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Testing Lung Cancer Patients' and Oncologists' Experience with the Lalaby App for Monitoring the Quality of Life through Mobile Sensors and Integrated Questionnaires

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ABSTRACT

As there is now a growing interest in mHealth apps for cancer patients, we here present and test the Lalaby App to monitor lung cancer patients' Quality of life (QoL) through mobile sensors and integrated questionnaires. The app was used in a 2-week study to register two lung cancer patients' activity without problems or interruptions. The patients frequently reported activities, symptoms, and questionnaires, indicating their engagement with the app. They registered their experience through the UEQ-S integrated into the app. Patient 1 mainly reported a neutral experience, while Patient 2 found it highly positive. They considered the app leading-edge and helpful and would recommend it to others, while both patients valued it positively (3.72 and 4.64 on a scale of 1–5). The app's aesthetics and its notifications helped their engagement. We found correlations between sensors' data and patients' QoL. We also detected QoL and functional status variations after treatment for both patients. After a "Tasks Test," two oncologists assessed the app's dashboard usability as excellent (SUS scores 85 and 87.5 on a 0–100 scale), easy-to-use and helpful. Their experience was positive (UEQ-S overall scale 2.81 (mean), −3 to +3 scale). The app allows monitoring the QoL of lung cancer patients remotely and in real-time while controlling patients' experience to stop the use if necessary, avoiding overwhelm.

1. Introduction

Lung cancer accounts for the highest cancer mortality rate worldwide (World Health Organization, 2022). Recent medical approaches to cancer treatment focus on prevention, cure, prolonging life, and improving patients' quality of life (QoL), which is altered due to the various symptoms produced by cancer itself and also by treatment such as chemotherapy (Park et al., 2019). As most antineoplastic treatments are administered to outpatients to minimize interference with the patients' lives and reduce hospital admissions, the patients themselves are often required to manage their own side effects at home without direct support from health professionals, so that there is a growing interest in getting either the patients themselves or automatic devices to register their QoL data throughout the disease. However, this system can meet with problems regarding how to collect the information directly by a means compatible with the disease and at a reasonable cost. Several mobile applications (Purswani et al., 2019) and wearable

devices (Gochoo et al., 2021; Gresham et al., 2018; ud din Tahir et al., 2021) have recently appeared as proposals to solve this problem, including the Lalaby App, which we describe here.

Purswani et al. (2019) systematically searched published clinical studies on cancer patients that incorporated smartphone apps. Of the 22 apps analysed, 18 were designed for patient use, 14 of which relied on data entry by patients. However, only four apps automatically collected data from smartphone sensors, including the present proposal. According to Purswani et al., the physical activity metrics captured by smartphone accelerometers have received most attention to date. Other digital biomarkers related to toxicity monitoring, such as sleep, movement, vital signs and quality of life, are being actively researched by several other groups, including the research team composed of the present authors.

Regarding smartphone apps to enhance cancer patients' QoL (Asensio-Cuesta et al., 2019; Mayer et al., 2018; Rosen

et al., 2018; Uhm et al., 2017), Asensio-Cuesta et al. (2019) analysed the potential use of mobile sensors for monitoring QoL in cancer patients (Asensio-Cuesta et al., 2019). Mayer et al. (2018) evaluated the impact of the *SurvivorCHESS* app on physical activity, quality of life and distress in colon cancer survivors. QoL was measured by the Functional Assessment of Cancer Therapy-Colon (FACT-C, Version 4) (Ward et al., 1999). Uhm et al. (2017) investigated the *Smart After Care app's* effect on exercise in breast cancer patients. They used the EORTC QOL-C30 to assess the general QoL and the QoL Questionnaire Breast Cancer Module 23 (EORTC QOL -BR23) as a breast cancer-specific QoL tool. Rosen et al. (2018) studied QoL among women diagnosed with breast cancer and evaluated the efficacy of a commercially available mobile app for mindfulness training. QoL was measured by the Functional Assessment of Cancer Therapy—Breast Version 4 (FACT-B) (Brady et al., 1997). Although the above-mentioned apps used questionnaires to measure QoL, none used mobile phone sensors to automatically collect objective patient data, as does the Lalaby app.

Only a few mobile applications have been proposed and tested focusing on monitoring patients with lung cancer. Mccann et al. (2009) evaluated the impact of a mobile phone-based advanced symptom management system (ASyMS) on chemotherapy-related toxicity in the lung, breast, or colorectal cancer patients. Individuals reported many benefits of using the app, including improved communication with health professionals, improvements in the management of their symptoms and feeling relieved their symptoms were being monitored at home, so that the app had the potential to positively impact the management of symptoms in patients receiving chemotherapy. The *Lung Cancer Navigator app* (Lung Cancer Navigator Mobile App, 2022), created by the non-profit-making LUNGevity Foundation, provides information to help patients understand the diagnosis and integrate tools and forums for asking questions, detailing symptoms, managing medications, and communicating with healthcare providers to request support from friends and family. The *Lung Cancer App (LuCApp)* (Ciani et al., 2019) is a mobile application developed by researchers and clinicians to promote real-time monitoring and management of patients' symptoms, including triggering alerts to the physicians in case predefined severity thresholds are met. The *LuCApp* testing protocol has been defined as a clinical trial to evaluate the usability, effectiveness, and cost-effectiveness of *LuCApp* versus standard of care. Other examples are the *Efil breath app* (Kwon et al., 2018) to monitor and manage chronic obstructive pulmonary disease patients, which has been tested in a randomised controlled trial, concluding that this technology can encourage the improvement of physical activity, dyspnea, and quality of life (Ji et al., 2019). Finally, the *Smart Aftercare* app is focused on pulmonary rehabilitation for chemotherapy-treated patients with advanced lung cancer (Park et al., 2019). However, none of these solutions use the potential of smartphone sensors to collect objective data from the patients, an aspect in which the present proposal is highly innovative.

