P4
5	A	M2 N2 P2	M3 N4 P1	M4 N1 P2	M5 N5 P3	M3 N3 P4	M6 N5 P3
6	B	M4 N2 P3	M2 N4 P1	M4 N1 P4	M3 N5 P5	M6 N6 P4	M4 N4 P5
7	A	M1 N2 P3	M2 N4 P1	M1 N1 P4	M3 N5 P5	M6 N6 P4	M4 N4 P5
8	B	M4 N1 P1	M2 N3 P3	M3 N2 P4	M5 N5 P6	M6 N4 P4	M3 N3 P5
9	A	M1 N1 P2	M4 N3 P3	M3 N4 P4	M4 N6 P3	M3 N5 P4	M5 N6 P5
10	B	M2 N4 P4	M3 N3 P1	M4 N1 P2	M6 N4 P6	M3 N3 P3	M6 N6 P4
11	A	M2 N1 P2	M1 N4 P4	M4 N3 P2	M6 N5 P4	M3 N6 P5	M5 N4 P4
12	B	M1 N1 P4	M3 N3 P2	M4 N4 P1	M6 N5 P6	M3 N3 P5	M5 N5 P4

At the beginning of each repetition the experimenter would communicate the set of three garments to be selected for that exact repetition. Time count started immediately after the communication. A repetition was considered complete, and the timing was stopped, when there were exactly 3 clothing items in the basket. Of course, the 3 selected items would not necessarily match with the 3 clothes communicated. The task was considered completed when all the repetitions were completed. The order in which participants selected the clothes was considered irrelevant. At the end of each repetition the participant put back the clothes into the chest, except for the third and fourth repetitions when the set of clothes was changed. During the execution of a repetition the participant had the chance to ask the experimenter to repeat the clothes he was supposed to find.

For each participant, completion times have been reported in terms of seconds with relative accuracy (whenever a garment selected does not match with the garment communicated, an error is assigned to the repetition), for each repetition, separating them according to the system used for the selection of the clothes (*Cromnia* or traditional method). After the experiment the participants were asked to respond to a SUS questionnaire referring to the use of *Cromnia*.

We applied the statistical software Anova2 tests to all observed measures and conducted parametric statistical analysis.

To assess efficiency of the method adopted, we measured the mean time used to complete the task across the repetitions. To assess accuracy of the used method, for each participant we registered the number of correct selections during task completion. Any participant could make at most 9 errors per series of repetitions with a specific method.

For the completion time, results grouped by method and type of disability are shown in Figure 5. As it can be seen, for both totally blind participants and partially sighted participants the *Cromnia* method was faster (217.0 seconds vs 247.3 seconds for totally blind participants, 163.8 seconds vs 172.5 seconds for partially sighted participants). The main effect of type of disability on task

completion time was statistically significant ($F_{1,10} = 7.519, p < 0.05$). The effect of method was also high statistically significant ($F_{1,10} = 11.884, p < 0.01$).

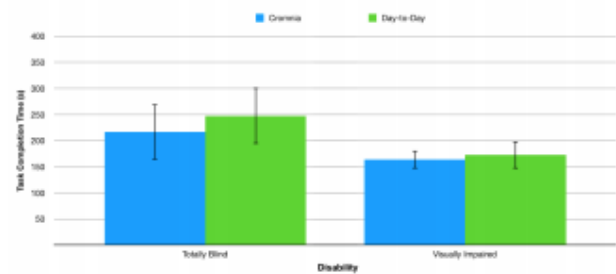


Figure 5: Task completion time for both methods, across the totally blind and the partially sighted participants. Error bars show standard deviation.

For the number of errors, results grouped by method and type of disability are shown in Figure 6. As it can be seen, for both groups of totally blind and partially sighted participants the *Cromnia* method was more accurate (0.17 errors vs 2.33 errors for totally blind participants, 0.00 errors vs 1.17 errors for partially sighted participants).

The grand mean for number of errors for participant was 0.92 errors. *Cromnia* was the most accurate at 0.08 errors, while the day-to-day method was the less accurate at 1.75 errors. The main effect of type of disability on number of errors was statistically significant ($F_{1,10} = 3.265, p < 0.05$). The effect of the method was also high statistically significant ($F_{1,10} = 34.483, p < 0.0001$). There was a not significant effect for disability interaction effect ($F_{1,10} = 3.103$).

