What Makes COVID-19 Dashboards Actionable? Descriptive Assessment and Expert Appraisal of 158 Public, Web-Based COVID-19 Dashboards

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Abstract

Background: Since the outbreak of COVID-19, activity has surged worldwide to develop dashboards as dynamic, visual tools for communicating COVID-19 data. Dashboards can inform decision-making and support behavior change. To do so, they must be actionable. What constitutes an actionable dashboard in the context of the pandemic has not been rigorously assessed.

Objective: To explore the characteristics of public, web-based COVID-19 dashboards by assessing (i) why (purpose and users), (ii) what (content and data), and (iii) how (analysis and display) they communicate COVID-19 data, and ultimately, appraising (iv) the common features of highly actionable dashboards.

Methods: We conducted a descriptive assessment and scoring using Nominal Group Technique with an international panel of experts (n=17) on a global sample of COVID-19 dashboards in July 2020. The sequence of steps included: multimethod sampling of dashboards; development and piloting of an assessment tool; data extraction and first round of actionability scoring; workshop based on a preliminary analysis of results; and reconsideration of actionability scores followed by joint determination of common features of highly actionable dashboards. We used descriptive statistics and thematic analysis to explore findings by research question.

Results: A total of 158 dashboards from 53 countries were assessed. Dashboards were predominately developed by government

authorities (100/158, 63.0%) and were national (93/158, 58.9%) in scope. Main findings by the study's objectives include: (i) Only 20 dashboards (12.7%) stated both the primary purpose and intended audience. (ii) Nearly all dashboards reported epidemiological indicators (155/158, 98.1%), followed by health system management indicators (85/158, 53.8%), whereas indicators on social and economic impact and behavioral insights were least reported (7/158, 4.4% and 2/158, 1.3%, respectively). Approximately one quarter (39/158, 24.7%) did not report data sources. (iii) Dashboards predominately reported time trends and disaggregated data most often by two geographic levels and by age and sex. Dashboards on average used 2.2 types of displays, mostly graphs and maps followed by tables. To support interpretation, color-coding was common (93/158, 89.4%), though only a fifth (31/158, 19.6%) included text explaining data quality and its meaning. (iv) In total, 20 dashboards (12.7%) were appraised as highly actionable, and seven common features were identified between them. Actionable COVID-19 dashboards: (1) know their audience and information needs; (2) manage the type, volume and flow of displayed information; (3) report data sources and methods clearly; (4) link time trends to policy decisions; (5) provide data 'close to home'; (6) breakdown the population into relevant sub-groups; and (7) use story-telling and visual cues.

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Multimedia Appendices

Multimedia Appendix 1: Dashboard Sampling Survey.
Multimedia Appendix 2: Assessment Tool.
Multimedia Appendix 3: Public, Web-Based COVID-19 Dashboards Assessed.
Multimedia Appendix 4: Illustrative Indicator Titles by Themes.
Multimedia Appendix 5: Summary of Dashboard Scoring.

Abstract

Background: Since the outbreak of COVID-19, activity has surged worldwide to develop dashboards as dynamic, visual tools for communicating COVID-19 data. Dashboards can inform decision-making and support behavior change. To do so, they must be actionable. What constitutes an actionable dashboard in the context of the pandemic has not been rigorously assessed.

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Results: A total of 158 dashboards from 53 countries were assessed. Dashboards were predominately developed by government authorities (100/158, 63.0%) and were national (93/158, 58.9%) in scope. Main findings by the study's objectives include: (i) Only 20 dashboards (12.7%) stated both the primary purpose and intended audience. (ii) Nearly all dashboards reported epidemiological indicators (155/158, 98.1%), followed by health system management indicators (85/158, 53.8%), whereas indicators on social and economic impact and behavioral insights were least reported (7/158, 4.4% and 2/158, 1.3%, respectively). Approximately one quarter (39/158, 24.7%) did not report data sources. (iii) Dashboards predominately reported time trends and disaggregated data most often by two geographic levels and by age and sex. Dashboards on average used 2.2 types of displays, mostly graphs and maps followed by tables. To support interpretation, color-coding was common (93/158, 89.4%), though only a fifth (31/158, 19.6%) included text explaining data quality and its meaning. (iv) In total, 20 dashboards (12.7%) were appraised as highly actionable, and seven common features were identified between them. Actionable COVID-19 dashboards: (1) know their audience and information needs; (2) manage the type, volume and flow of displayed information; (3) report data sources and methods clearly; (4) link time trends to policy decisions; (5) provide data 'close to home'; (6) breakdown the population into relevant sub-groups; and (7) use story-telling and visual cues.