Although many cancer patients considered mHealth apps as a useful complementary tool, there is a need for more closely tailored designs (Vo et al., 2019). Different methods have been applied to assess cancer patient's experiences with apps: Puszkiewicz et al. (2016) assessed cancer survivors' experiences of using a publicly available physical activity mobile application (*GAINFitness app*) through semi-structured interviews via telephone after the 6-week study period. Young-Afat et al. (2016) assessed patients' and health care providers' experience of a supportive health app during breast cancer treatment (*OWise app*) with in-depth face-to-face interviews. Langius-Eklöf et al. (2017) studied the adherence to reports and patient perception of an interactive app (*Interaktor app*) for managing symptoms for prostate cancer during radiotherapy using face-to face interviews. Jibb et al. (2018) collected the perceptions of adolescent cancer patients to determine the acceptability and perceived helpfulness of the *Pain Squad + app* through telephone-based, semi structured, and audio-recorded interviews. Although the above-mentioned researchers assessed the patients' experience after use through interviews, none of them assessed it continuously throughout the period of use, the novelty approach we propose here.

Patients typically report only the symptoms and functional status they can remember during a visit to the oncologist. Also, the oncologist generally has a limited time to collect further information on the patient's QoL, which could help his decision-making on the cancer treatment. Disagreements have been reported between patients' reporting of their symptoms and QoL with that of their clinicians (Chandwani et al., 2017), while the perception of the patients' state of health, and therefore QoL, can be influenced by their emotional situation (Valentine et al., 2022). For the correct evaluation of the impact of the treatment on the patient's functional and emotional state, tools are required that allow easy measurement and parameters that give oncologists objective information in real-time.

This paper describes a test on whether adequate remote acquisition of data from mobile sensors using the app Lalaby is achievable in patients diagnosed with Non Small-Cell Lung Cancer (NSCLC) receiving systemic treatment, together with the involvement of patients completing digital registries. We here describe the usability and patients' experiences in the form of test results performed during and after use of the device, also the effect of oncologic treatment on the patients' activity and symptoms according to the app's collected data and report on the correlation between the sensor data and QoL dimensions. The Lalaby app incorporates an online dashboard to provide the collected data graphically to oncologists, we also present the usability and experience test involving oncologists of Lalaby's dashboard.

2. Material and methods

2.1. Ethics

Ethical approval was obtained for the study from the Ethical Committee of the Universitat Politècnica de València (Ethical Code: P8_12_11_2018; Date: 14-11-2018), and the

Hospital Universitario Dr Peset de Valencia (Ethical Code: CEIm: 96/19; Date: 25-09-2019).

2.2. Recruitment

The participants in the study were two volunteers recruited face-to-face by the oncology department according to the following inclusion criteria: adults (over 18 years old) diagnosed with advanced-stage Non-Small Cell Lung Cancer (NSCLC) with a life expectancy of 6 weeks or more, candidates for starting chemotherapy, a performance status between 0 (asymptomatic) and 2 (symptomatic, <50% in bed during the day) according to the ECOG-Performance Status scale (Oken et al., 1982), possessing a smartphone with an Android Operating System (Android Version 4.0.3 or higher, optimal 7.0) and Internet access (Wi-Fi + 3 G or 4 G). The participants were informed of the objective of the study and signed an informed consent form.

The exclusion criteria were as follows: individuals unable to provide written informed consent, patients without a compatible smartphone, unfamiliar with mobile apps or those with a non-compatible device.

2.3. Study design

The duration of the patient's test was established at six weeks. At the medical visit on the day starting the treatment, a researcher conducted a short structured interview on the patient's previous experience with health apps, based on [28] [29], before installing a Lalaby App (see Figures 1 and 2, also description of functionality in the Supplementary Material) on the patient's smartphone and provided a brief written guide on its use (2 pages). After running the app, the notifications of activity/symptoms (2 times a day) and questionnaires (once a week) were configured according to the patient's preferences. The activities/symptoms needed to be reported twice a day (in the afternoon and at night) and the questionnaires were to be filled out once per week. The

questionnaires included in the app were the EORTC QLQ-C30 (Spanish Version) (Bjordal et al., 2000), with 30 questions on limitations, and physical, emotional and social issues; the ECOG scale (Oken et al., 1982) perceived by the patient, concerning their level of functioning (0–4). Pilot correlations between the EORTC QLQ-C30 and data from sensors were also explored using multiple regression models. Due to the small sample size, each cycle of treatment was considered individually.

To avoid data collection failures, a researcher reviewed the Lalaby app log dashboard daily to verify that the data acquisition was functioning correctly. If a problem occurred it was arranged that the oncologist would contact the patient to clarify the reason, including technical problems, fatigue, or difficulty and would try to solve it in collaboration with the research team.

2.4. Patient experience and usability tests

To test the patient's experience and usability, after the app installation, the patient was asked to complete a cycle of use under supervision, which included the activity/symptom and the 3-questionnaire report, and consulting and using notifications. The "Thinking Aloud" technique was applied during this patient's first interaction to detect usability issues. During the cycle of use, a caregiver was also involved in using the app to reinforce the patient's involvement. A contact number was supplied in case of possible errors or doubts.

After six weeks of use, a researcher conducted a structured interview with the patient, while the patient's experience was assessed weekly through the short version of the User Experience Questionnaire (UEQ-S) (Schrepp et al., 2017) included in the app and a global satisfaction scale of 1–5.

