Browser-based Infographic Tailoring Self-service Interface (BITSI)

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ABSTRACT

Tailored infographics are useful tools for communicating health information to patients and research participants, particularly those with low health literacy, but software is required to automate the tailoring. The Browser-based Infographic Tailoring Self-service Interface (BITSI) is a bespoke software solution for tailoring infographics. BITSI produces batches or single PDFs of tailored infographics in English and Spanish of Asthma Control Test scores at one or two time points using a number line format. This open-source software uses R and a LaTeX compiler; development of a Shiny web application supported a user-friendly, browser-based interface. We improved upon previous infographic tailoring solutions by streamlining installation and creating a user-friendly point-and-click data entry interface. Due to its interface, BITSI is amenable to interfacing with other systems through application programming interfaces, such as with electronic health record systems. These improvements make deployment of tailored infographics in clinical and research settings feasible and practical.
Keywords: Comprehension, audiovisual aids, information visualization, patient-reported outcomes.
Index Terms: H.1.2.a Human factors,I.6.9.c Information visualization, J.3.b Health, K.m.d Healthcare

1 INTRODUCTION

There is increasing interest in using infographics to support patient education and patient-clinician communication. Visualizing health information using icons, charts, and illustrations has been shown to increase the comprehension of personal health information, particularly in populations with low health literacy [8]. Research in this area is ongoing, and various strategies—including tailored infographics—have been used for patient-facing visualizations and to return health-related research data to participants [21].

We define **tailored** infographics as information visualizations that vary in appearance based on the incorporation of data about the intended viewer, such as a lab result or a patient-reported outcome (PRO). By contrast, **generic** infographics are the same for every viewer, such as a poster outlining proper hand washing procedure.

With the proliferation of mobile devices, tailored visualizations are at our fingertips. For example, most people have become accustomed to viewing dynamic charts of their step counts and sleep metrics. However, we anticipate continued demand for novel visualizations to meet specific health communication needs and therefore a concomitant demand for software solutions that automate the tailoring to facilitate easy deployment by clinicians and researchers. Our prior research has focused on developing visualizations targeted to the learning needs of people with low health literacy and limited English proficiency [2, 5]. In this paper, we report on our most recent software solution for infographic tailoring, the **B**rowser-based **I**nfographic **T**ailoring **S**elf-service **I**nterface, or **BITSI**.

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1.1 Related Work

The academic literature provides some examples of custom software solutions for tailoring health-related images for a patient or lay person audience. Two of these are the Digital Exposure Report-Back Interface (DERBI) which uses decision rules to customize report-back images of environmental exposure data [9] and the Ambulatory Cancer Care Electronic Symptom Self-reporting (ACCESS) system which creates tailored visualizations of recovery progress for post-operative cancer patients [1]. However, the focus of those reports is not on the programming approach so the rest of this brief review will be of those that provided programming details.

In in the field of environmental health, a system to Measure Air quality, Annotate data streams, and Visualize real-time PM2.5 levels (MAAV), is currently used in research applications for people with asthma to provide visualizations of real-time measures of air quality [14]. MAAV is deployed to participant homes and its environmental sensors collect air quality data which are visualized in real time on an Amazon Fire tablet [14]. The visualizations are run on a kiosk browser using JavaScript and D3.js [14]. Due to the specialized equipment needed, MAAV does not appear to be easily adaptable to other applications. Also used in environmental research, Macro for Compilation of Report-backs (MCR) uses visual basic for applications (VBA) functions to compile result reports for study participants in environmental exposure studies [16]. With some back-end programming, the MCR master file can be adapted to different use cases and MCR is relatively easy for those without technical expertise to generate personalized reports [16].