Conclusions: COVID-19 dashboards are diverse in why, what and how they communicate insights on the pandemic and support data-driven decision-making. In order to leverage their full potential, dashboard developers should consider adopting the seven actionability features identified.

Keywords
COVID-19; Pandemics; Internet; Performance Measures; Public Reporting of Healthcare Data; Public Health Surveillance; Health Information Management

INTRODUCTION

Since the outbreak of COVID-19, public reporting of pandemic-related indicators such as new cases, death counts and testing rates, has surged. This heightened level of activity attests to the core function of governments to protect the public's health and safety, as well as the critical role of providing information to do so [1-4]. The uses and advantages of publicly reporting health information are known. These include: allowing for international comparisons [5,6]; monitoring and improving the quality of care [1,6,7]; fostering accountability and transparency [8-10]; empowering the public to form an opinion on and build trust in their government's response; and, supporting individuals to make informed, risk-minimizing behavior changes [11,12].

Dashboards are a dynamic modality for reporting data visually, typically designed as a single screen with the aim to quickly and effectively present users with critical information to act upon [13-15]. Unlike static reporting modalities, such as articles or reports, dashboards have the potential to present real-time (or near to) data updates, at-a-glance [15]. In the health sector, dashboards have been relied on for health system performance assessments [15,16], internal management [17,18], and earlier outbreak responses [19,20].

In 2020, the worldwide urgency for COVID-19 data, coupled with the penetration of the internet [21], digitalization of health information systems [22,23], and access to online, open-source software [24], has enabled unmatched speed, scale and diversification of actors in the development of dashboards to monitor and report on the COVID-19 pandemic. As a result, public, web-based dashboards have been widely adopted as the reporting modality for COVID-19 data. Examples extend well-beyond national, regional and local governments to include dashboards by international organizations (e.g. World Health Organization (WHO) [25]), academia (e.g. John Hopkins Centre Coronavirus Resource Center [26,27]), and industry (e.g. Deloitte [28]), as well as independent initiatives (e.g. nCoV2019.live [29]).

While COVID-19 dashboards may be widely accessible, their effective *use* to modify the course of the pandemic through data-driven decision-making is determined by their actionability. To be actionable, the information should be both *fit for purpose* – meeting a specific information need – and *fit for use* – getting the right information into the right hands at the right time and in a manner that is understood [30-32]. It other words, the mere accessibility of COVID-19 dashboards does not guarantee data-informed decision-making [12,33]. While communication sciences, health promotion and the emerging field of health care performance intelligence offer insights into the effective delivery of information [14,33-36], what makes dashboards actionable in the context of COVID-19 has yet to be rigorously assessed.

In this study we set out to explore the state-of-the-art of publicly available, web-based COVID-19 dashboards and identify the features conducive to their actionability. To do so, we took a snapshot of this dynamic landscape and assessed COVID-19 dashboards in July 2020. The resulting overview of the dashboard landscape serves both for taking-stock of their use in this initial period and to accelerate progress in the phases still to come. With these aims, the study was guided by four key questions: (i) Why and for whom have COVID-19 dashboards been developed? (ii) What information do they provide? (iii) How is this information analyzed and presented? And (iv) what are the common features of highly actionable dashboards?

METHODS

Study Design

We conducted an observational descriptive assessment and scoring using Nominal Group Technique (NGT) [37,38] on a global sample of COVID-19 dashboards. The review of each dashboard was conducted using a study-specific assessment tool that was piloted and validated among a panel of scorers (n=17) prior to its use [37,38]. NGT was chosen over other consensus methods (e.g. Delphi) in order for scorers to independently appraise a subset of dashboards using the assessment tool and collectively discuss what makes them actionable through a series of workshops [38,39]. All workshops were conducted virtually rather than face-to-face in accordance with pandemic-related public health measures.