Three weeks into the study, the two oncologists involved attested the dashboard usability online through TEAMS software sessions involving two researchers, one to guide the
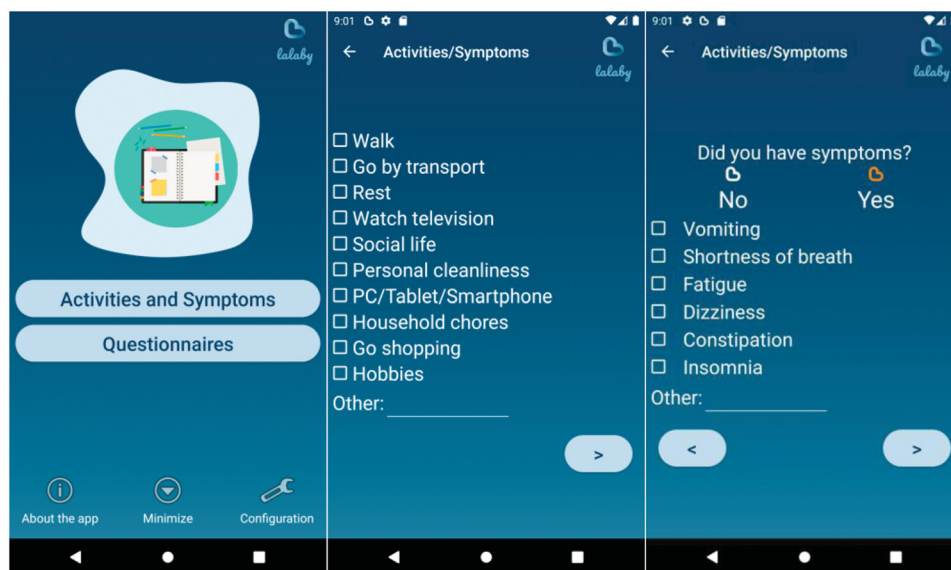

Figure 1. Lalaby app screenshot of the main menu (left), activities (centre), symptoms (right).
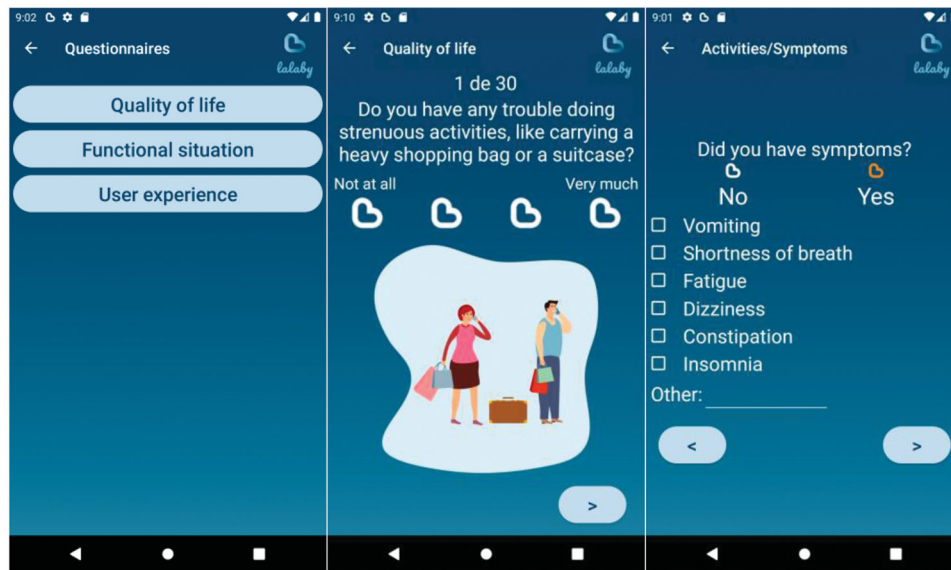
Figure 2. Lalaby app screenshot of the questionnaire menu (left), first question of the EORTC-C30 questionnaire (centre), first question of the ECOG-PS questionnaire (right).

session and the other as an observer to collect the information. The oncologist was asked to share the screen while using the dashboard and to perform 6 tasks simulating a real use case, while talking aloud. After each task, the participant answered questions to measure the completeness of the task (yes/no), the efficiency (time required, scale of 1–5), effectiveness (number of errors, from 1 to more than 10), difficulty (scale 1–7), comprehension of the information displayed (scale 1–10), satisfaction (scale 1–5), measures defined according to ISO 9241-11: 2018 (en) Ergonomics of human-system interaction – Part 11: Usability: Definitions and concepts (ISO, 2018). An additional question was included for tasks 2–6 on the usefulness of the information shown from the perspective of the patient's QoL follow-up and evaluation. Once the tasks test was completed using an online questionnaire created on Google Forms, the oncologists responded to the UEQ-S and the System Usability Scale Questionnaire (SUS) (Brooke, 1996).

2.5. Results

Two Caucasian male patients diagnosed with stage IV Non-Small Cell Lung Cancer receiving intravenous treatment participated in the study in which they used the app for six weeks. Patient 1 was in an age range between 55 and 60 and patient 2 in the range between 70 and 75.

Data were collected automatically from the patients' mobile sensors (Table 1). Figure 3 shows a graph of the Lalaby dashboard's representation of the sensor data collected from Patient 1 (see Figure 4 in Supplementary Material for Patient 2).

Both patients reported irregular activities and symptoms (Table 2). Some weeks Patient 1 registered 10 or more reports, although we also registered a week with only three reports. Patient 2 reported activities and symptoms irregularly from 1 to 4 times a week.

Table 1. Summary table of mean values of the data obtained by the patients' sensors per day.