In the healthcare and health promotion space, the Food4Me study used research participant dietary intake data to create images visualizing actual versus recommended intake as well as text displaying personalized nutrition recommendations [10]. The Food4Me system uses a series of decision trees stored in a relational database (MySQL) to create the personalized recommendations and visualization [10]. Thus far used in a research context, the Food4Me system has not yet been adapted to other use cases. The Electronic Social Network Assessment Program (eSNAP) creates visualizations of social networks geared to caregivers of neuro-oncology patients [18]. eSNAP is currently used in the research context with the possibility of expanding to clinical applications [17,18]. The system uses a web based application programmed with Hypertext Markup Language (HTML), Cascading Style Sheets (CSS), and Javascript [17, 18]. Customization for other use cases may be possible. While technical expertise is needed on the back end, eSNAP automatically creates visualizations for participants after they answer questions about themselves on the web based application [14, 18]. In addition to web-based applications, mobile applications can also be used to display personalized images: a team at RAND Corporation developed a mobile health application (mHealth app) for adults with asthma, which creates tailored visualizations of Asthma Control Measure (ACM) scores [13,19]. The mHealth app was developed with React Native and is integrated with the electronic health record (EHR) with application programming interfaces (APIs). It is hosted within the institution's firewall to safeguard protected health information (PHI) [20].

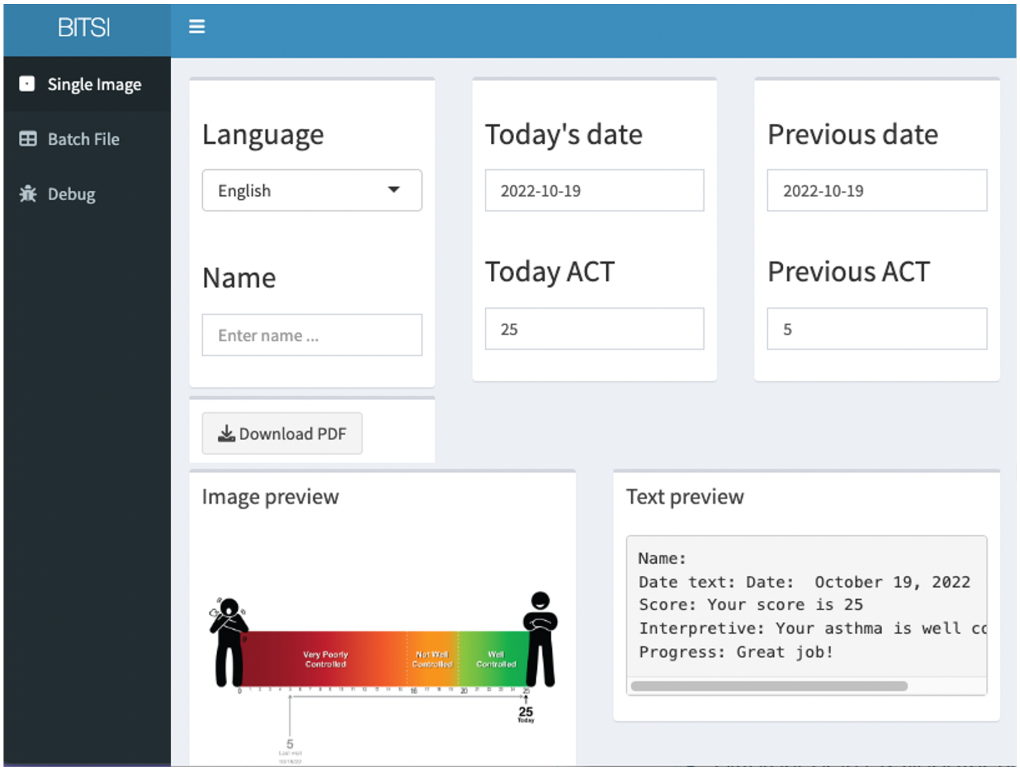

Figure 1: Screenshot of the BITSI interface for inputting data for a single patient.

1.2 Motivating Use Case

In a prior study, our team collaborated with urban adults with persistent asthma to undertake an extensive iterative participatory design and comprehension assessment process. The result was a tailorable infographic to display level of asthma control based on a short self-report measure, the Asthma Control Questionnaire (ACQ) [12]. The purpose of the infographic was to support patient-clinician communication about asthma control status and the importance of medication adherence to achieving and maintaining control. Our design process ensured that the images produced were culturally congruent, comprehensible, and aesthetically engaging for target viewers [3, 4].