Panel of Scorers
A panel of scorers was assembled through an existing international network of health care performance intelligence researchers [40]. Scorers had common expertise and training in health care performance data and its use for management and governance. Collectively, the scorers (8 females, 9 males) ranged 15 nationalities and were proficient in more than 20 languages (Bosnian, Catalan, Chinese, Croatian, Danish, Dutch, English, French, German, Indonesian, Italian, Kazakh, Malay, Montenegrin, Norwegian, Portuguese, Romanian, Russian, Serbian, Slovenian, Spanish, Swedish, Turkish). This allowed for dashboards to be assessed in their original languages, rather than a translation, avoiding the use of translation software and its limitations when used with data visualizations.

Inclusion and Exclusion Criteria
We defined COVID-19 dashboards based on the following criteria: (i) reporting of key performance indicators related to the COVID-19 pandemic; (ii) the use of some form of data visualization; (iii) dynamic reporting, meaning data is updated regularly; and (iv) publicly available in an online, web-based format. No restrictions were placed on a dashboard's primary level (e.g. international, national, regional, local) or the type of organization responsible for its development (e.g. international, governmental, academia, news or media, industry, private initiative). We excluded dashboards available only via mobile applications (e.g. Telegram) or requiring users to log-in (e.g. Facebook). Dashboards beyond the language competencies of the panel of scorers were also excluded.

Step One: Dashboard Sampling

Our search strategy for dashboards aimed to be thorough but not exhaustive. This was in line with our aim of exploring the state-of-the-art in public, web-based COVID-19 dashboards. An initial list of dashboards was collected through sampling conducted 19 May–30 June 2020. Three methods were applied: (i) surveying the authors; (ii) surveying other international networks of public health, health services and system researchers and practitioners (Young Forum Gastein, European Public Health Association, European Network of Medical Residents in Public Health); and (iii) a snowballing of sources identified through (i) and (ii). The sampling survey was developed using a Google Forms data collection tool and disseminated by email (Multimedia Appendix 1).

The consolidated list of dashboards was screened by one team member with the aim to: confirm the inclusion criteria were met; exclude duplicates; and, assess each dashboard's available languages against the panel's competencies. Dashboards were labeled as red (exclude), green (include) and yellow (for second opinion). A second team member assessed dashboards labeled yellow, from which a final joint decision on inclusion or exclusion was made.

Step Two: Developing an Assessment Tool

An assessment tool was developed, drawing primarily on two existing theoretical models. From communication sciences, we applied Lasswell's Model (1948) stating that for mass communication processes to be understood, each element of "who (says) what (to) whom (in) which channel (with) what effect" has to

be presented and understood [41]. These five elements – the communicator, message, medium, audience, and effect – informed the basis of the assessment tool's considerations. We tailored these considerations to the communication of COVID-19 data by drawing on the emerging discipline of performance intelligence in health [36,42]. Specifically, we incorporated key considerations from a definition of actionability and its notions of fitness for purpose and use [43]. The resulting considerations are in line with existing health information instruments (e.g. [44,45]), though tailored to the aims of the study.

These considerations were clustered to depict COVID-19 dashboards by their general characteristics and a description of why, what, and how data is communicated, followed by an appraisal of their overall actionability (Table 1). Actionability scores were defined on a Likert scale from "not actionable" (score=1) to "extremely actionable" (score=5) and assigned based on the scorer's judgement of the considerations assessed and their expert opinion of the dashboard's fitness for purpose and use. Scores were to be accompanied by a written statement explaining the rationale behind the response. In line with the study's aim to consolidate key features of highly actionable dashboards, the scoring was merely a means to this end: the panel's individual appraisal of actionability facilitated the clustering of dashboards as low (score=1 and 2) and highly (score=4 and 5) actionable for further collective deliberation on their common features.

An Excel-based tool was developed to record findings. Each consideration of the assessment tool was formulated as a question with defined answer options. The tool included the underlying theory for the considerations by referring back to the concepts applied and available evidence [1,2,5,16,30,31,33,46-56] (Multimedia Appendix 2) to remind the panel on the significance of each and aid the assessment and scoring process.

Table 1. Overview of the assessment tool.