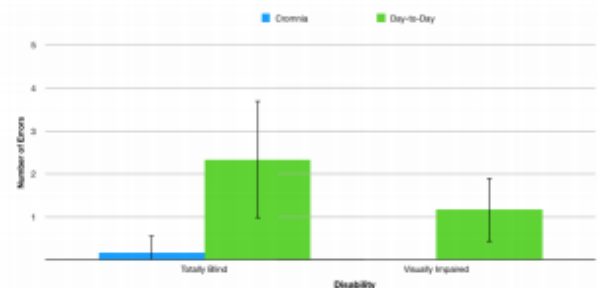


Figure 6: Number of errors for both methods, across the totally blind and the partially sighted participants. Error bars show standard deviation

The average SUS score was 84.46 for the *Cromnia* method (SD=14.20). All the totally blind participants said they prefer the *Cromnia* method instead of the day-to-day method, while only half of the partially sighted participants said they prefer the *Cromnia* method instead of the usual method. Moreover, all the participants had already used other types of assistive software, but not all of them were using the smartphone as an aid, especially to

resolve personal problems. Such result relates to the importance of social acceptance of assistive technologies. Using the smartphone as software aid was considered by participants always a preferable choice compared to hardware support, mostly because the software solution is more discrete and less bulky.

5 Concluding remarks

We have presented *Cromnia*, an assistive software which combines accessibility, empowerment-oriented design and neural networks to address problems of autonomy for visually impaired people. The initial experimental results suggest that *Cromnia* app is more efficient and accurate than traditional methods used by visually impaired people to dress up. Participants appreciated the benefits of a software aid for augmenting personal autonomy and they were keen to experience new versions of the application, in order to be able to eventually use it in their real lives. The current release of *Cromnia* is available from the AppStore and a high number of people have downloaded it so far. In the near future, comments coming from the community of users will be used to enhance usability and accessibility of the application and further user studies will be carried out to measure the degree of empowerment a person may achieve through the use of the application.

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REFERENCES

- [1] B E. Brady, M.R. Morris, Y. Zhong, S. White, and J.P. Bigham. (2013). Visual challenges in the everyday lives of blind people. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 2117-2126). ACM.
- [2] R. Cassino, M. Tucci, G. Vitiello, and R. Francese. (2015) Empirical validation of an automatic usability evaluation method. *Journal of Visual Languages & Computing*. Vol. 28. Pages 1-22. <https://doi.org/10.1016/j.jvlc.2014.12.002>.
- [3] S. V. Chhaya, S. Khera, and P. Kumar. (2015). Basic Geometric Shape And Primary Color Detection Using Image Processing On MATLAB. *International Journal of Research in Engineering and Technology*, Vol. 4, No 5, pp. 505-509, May 2015.
- [4] L. Elrefa'ei, M. Almasawa, and N. Abdullah Al-gohany. (2017). Development of An Android Application for Object Detection Based on Color, Shape, or Local Features. *The International journal of Multimedia & Its Applications*. 9. 21-30. 10.5121/ijma.2017.9103
- [5] K. Grauman and L. Bastian (2010). *Visual object recognition*. Morgan & Claypool Publishers.
- [6] P. Kaur, M. Ganore, R. Doiphode, A. Garud, and T. Ghuge. (2017). Be My Eyes : Android App for visually impaired people. doi: 10.13140/RG.2.2.12307.48164.
- [7] L. Jones. Lessons for Living with Vision Loss. American Foundation for the Blind <http://www.afb.org/info/programs-and-services/professional-development/aging/lessons-for-living-with-vision-loss/1234> .
- [8] B. Leporini and M. Buzzi. (2018). Home Automation for an Independent Living: Investigating the Needs of Visually Impaired People. *Proceedings of the Internet of Accessible Things* (W4A '18). ACM, New York, NY, USA, Article 15, 9 pages. DOI: <https://doi.org/10.1145/3192714.3192823>.
- [9] S. Rege, R. Memane, M. Phatak, and P. Agarwal. (2013). 2D Geometric shape and color recognition using digital image processing. *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering*. Vol. 2, No 6, pp. 2479-2487.
- [10] Sebillio, M., Tortora, G., Tucci, M., Vitiello, G., Ginige, A., Di Giovanni, P. (2015). Combining personal diaries with territorial intelligence to empower diabetic patients. *Journal of Visual Languages and Computing*. Vol. 29, pp. 1-14. DOI: 10.1016/j.jvlc.2015.03.002
- [11] G. Vitiello V. Vella, J. P. Mathieu, M. O. Elias, S. Bedin, K. Segatti, R. Ferretti, J. Hüllen, A. Borrell. (2016). Elicitation of needs and definition of relevant ontologies report. https://www.bfw-dueren.de/projekte/abgeschlosseneprojekte/pro4vip/pro4vip_survey.pdf.
- [12] G. Vitiello, R. Francese, M. Sebillio, G. Tortora and M. Tucci. (2017). UX-Requirements for Patient's Empowerment — The Case of Multiple Pharmacological Treatments. *IEEE 25th International Requirements Engineering Conference Workshops (REW)*. pp. 139-145. doi: 10.1109/REW.2017.67.
- [13] *OrCam MyEye 2.0*. retrieved from <https://www.orcam.com/en>, September 2018.
- [14] *Colorino - Talking Color Identifier and Light Probe*. retrieved from <https://www.independentliving.com/product/Colorino-Talking-Color-Identifier-and-Light-Probe/dressing-aids>, September 2018.