The aim of the present pilot study, Personalized Infographics to Control Teen Asthma (PICTA), is to evaluate the feasibility of using the infographic to support a medication adherence intervention for adolescents with asthma, aged 12-17. For the purposes of the study, we adapted the previously-developed infographic so that it now displays the patient's total score on the Asthma Control Test (ACT) (© QualityMetric Incorporated). The ACT is a five-item, self-report measure of asthma control validated for patients 12 and older [15] that is widely used in clinical settings. Scores range from 5 to 25, with higher scores indicating better asthma control. Although scores below 5 are not possible, we included them in the infographic, as shown in **Figure A1**, because some viewers find it confusing if scales start at numbers other than 0 or 1 [6]. Currently, asthma.com offers online self-administration of the ACT (in the section "Understanding Asthma") with a simple tailored visualization of the results. This feature was not available at the time we initiated the study (January, 2020); it became available during the time our study was postponed due to the COVID-19 pandemic.

To carry out the study, we need software that automates the tailoring of our infographic with participants' total ACT scores. Planned study procedures are as follows:

1. a researcher collects baseline data from the participant, including responses to the ACT
2. the researcher uses the software interface to select a language (English or Spanish) and enter the participant's name, baseline total ACT score, and date of administration,
3. the software generates a PDF showing the baseline ACT score,
4. the PDF is downloaded and then printed (to support an in-person clinical visit) or shared on the screen (for a telehealth visit),
5. the researcher collects a follow-up ACT score from the participant one month later and again generates a PDF to share during a debrief session with the participant, this time showing both baseline and follow-up ACT scores.

1.3 Prior Work

In our prior work we developed a novel software solution, Electronic Tailored Infographics for Community Engagement, Education, and Empowerment ($EnTICE^3$) [7]. This solution was created to automate tailoring of infographics that had been developed with participatory design methods for a suite of self-reported and anthropometric measures [2, 5]. The purpose of the infographics was to return research data to study participants. $EnTICE^3$ was written using the R programming language with all of the graphical components placed using the "ggplot2" R library. The reports were created by using the R "knitr" library to generate LaTeX documents that were compiled into PDFs. Its main limitations were that the user interface required knowledge of the software stack to create the patient reports and it did not support an API.

Although $EnTICE^3$ met the needs of the original study, technical limitations of the software lessened its usefulness for the present study and prompted the development of BITSI. Variations in the fonts and drivers installed on the computers of the various research team members caused inconsistent PDF rendering during the initial rollout of $EnTICE^3$. As a solution, $EnTICE^3$ was packaged into a Linux-based virtual machine that contained all the necessary files.

Although functional, this approach was cumbersome for end users as each one had to get administrator privileges and go through an onerous installation, guided by a multi-page instruction packet. Further, to use EnTICE[3], users had to be trained to modify a syntax-based template and run it in RStudio. As with any syntax-based system, inputs had to be exact or it would fail to produce the desired output, which was frustrating for end users without a computer science background. Thus, the key improvements slated for BITSI were streamlined installation, support for an API, and a user-friendly interface.

2 METHODS

2.1 Overview

The overall process for the development of BITSI was that the principal investigator (AA) specified system requirements and provided image files, the programmer (DC) programmed an alpha version, and then together, they conducted iterative rounds of testing and revision until the system performed as required.

2.2 System Requirements and Image Files

The PI specified system requirements in two ways. One, she described the desired improvements over EnTICE[3] functionality. Chiefly, these were simplified installation and a user-friendly interface. Two, she provided a style guide for the English and Spanish asthma control infographics [7]. A style guide is a structured communication format that details all of the design specifications of an infographic according to a set of defined fields (**Figure A2**). The fields are:

(a) the variable(s) needed to generate the infographic (e.g., ACT score),
(b) the units in which numerical data will be displayed,
(c) which components of the infographic will be tailored,
(d) any criteria for interpreting tailoring data (e.g., ACT scores 20-25 are considered "well controlled"),
(e) the colors to be used in the infographic, in both words and hexadecimal format (e.g., dark red #891924),
(f) specifications for any tailored text, including font, point size, and placement, and
(g) reference images, with and without explanatory annotation.