Measurement	Patient 1	Patient 2
Total number of calls	81	27
Total data usage (MB)	13797.2 MB	2873 MB
Total distance travelled (km)	2.14 km	3.19 Km
Mean quantity of movement (m/s^2)	0.22 m/s^2	0.04 m/s^2
Mean frequencies of sound (HZ)	379.7 Hz	807.7 Hz

The most frequently reported symptoms for both patients were tiredness and pain (see Table 2 and Figures 2 and 3 in Supplementary Material). Variations in activities and symptoms were reported after chemotherapy cycles (see Figures 8–12 in Supplementary Material). Patient 1 discussed his persistent fatigue with the oncologist, while Patient 2 reported no symptoms or treatment toxicity during his medical visits.

From the "Thinking Aloud" during the first patient-app interaction, we identified requirements mainly from Patient 2. Patient 1 was a regular user of apps for measuring physical activity, social networks and games but found it difficult to understand and answer the ECOG questionnaire regarding text and interaction and needed help. He enjoyed the aesthetics and interaction. While Patient 2 was not a regular user of phone apps and preferred the computer. During the interaction, he indicated: small font size, small buttons, small distance between option buttons, so that more than one button was pressed at a time, and he did not understand the ECOG text and interaction. He liked the aesthetics, and his first impression was that it was easy-to-use and that it could be helpful to him. He did not use any other health app and did not fully understand how the notifications worked, but his companion (caregiver) was willing to help him to use the app. Regarding the functional evaluation using this scale, after the first chemotherapy cycle, the functional status of Patient 1 worsened drastically from an ECOG of 2–4 and did not improve to 3 until the fifth day after treatment. However, after the second cycle it improved
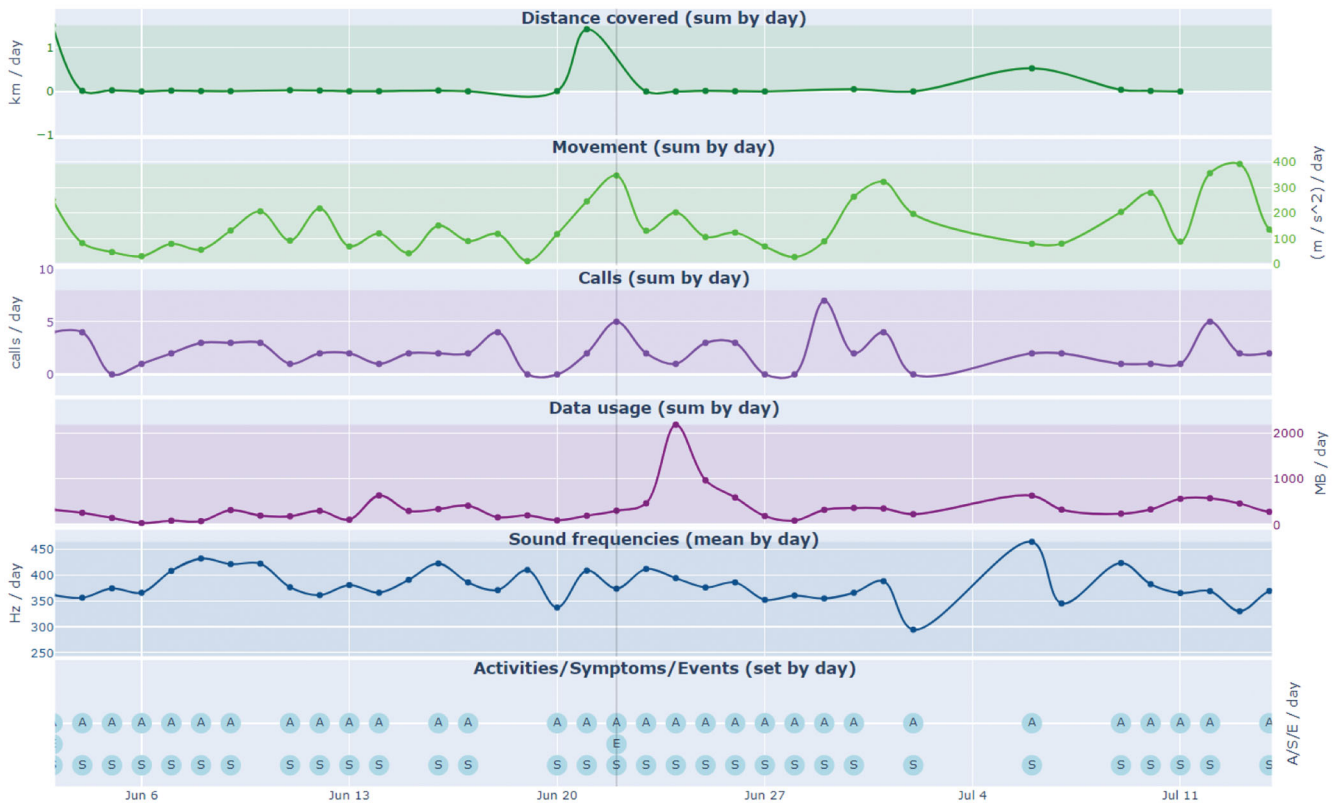
Figure 3. (Top) graph from the Lalaby dashboard of the daily sensor records for Patient 1, (bottom) reported activities, symptoms, and events (chemotherapy cycles).