Clusters	Considerations
General characteristics	Level (scale) of focus
	Responsible organization and type
	Language(s) available
	Scope of webpage information
Why	Purpose of use of the dashboard
	Intended audience (user)
What	Indicator titles
	Data sources
	Availability of metadata
	Frequency of data updates
How	Use of time trend for analysis
	Geographic level (scale) of analysis
	Types of possible breakdowns
	Use of visualizations
	Degree of interactiveness
	Use of simplicity techniques
Actionability score	Overall appraisal of actionability

Step Three: Piloting and Calibrating

A prototype of the assessment tool was piloted by two authors on five dashboards. The extracted data was reviewed jointly with two other team members. This resulted in refinements to the phrasing of questions and answer options. A second iteration of the assessment tool was then piloted with the panel of scorers on a sample of 18 dashboards representing a range of contexts, levels and organization types. Each dashboard was independently reviewed by two scorers. Prior to piloting, a virtual training session with the panel of scorers was organized, recorded, and disseminated to serve as a resource. Each scorer was given six days (17–22 June 2020) to review their assigned two pilot dashboards.

Pilot data were reviewed to assess the consistency of responses (i.e. scorers of the same dashboard recorded equivalent answers) and meaningfulness of the answers (i.e. the answer categories meaningfully differentiated between dashboards). Where possible, the tool's open-ended answer options were further specified into categorical values based on recurrent themes in the pilot dataset. Definitions were added for key terms based on comments of scorers. The reviewed pilots and tool amendments were returned to the panel of scorers and a follow-up meeting was organized to discuss.

Step Four: Data Extraction and Round One Scoring

Each scorer was assigned between 5–12 dashboards to assess. The dashboards were distributed with first order priority given to the language competencies of each scorer. To synchronize the assessment, scorers were given a two-week period to complete data extraction. The assessment was limited to a dashboard's main page and a 'one-click-away policy' was applied: content accessible within one click was also assessed. In order to store a record of the dashboard on the date reviewed, the main page of each dashboard was archived, generating a permanent and publicly available record of their contents [57].

Step Five: Preliminary Analysis and First Consensus Workshop

The data records from each scorer were consolidated by the lead authors into a master dataset for analysis and subsequently underwent a series of data quality checks to detect data entry errors, inconsistences or missed fields. In all instances where errors were detected, corrections were suggested, discussed jointly, and, once agreed upon, changes were entered into the master dataset.

The findings were totaled and averaged by research question. Free text fields and comments were analyzed in a deductive and inductive approach: topics explored in the tool (Multimedia Appendix 2) were used to guide the deductive thematic analysis [58] and new themes that emerged were identified using an inductive approach [59]. This included an analysis of indicator titles using an existing classification of types of pandemic-related information [3]. Due to the observed variability in phrasing of indicator titles and calculations, key performance indicators were grouped by themes.

A workshop with the panel of scorers was organized to discuss the preliminary results and distribution of actionability scores. During the workshop, panelists individually shared the rationale for their scoring of low (score=1 and 2) and highly (score=4 and 5) actionable dashboards. The common features of dashboards scored as highly actionable were discussed to further calibrate the panel's scoring of actionability. From this, a working list of actionability features was consolidated.

Step Six: Round Two Scoring and Second Consensus Workshop

All panelists were returned their original data records and given one week to revisit their initial actionability scoring, drawing on the workshop's discussion. Panelists were given the possibility to increase, lower or leave each score the same. Following rescoring, the distribution of scores were recalculated. The data records for the top dashboards (score=5) following this second round were consolidated and provided to the panel, together with the working set of actionability features. A second consensus workshop was convened and, in a similar way as the previous, a roundtable was conducted for each scorer to share their views. This was followed by a joint discussion to reach agreement on the common features of highly actionable dashboards.