To supplement the system requirements, the PI provided an image file (png format) of the gradient number line with endpoint anchor illustrations. This base image was treated as a graphical object (grob) and all other patient-specific elements were programmatically generated and layered on top of the grob. To circumvent any issues with fonts, the only fonts used in the infographic design were from the Arial family because of its nearly universal availability.

2.3 Software Development, Testing, and Revision

The programmer developed a software and dashboard using Shiny for R. Prior to testing, the programmer and PI installed R and RStudio in four different operating systems: Mac OS, Windows, Windows via Parallels (for Mac), and Linux. The programmer posted the project to GitHub and provided a zip file for the PI to download containing all the requisite files. The PI installed BITSI and tested it on Chrome, Firefox, and Safari, with a number of valid and invalid inputs, checking the output PDFs for adherence to the design specifications defined in the style guide. Problems were logged and relayed to the programmer, who revised the code as needed and then posted an updated zip file on GitHub for fresh installation. This process was repeated until the PDF outputs in both English and Spanish were generating according to style guide specifications (i.e., the design previously approved by patients [4]) in all testing environments. Research staff were the only end users at the pilot stage so further usability testing was not needed.

3 RESULTS

3.1 Overview

BITSI is an open-source bespoke software solution for tailoring PDFs of an asthma control infographic in either English or Spanish for research and/or clinical use. It is launched from RStudio as a Shiny app and opens in the user's default browser. BITSI uses a coordinate system to layer annotations and graphical components over a static base image and then generates the completed document(s) in PDF format.

3.2 Features

Notable features of BITSI are that when launched, it has a user-friendly point-and-click interface (**Figure 1**). To generate a single image, the user selects the target language, enters the name of the patient (including accented or special characters), the date and value of the most recent total ACT score, and if desired, the date and value of a previous ACT score. There is an image preview at the bottom left of the interface and a text preview at the bottom right so that the user can verify that data were entered correctly. Upon clicking "Download PDF," the infographic is generated and downloads to the browser's default download location. The naming convention used to facilitate matching each image file to the corresponding participant or patient is: measure-language-name-year-month-day.pdf (e.g., act-english-Simba-2022-01-13.pdf).

To generate a batch of images, the user must first prepare a spreadsheet in .xls, .xlsx or, .csv format with a column for each of the necessary variables. A template is provided in the BITSI download to facilitate proper formatting. Upon reading the spreadsheet file BITSI provides three tables in which the user can browse the data: data errors, good data, and full dataset (**Figure A3**). The data errors table lists any spreadsheet entries that contain invalid data along with the reason for the error, such as an impossible date (e.g., June 31) or a total ACT score that is out of range (i.e., less than 5 or greater than 25). When the user clicks "Generate batch files," only entries in the good data table will have a PDF generated and compressed into a zip file; those in the data errors table are suppressed. The full dataset table allows the user to browse all the entries.

3.3 Software Stack

The user-interface uses the Shiny library in R, which provides input widgets to interact with the underlying infographic generating logic. The infographics are created by layering different graphical objects (i.e., "grobs") using the "ggplot2" library. The R programming language also handles all the programming logic for generating the reactive text to ACT values in both English and Spanish. The images and text are placed in a LaTeX template that gets processed by "knitr" and compiled into a PDF using XeLaTeX. The PDF toolchain allows the reports to be consistently generated with the text and images in predictable locations without having to rely on any specific device the user interacting with the interface may be using.

Although BITSI runs in a web browser, no information leaves the machine it is installed and set up on. This can be on a laptop or server managed by a hospital. The browser interface (using Shiny) allows the installation and setup of BITSI to be decoupled from the user interacting with the web interface. This decoupling also allows BITSI to run as a standalone application or put into a container instance that can be used in other web applications by exposing a user-defined port. BITSI has recently been extended by creating application programming interface (API) endpoints to integrate with other applications and systems.

BITSI is available with detailed installation instructions and an API at https://github.com/chendaniely/bitsi. The demonstration-only version of BITSI (not for use with patient data) is available at http://bitsi.pics.