Table 2. Summary table of activities, symptoms report EORTC QLQ-C30, ECOG and UEQ-S by Patient 1 and 2

Measurement	Patient 1	Patient 2
Times activities/symptoms reported	47	30
Days with report	31	29
Number of activities	168	83
Number of symptoms	63	89
Most frequent activities (in order)	Resting, personal cleanliness, watching TV, walking, and a little time occupied with social life	Walking and watching TV, personal cleanliness, going shopping, housework, social life, resting, using a computer, and going by transport
Most frequent symptoms (in order)	Tiredness, pain, dizziness, and lack of air	Tiredness, pain, vomiting, dizziness, shortness of breath
Times EORTC QLQ-C30 reported	51	14
Times ECOG reported	17	8
Times UEQ-S reported	24	4

to an ECOG-performance status of 2. After the first chemotherapy cycle, Patient 2 improved functionality from ECOG 3 to 1. On the other hand, the oncologists evaluated both patients as functionally suitable candidates for receiving systemic oncologic treatment (median ECOG = 1 for both). Figures 7 and 8 in the Supplementary Material show a daily graphical representation of the ECOG scale on the Lalaby dashboard, also the events indicating dates with "chemotherapy."

The patients' understanding of the EORTC QLQ-C30 questionnaire was good, and no doubts were identified in the interpretation of the 30 questions, so that its inclusion in the app was considered appropriate. Figures 5 and 6 in the Supplementary Material show a graph of the EORTC QLQ-C30 global health, functional, and symptom scales, also the daily "treatment" cycles for Patients 1 and 2, respectively.

Regarding the correlation between data from sensors and the EORTC QLQ-30 scale, multiple regression models were used to explore the correlation between the sensor data (including number of calls, data usage, sound frequency and movement) and the scores obtained in different dimensions of the EORTC QLQ-30 scale. Interestingly, the number of calls was inversely correlated to the emotional score (coefficient $= -133$; p-value $= 0.0251$) and directly correlated to movement (coefficient $= 0.99$; p-value $= 0.0252$). The data usage was inversely correlated to the emotional score (coefficient $= -0.31$; p-value $= 0.033$), also the sound frequency (coefficient $= -0.0006$; p-value $= 0.044$). The symptomatic dimension score was directly correlated to number of calls and inversely correlated to movement (p-value $= 0.0119$ and 0.064, respectively; both being clinically and statistically significant). No other significant correlations were found, and these should be taken cautiously.

UEQ-S was finally analysed. Patient 1 filled out the UEQ-S 24 times (see Figure 4). The app's global assessment mean value for Patient 1 was 3.72, on a scale of 1–5 (the higher the better). The mean of Patient 1's UEQ-S scores were 0.71 on the hedonic scale, 0.47 on the pragmatic scale and 0.59 on the global scale. These values indicate a neutral evaluation in the three scales, with the hedonistic scale being the best valued (values between −0.8 and 0.8 represent a neural evaluation). The positively scored adjectives were "inventive" and "leading edge" (scores up to 0.8) while the rest were scored with neutral values. Figure 5 shows from the dashboard data that the patients' experience with the app remained neutral throughout its use. However, nine reports indicate a positive evaluation of the hedonistic scale with values above 0.8.

Patient 2 reported the UEQ-S 4 times. The mean score was 4.64 (see Figure 5). The mean UEQ-S scores were 2.5 on the hedonic scale and 2.68 on the pragmatic scale; 2.59 on the global scale (>0.8 represents a positive evaluation, and 3 is the best value). All adjectives (values >2) were scored positively for the app, from highest to lowest leading-edge, inventive, interesting, exciting, clear, easy, and supportive.

In the interview after the period of use, both patients indicated that they would recommend using the app to other patients, although they would have liked to have feedback from the app and not just to have to report data. Patient 1 indicated that he would like to see the report of symptoms over time and their frequency. He would also like to know the QoL level and its evolution and to have an agenda included in the app to manage medical consultations.

3. Dashboard usability and UX test (think aloud, task test, and UEQ-S)

The two oncologists involved in the dashboard usability test were women with 8 and 31 years of experience, neither of whom had previously used a clinical decision support system. Figure 6 shows the usability measurements obtained in the Task Test with the oncologists (see Table 1 in Supplementary Material with the results of the Tasks test).

No problems were detected in task 1, "Check the data collected from the patient ID." In task 2, "Check sensor graphics by day in the last 2 months," an update error of the
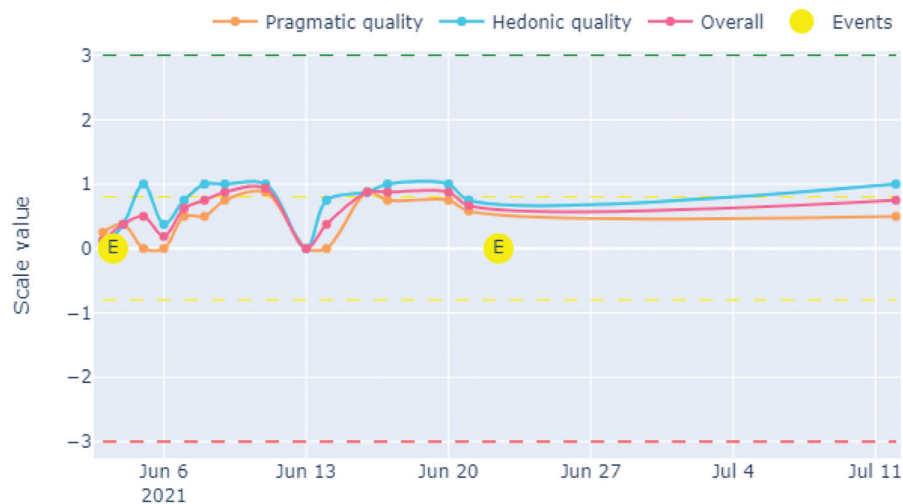

Figure 4. Patient 1: grap of the UEQ-S scales from the Lalaby dashboard. E (Event) indicates dates with "oncologic treatment." [−0.8, 0.8] Neutral evaluation; [0.8, 3.0] Positive evaluation; [−3.0, −0.8] Negative evaluation.
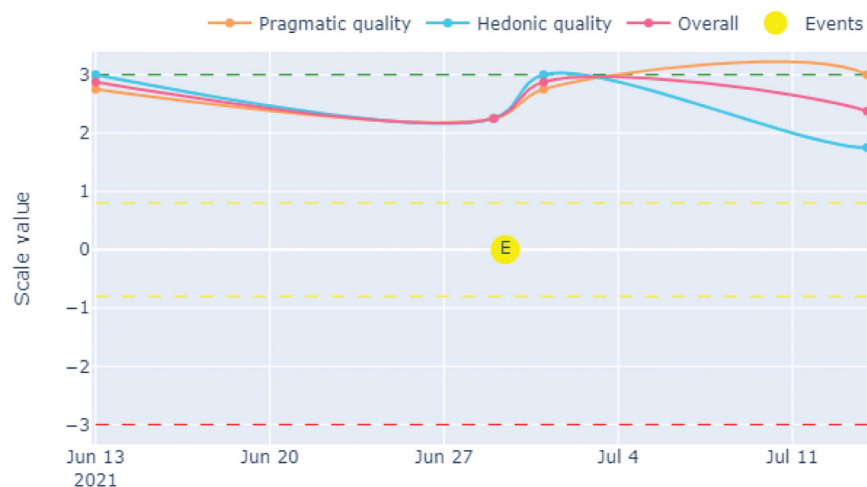

Figure 5. Patient 2: graph of the UEQ-s scales from the Lalaby dashboard. E (Event) indicates dates with "oncologic treatment." [−0.8, 0.8] Neutral evaluation; [0.8, 3.0] Positive evaluation; [−3.0, −0.8] Negative evaluation.
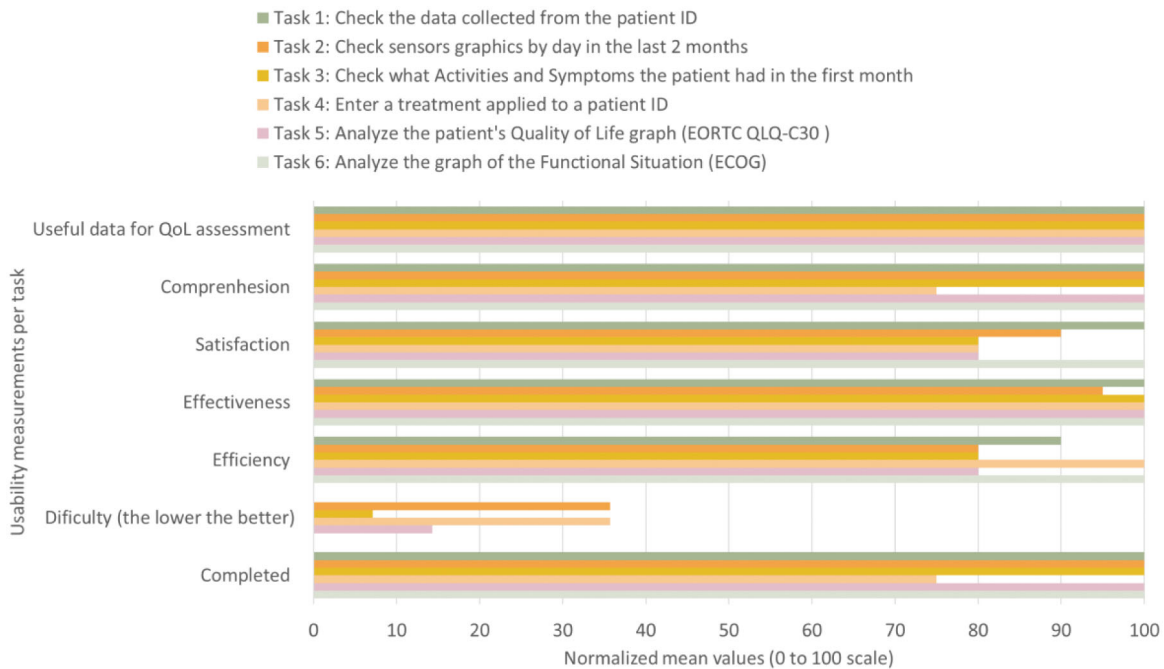
Figure 6. Normalized mean values (0–100 scale) of the usability measures obtained in the onchologists Task test.

sensor graphic axes was detected when changing the display unit (hour, day, week, month, year). One of the users indicated the need to add reference values to the graphs to better assess changes in the patients. In task 3, "Check what Activities and Symptoms the patient had in the first month," both users recommended an improvement to add filters by dates, symptoms, and activities to the table. In task 4, "Enter a treatment applied to a patient ID," Oncologist 1 was unable to complete task 4 (Introducing treatments without help). The problem detected referred to the generic label "Enter patient events" since the terminology "events" in the medical field generally relates to adverse situations and not treatments. In task 5, "Analyse the patient's Quality of Life graph (EORTC QLQ-C30)," both users indicated that they would like a graph including all EORTC QLQ-C30 subscales. In task 6, both users said that the ECOG values reported by the two patients were higher than their evaluation (the higher the worse the functional situation). This could suggest that the ECOG varies according to whether it is filled out by the doctor or the patient.

After performing all the tasks, both oncologists indicated that the information shown was useful for QoL assessment. The two oncologists SUS scores were 85 and 87.5, indicating "Excellent" usability, according to Bangor et al. (2009).

The UEQ-S overall scale was 2.81, pragmatic quality was 2.75 and the hedonic scale was 2.87, indicating a good experience, where −3 (extremely bad) and +3 (extremely good). Using the "Think Aloud" technique, both oncologists indicated a willingness to use the Lalaby dashboard to help with their decisions.