3.4 Installation

Both R and RStudio must be installed prior to BITSI installation. The user then downloads the BITSI zip file, unzips it, loads the project in RStudio, and runs two installation scripts. BITSI is now ready to use and launch using standard R Shiny methods (e.g., loading the global.R file in RStudio and clicking "Run App"). BITSI will open in a new tab in the user's default browser.

3.5 Testing

The system was developed and tested on multiple operating systems (MacOS, Windows, and Linux) and web browsers (Chrome, Firefox, and Safari). Accented characters were the main challenge that arose during testing because Shiny and R handle them differently. As such, names with accented characters passed in from Shiny in the "Name" widget or appropriate column in the batch file will render correctly as-is. However, the accented characters in the interpretive statements (e.g., "Su asma está bien controlada") had to be entered as the corresponding unicode escape sequence (e.g.,est\u00e1 instead of está) because they are handled by R.

4 Discussion

BITSI is a bespoke software solution that makes it easy for clinicians and researchers to deploy tailored asthma control infographics without the need to acquire specialized skills. Strengths include a user-friendly interface, tailoring in English and Spanish, the ability to present one or two data timepoints, single or batch file generation, and open source. The use of a coordinate system to specify placement of graphical components means that BITSI can be reprogrammed to generate other types of tailored infographics with only modest effort. Number line-based images would be among the simplest to program, extending BITSI's utility to visualizing many other PRO measures.

BITSI is similar to its predecessor, EnTICE[3], in that it uses the R programming language and the "ggplot2" library to create the main components of the infographic. A LaTeX compiler is used to create the final PDF with all the relevant images and reactive text. A key difference between them is that for BITSI, Shiny is used to wrap around all of the R code to make the point-and-click interface possible, replacing the previous syntax-based system. EnTICE[3] was written to only work as a standalone application for internal use whereas BITSI has a web interface on top of it and an API. Also added were error detection for batch data files and robustness to some missing data (e.g., patient name may be left blank).

The importance of a predictable and consistent graphical output drove decision making about the programming approach we used. PDFs were used because of how the final output can be confidently generated without relying on any idiosyncrasy of the user interfacing with the application (i.e., print to PDF would potentially render differently from machine to machine). This guided the decision to find a system that interacts well with LaTeX documents. R was selected over Python or JavaScript as the ecosystem for BITSI because of its robust document publishing (e.g., PDFs), the ability to layer image components for the infographic, and literate programming abilities to interweave code output with prose.

The development of BITSI fits into a larger trend, described in the related work section, of providing patients and research participants with infographics and reports that are tailored with their own data. Helping patients and participants not only see, but also correctly interpret their data is an important part of a learning health system [11]. For this trend to continue, bespoke software solutions will continue to be needed. BITSI was built entirely with open-source, freely available resources (e.g, Shiny, LaTeX, etc.). The availability of these resources lowered the bar to entry and allowed us to accomplish our goals within the resources of a small pilot study.

4.1 Limitations of the System and Approach

Despite offering some improvements over EnTICE[3], BITSI has its own limitations. For example, we did not program BITSI to calculate the total ACT score from individual items because our procedure workflow did not require it; this feature could easily be added. To customize BITSI for other infographics, such as number-line based measures, each new image must be specifically programmed. Identifying the actual coordinates of a new image when programming is challenging as there is currently no R program that easily does this, so a time consuming "eyeball and refine" approach must be used. Finally, in order to protect and maintain control over patient data, BITSI must still be installed locally. The multi-step process may be challenging for those unfamiliar with R and RStudio. The limitation stems from creating a universal set of instructions that can be automated across all operating systems, particularly on Windows, where the software tools are not automatically put into the system PATH and thus administrative privileges are required to make modifications. Having detailed setup instructions that do not require administrative privileges was deemed to be less complicated, more flexible, and more readily compatible with software updates.

4.2 Implications for Research and Future Directions

By providing a user-friendly interface, BITSI democratizes access to tailored infographics in English and Spanish. Once installed, BITSI is simple enough that clinicians and office staff should be able to use it at the point of care, expanding its clinical applications. Additionally, BITSI has the potential to be linked to the EHR using a SMART on FHIR (Substitutable Medical Apps, Reusable Technologies; Fast Health Interoperability Resources) application. BITSI can be used to support research studies on or using tailored infographics. Automated infographic production improves accessibility and reduces burden for research staff. BITSI is most amenable to extension in cases where the infographic is generated by annotating or layering additional graphical components onto a static base image. For infographics that have already been programmed into BITSI, including additional languages is also fairly straightforward.

Future directions for research include adding automations that make it easier to reprogram BITSI for novel infographics. The most time-consuming part of setting up an infographic within BITSI is finding the coordinates to overlay any additional patient information. There are mechanisms within the R ecosystem to help identify these coordinates faster by clicking on an image. However, individual coordinates still need to be identified for each infographic. A more user-friendly interface can be created where a user can point to parts of an uploaded image and be given a series of options for customizations. This can be used to build a more generic infographic tailoring platform.

5 Conclusion

Our development of BITSI and its motivating use case demonstrate that it is possible to create a bespoke infographic tailoring solution within the constraints of a small pilot research study using open-source resources. We improved upon previous solutions by streamlining installation and creating a user-friendly point-and-click data entry interface. Due to its web browser interface and API, BITSI can interface with other systems, such EHRs. These improvements are important because they make deployment of tailored infographics in clinical and research settings feasible and practical.

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Appendix

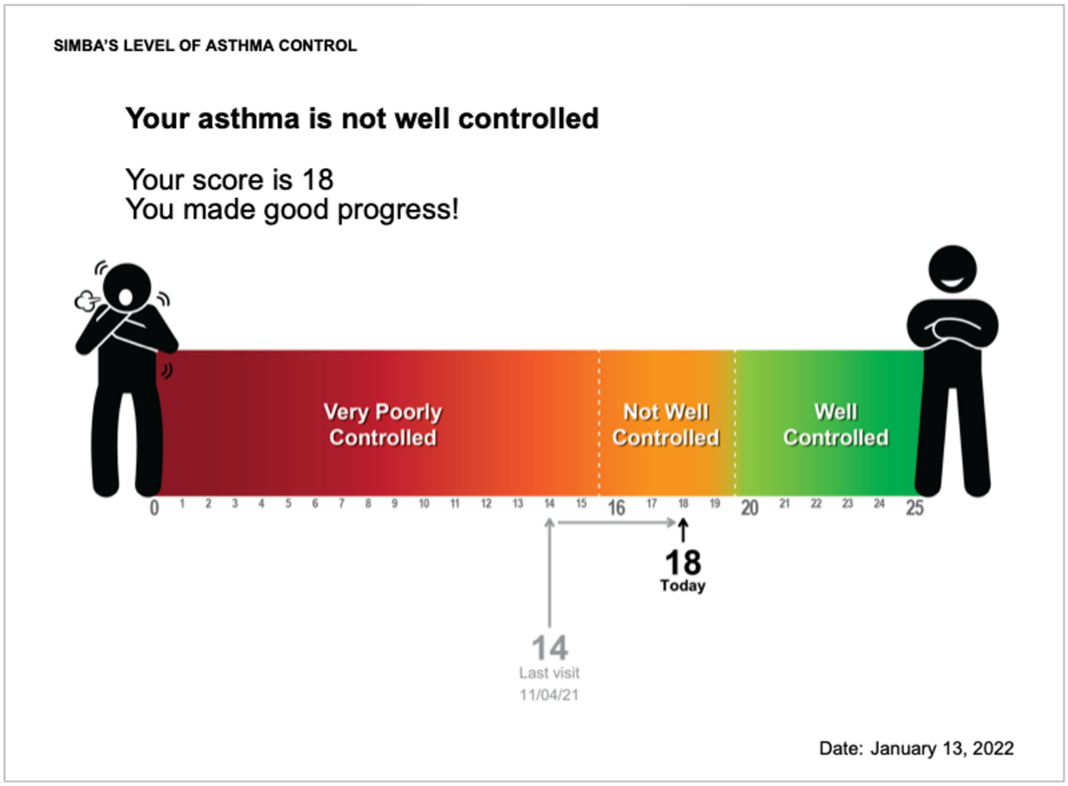


Figure A1. Sample of an infographic generated by BITSI that shows scores on the Asthma Control Test at two different time points.