4. Discussion

The two patients involved in the pre-pilot test completed the six-week use of the Lalaby App without problems or interruptions. During this time, the app created a log that was reviewed daily to verify that it was functioning correctly. No incidents arose during the test. The patients reported activities, symptoms and questionnaires frequently, indicating their engagement with the app. Neither patient considered the app a burden and its use was compatible with the disease and treatment.

As regards the app's collected data for monitoring lung cancer patients' QoL, the self-reported data on symptoms and activities showed that Patient 1 conducted a reduced program of activities, mainly at home, and did not have an active social life after the first chemotherapy cycle. This correlated with data retrieved from the sensors, which showed reductions in calls, distance travelled and data usage after each cycle, although they recovered within two weeks. We found that the number of calls was inversely correlated with the emotional score of the EORTC QLQ-30, and emotional status has been associated before with reduced health-related quality of life (HRQL) scales (Arrieta et al., 2013).

Interestingly, according to the EORTC QLQ-C30 questionnaire, after the first chemotherapy cycle, Patient 1's symptoms decreased (although he reported fatigue every day) and the patient increased his functionality. Although the global burden of his symptoms was objectively reduced, pain and dyspnea disappeared and he achieved a partial response in a radiological evaluation, while his perceived overall health did not improve (Figure 5, Supplementary Material). A deeper analysis of the data showed that another two aspects that he considered deficient were his life-role and his social functionality. This, together with the fatigue, could have had a significant impact on his perceived QoL, as has been previously reported (Henoch et al., 2007; Luszczynska et al., 2013).

We were surprised to find that, according to the Lalaby digital registry, Patient 2 reported a wide range of symptoms

but did not report them in medical visits. The sensors did not capture any changes in functionality, movement or calls, and as the overall burden of symptoms improved during the treatment, we concluded that they did not interfere with his perceived and quantified QoL. One possible reason is that the symptoms are not graded, and mild symptoms, that would not interfere with QoL (Atkinson et al., 2016), cannot be distinguished from severe symptoms. We plan to address this aspect in future studies. All this information shows that the sensor data are of medical interest, since they could help oncologists make decisions about changes or adjustments in treatment and medication to relieve symptoms and improve activity. They could also be used to discuss emotional, social or cognitive issues that do not usually arise in medical visits but could significantly interfere with the patient's QoL and could influence decisions regarding oncologic therapy.

After the first cycle of chemotherapy, the ECOG functional status of Patient 1 worsened drastically from level 2 to 4, (the higher the worse) and did not improve to 3 until the fifth day. However, after the second cycle it improved to level 2 (Figure 7 in the Supplementary Material). After the first cycle of chemotherapy, Patient 2 improved functionality from level 3 to 1. However, after the second and third cycles he indicated level 4 (Figure 8 in the Supplementary Material). In our analysis, self-reported ECOG was significantly higher than the values assigned by the oncologists (3 vs 1), in agreement with other studies (Johansen et al., 2013; Malalasekera et al., 2016). We found discrepancies in the functional scale (Figures 7 and 8 in the Supplementary Material), mainly in Patient 2, based on EORTC QLQ-C30 and reported daily activity (Figures 2 and 3 in the Supplementary Material). In the post-follow-up face-to-face interview with the patient, we realized that the patient found it difficult to choose the most suitable description of the performance status, as will be explained below, addressing the user experience perspective.

This novel approach to non-invasive QoL monitoring through the patient's smartphone sensors has not previously been carried out in lung cancer patients, as far as we know. It represents a technological paradigm change that focuses on measuring essential life biomarkers (movement, displacement, social communication, sleep and exposure to noise, among others (Beauchamp et al., 2020)) directly from patients to help treatment decisions. Including the QoL questionnaires in the app complements the information collected in medical visits with additional information that the patient often does not remember at the time of the visit or that it is not possible to collect due to time constraints. For example, filling out the EORTC QLQ-C30 questionnaire takes approximately 9 min (Mystakidou et al., 2001), and this task can be performed by the patient himself before the medical appointment.

Due to the high availability of smartphones in our social environment this system can be easily used at very little cost. Likewise, the global assessment of our patients, including objective data from phone sensors and their perception regarding their functionality and quality of life would help to make better therapeutic decisions. Currently, there are

multiple treatment options available for Non-Small Cell Lung Cancer, with widely differing toxicities. The serial determination of these parameters and their correlation with objective data from the mobile sensors would provide a means of reassessing the administration of the treatment in different stages of the disease.

The Lalaby app would also improve the patients' communications with health professionals as they feel reassured when their symptoms are monitored at home and checked by a professional between medical visits. The app would thus positively impact the management of symptoms in patients receiving chemotherapy treatment.

From perspectives of usability and user experience, based on the UEQ-S results, "Think Aloud" technique and interviews, we can state that the patients found the novel app useful and pleasant to use, and referred to it as "inventive" and "leading edge." They liked its aesthetics and interaction. Patient 1's experience was mainly neutral (Figure 4), while it was very positive for Patient 2 (Figure 5). We consider that the aesthetics and graphic design of the app's interface would contribute to the positive user experience and be reflected in neutral to positive values in the hedonistic UEQ-S scale they report. The app's functionality was also considered useful as shown by the UEQ-S pragmatic scale reported by both patients. The novelty of our approach of testing patient experience through the UEQ-S scale among users should be noted. Previous studies that assessed cancer patients' perception of mHealth apps was mainly based on subsequent interviews (Jibb et al., 2018; Langius-Eklöf et al., 2017; Puszkiewicz et al., 2016; Vo et al., 2019). Our proposed approach would permit better control of the patients' experience and could implement alerts to stop its use when the patient's experience is negative, and so protect the patients against excessive use.