Asthma Control Test Pamphlet Interior, English

Variables:	Patient name, today's ACT score and date, [previous ACT score and date]
Units:	Whole numbers
Tailoring:	Patient's name, interpretive statement, score statement, progress statement, if applicable, today's score, previous score and date if available, and today's date.
Criteria:	5-15 is 'very poorly controlled', 16-19 is 'not well controlled', 20-25 is 'well controlled'. A difference of 3 or more points is considered clinically meaningful. Although scores 0-4 are not possible, they are shown because a scale that starts at 0 is more intuitive.
Colors:	Main text color is black. If there is a previous score, the associated text and arrows are 50% gray (#939598). Numbers along the bottom of the number line are 75% gray (#636466). Text inside number line is white, with a black drop shadow. Gradient goes from dark red (#891924) at left to medium red (#BE1E2D), orange (#F15A29), yellow-orange (#F7941D), lime green (#8DC63F), to green (#00A651) at right.
Text specs:	*Title* at upper left is 12pt Arial Bold, all caps, flush with left margin (0.5"). *Date* is 14pt Arial, flush with the right (0.5") and bottom (0.5") margins.

The following text block should be centered vertically between the title and the tops of the people's heads:

Interpretive statement is 22pt Arial Bold, indented 0.75" from left margin, no punctuation at the end. Options, based on above criteria, are:

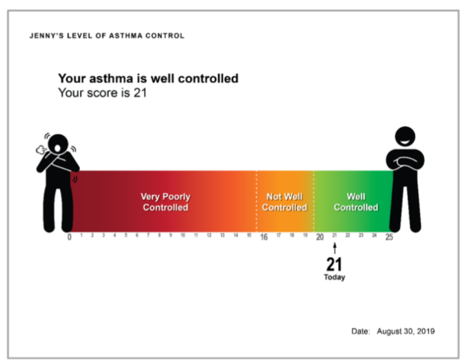
- "Your asthma is very poorly controlled"
- "Your asthma is not well controlled"
- "Your asthma is well controlled"

Score statement is 22pt Arial, flush left with interpretive statement, no punctuation. If there is only one score, it comes immediately below the interpretive statement, single spaced. If there are two scores, leave a space equivalent to one line of text between the interpretive statement and the score statement.

Progress statement (if two scores are available) is 22 pt. Arial, flush left with the statements above it, and has punctuation at the end. Options are:

- "It has gotten worse since your last visit." if today's score is 3 or more units lower than the previous score.
- "It is about the same as at your last visit." if today's score is 19 or less and the difference between scores is 2 units or less.
- Omit the progress statement if the score is 20 or higher and today's score is greater than or equal to the previous score, or no more than 2 units lower than the previous score.
- "You made good progress!" if the score is 19 or less and 3 or more units higher than the previous score.
- "Great job!" If today's score is 20 or higher and the previous score was 19 or lower.

Examples:



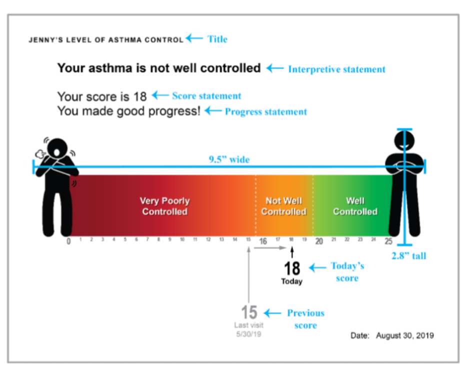


Figure A2. An excerpt from the style guide for the asthma control infographic. The design specifications are provided in defined fields (L), alongside a sample image of how the infographic should look (top, R), and a second, annotated example that that specifies placement of the various text and image components.

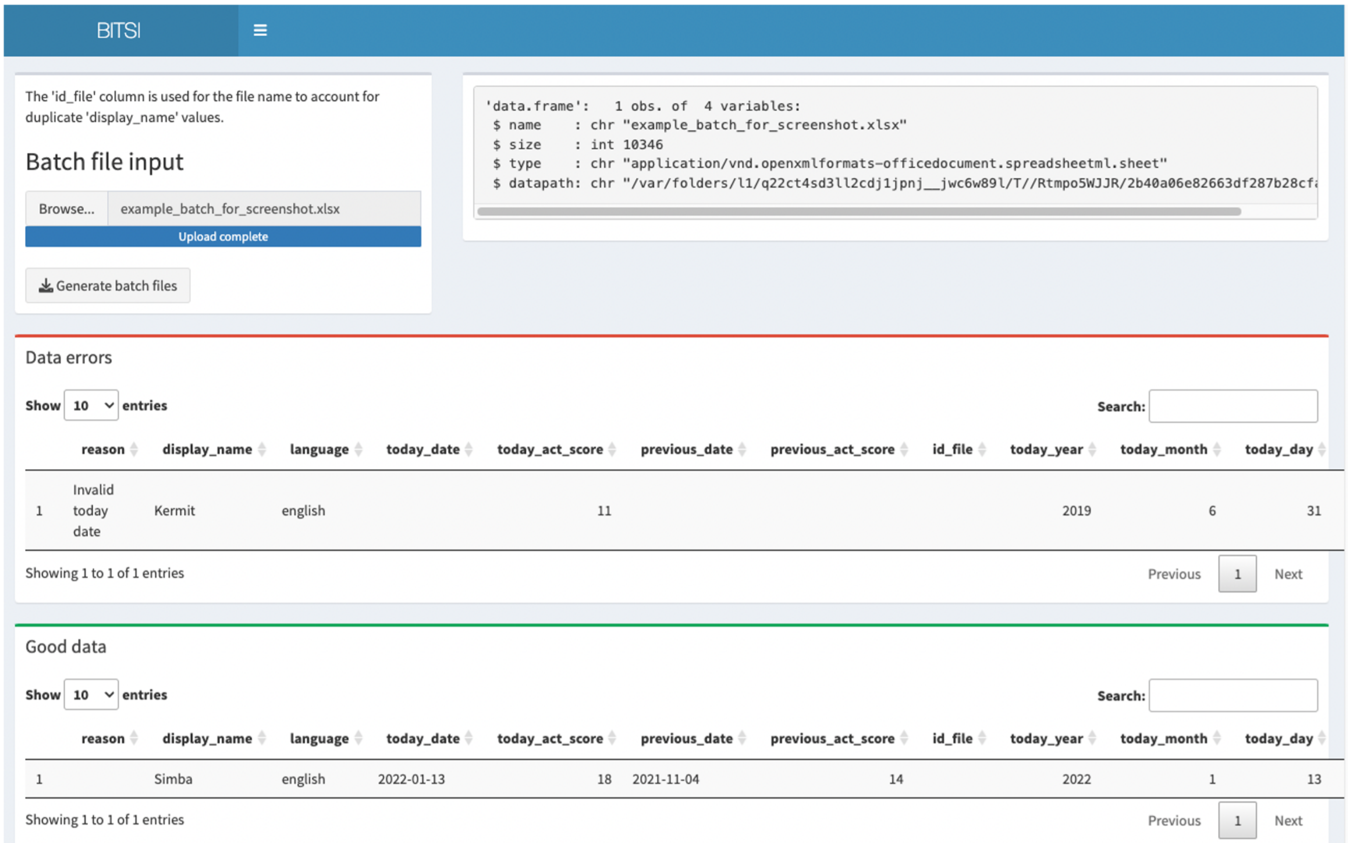


Figure A3. Screenshot of the BITSI interface for running batch files. The data errors section is a list of entries that contain invalid data (e.g., invalid date of June 31st); PDF files will not be generated for these entries. A zip file of PDFs will be generated for entries shown in the good data table at the bottom of the screen. Below that (not shown), is a third table for browsing the full dataset.

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