The patients reported activities and symptoms without problems, although the frequency was lower than expected (84 reports/patient: 2 times/day for six weeks). Patient 1 reported 47 times, and Patient 2 reported 30 times (Table 2). As this result could indicate that reporting activities/symptoms more than once a day could lead to user fatigue, a protocol involving more patients should be reviewed and reduced to direct interaction with the app once a day. Patient 1 reported more frequently than Patient 2. This was attributed to the fact that Patient 1 was younger and used his mobile phone regularly, mainly related to social networks and games, as we extracted from the previous interview. Also, Patient 2 had more symptoms than Patient 1, which could have affected his engagement with the app. To improve this aspect, we plan to add a voice recording option and natural language processing (NLP) to minimize the patient's burden and facilitate its use in patients with multiple symptoms and will test the usefulness of this functionality in a larger pilot test.

While we only expected to receive six reports/questionnaires per patient, we in fact got more, mainly in the EORTC QLQ-C30. Patient 1 reported 51 times, and Patient 2, 14 times. Both patients indicated that they were confused by a notification that indicated the correct functioning of

the app and that they erroneously interpreted it as a request for action. We shall therefore clarify this notification text and remove the clicking access to the main menu to avoid errors and unnecessary reports. Patient 1 indicated that he reported the questionnaire more frequently because it reflected the daily status better than simply reporting the activities/symptoms. From this result, we identified the need to include more activities and symptoms in the list of options based on the EORTC QLQ-C30 and oncologists' criteria. We also plan to calculate the average values of the EORTC QLQ-C30 scales by day, week and month and show them in the dashboard to simplify its interpretation.

Patient 1 answered the ECOG questionnaire 17 times, while Patient 2, 8 times, and the expected answer was six times per patient. The explanations also the above-mentioned notification error.

The "Think Aloud" method highlighted some problems that needed to be corrected in the app before testing a pilot system involving a higher number of patients, such as reviewing the ECOG questionnaire to be scored by patients, texts, and interaction. It was difficult for both patients to read all the options on different screens and then go back to choose one. This type of interaction requires the patient's memory and reduces usability (Nielsen, 2022). The font size and the distance between buttons should be increased. The average age of lung cancer patients when diagnosed is about 70 (Key Statistics for Lung Cancer, 2022), when they are likely to suffer from presbyopia, an age-related loss of lens accommodation that results in an inability to focus on close objects. Also, when selecting a score as a response in a scale, the lower scores should not be coloured (checked) as a continuous scale but only the chosen option should change colour (discrete scale). We plan to include feedback for the patient, such as graphical reports on symptom frequency and evolution and a global QoL score over time, plus a scheduler for medical appointments.

We realized the importance of involving caregivers in the study; for example, Patient 2, who was not a regular app user, was initially a little unsure whether he would use the app but was encouraged to participate because his caregiver offered to help. The patient reported a very positive experience during its use.

In the post-use interview, both patients indicated that they would recommend the app to other patients and reported benefits such as improved communication with oncologists and feeling reassured their symptoms were being monitored while at home. Both users considered the notifications very useful to remember reporting and guide the required interaction. We consider that this contributed to their engagement with the app.

On the other hand, the app's dashboard level of usability was good and was helpful in the patient's QoL analysis. However, some improvements and corrections were identified to be made before testing on a large sample of patients, including: update labels of the sensor graphs according to the time unit chosen (hour, day, week, month, year); adding reference values to the sensor graphs, adding filters by date and type of activities and symptoms in the table of activities/symptoms; including visual graphs for relative frequency of activities per week/month/year; improving functionality of entering events and differentiating between "events" and "treatments"; including in the EORTC QLQ-C30 QoL graphs the functioning and symptoms' included and excluded sub-scales .

Although the usability and UX tests allowed us to detect errors and propose future improvements to the app and its dashboard, there are also limitations to be considered. A fundamental limitation was its small sample size, but as the aim was simply to assess the feasibility of using the Lalaby app in lung cancer patients, we plan to test it on larger cohorts in future studies. Furthermore, as digital patient monitoring is rarely used in routine clinical practice, there could be a bias for including patients, since this technology requires a smartphone and a minimal skill with mobile devices. Also, training participants (and healthcare professionals) is an essential issue in implementing these new systems, while some oncologists may be reluctant to accept these tools from the outset due to their previous clinical experience without these devices.

Finally, we are aware that the face-to-face installations may have contributed to the app acceptance by reducing the usability problems and improving UX, and this type of installation may not be feasible in future studies with many patients due to the cost and time constraints in medical practice. It will therefore be necessary to carefully analyse whether there are any differences in the results according to the different types of installation and determine how to proceed in extensive studies.

5. Conclusions

The Lalaby app makes several contributions: first, to the best of our knowledge, this is the first time automatic continuous smartphone sensing has been used to assess lung cancer patients' QoL. Second, we developed an app suitable for collecting useful data to assess the effect of treatment on these patients' QoL. Third, the app includes the continuous measurement of the patient's experience, integrating the UEQ-S questionnaire and a global evaluation. The UEQ-S data collected provides information on the evolution of the patient's experience over time and possible correlations between the patient's health and their perception of the app. This function can be helpful in deciding when to stop its use and in avoiding negative patient experiences. Although getting patients to collaborate in improving applications is somewhat unusual, we designed the app to involve both patients and oncologists in interviews and tests to get the final user's perspectives, which can be seen as one of its strengths. Finally, we designed a usable dashboard to support oncologists in their decisions based on the patients' QoL.

We expect the next steps in our research to be as follows: i) solve the usability errors detected, ii) develop the new functionality identified, analyse the patients' collected data in depth to extract clinical conclusions, and iii) extend the

study to fifty lung cancer patients to obtain a QoL prediction model from the data collected by the app.

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Disclosure statement

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