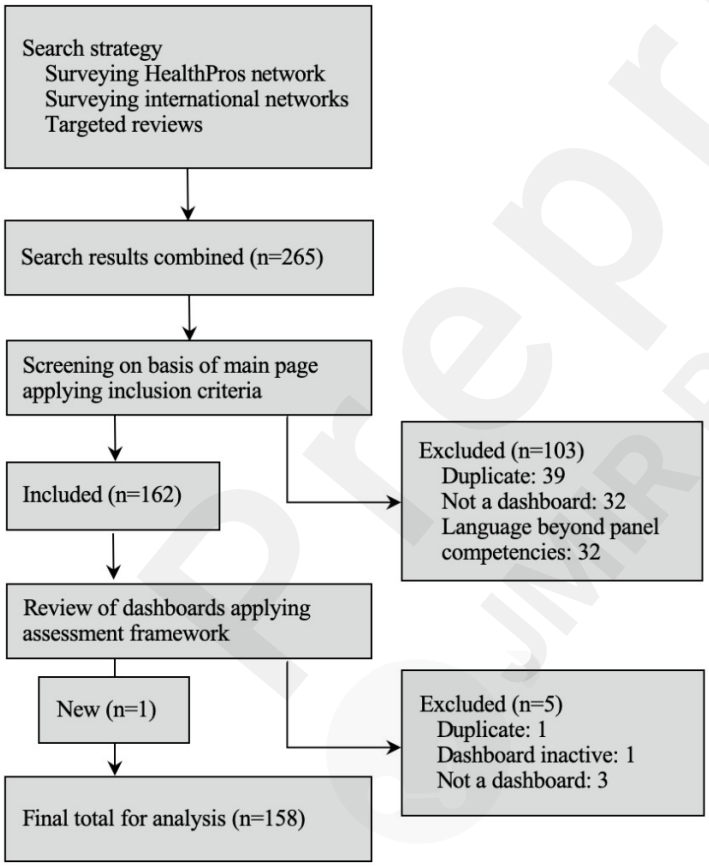
RESULTS

Identified Dashboards

Our multimethod search strategy initially identified 265 COVID-19 dashboards. More than 40 respondents contributed to the sampling survey, including all members of the study team and international public health experts. Following screening of each dashboard's main page, 103 were excluded. The remaining 162 dashboards were distributed among the panel of scorers for full review. During the assessment process, five additional dashboards were excluded and one new dashboard was included. A final total of 158 dashboards were included for further analysis (Figure 1).

Data extraction and the first round of scoring were conducted in a 2.5 week-period between 6–23 July 2020. The data extract and archived version of each dashboard was referred to throughout the study. Any updates following this date were, therefore, not accounted for. Dashboards were assessed in 22 different languages, predominately in English (n=85), followed by Russian (n=11), Spanish (n=9), French (n=9) and Chinese (n=6). A full listing of the dashboards assessed is available in Multimedia Appendix 3.

Figure 1. Flow diagram of COVID-19 dashboard sampling.



General Description of COVID-19 Dashboards Assessed

Table 2 summarizes key characteristics of the 158 dashboards assessed. Our sample included dashboards reporting on 53 countries in all 6 WHO regions [60]. On the date of the review, the severity of the pandemic with regards to total cases and deaths varied widely between location as reported in Multimedia Appendix 3.

More than half of the dashboards (93/158, 58.9%) were developed for use at the national level. Nearly two-thirds of the dashboards (100/158, 63.3%) were developed by government authorities, be it national-,

regional- or municipal-level. New initiatives or organizations formed in response to COVID-19 accounted for 10.1% (16/158) of the dashboards assessed [29,61-75].

With regards to language, only one fifth of the dashboards were available in more than one language with full functionality (32/158, 20.3%). In terms of their scope of information, gauged according to the content of a dashboard as well as information re-directed to through affiliate links, dashboards were nearly always epidemiological in focus (156/158, 98.7%), followed by providing information on infection control measures and health system management (65/158, 41.1% and 49/158, 31.0%, respectively).

Table 2. Characteristics of COVID-19 dashboards assessed.

Characteristics	Total (n)	Percent (%)
Dashboards	158	100.0
Range of countries	53	Not applicable
Region[a]		
Global	20	12.7
Europe and Central Asia	63	39.9
North and South America	45	28.5
Western Pacific	22	13.9
South-East Asia	4	2.5
Africa	3	1.9
Eastern Mediterranean	1	0.6
Level		
International	25	15.8
National	93	58.9
Regional (provincial, state, county)	33	20.9
Municipal (city, district)	7	4.4
Type of organization		
International organization	7	4.4
Governmental	100	63.3
Academia	9	5.7
News or media outlet	14	8.9
Industry	9	5.7
Independent initiative	16	10.1
Other	3	1.9
Languages available with full functionality[b]		
One language	126	79.7
Two languages	22	13.9
Three or more languages	10	6.3
Additional languages available with reduced functionality[c]		
One or more language	16	10.1
Scope of information[d]		
Epidemiological information	156	98.7
Infection control measures	65	41.1
Health system management	49	31.0
Social and economic implications	31	19.6
Population behavioral insights	25	15.8
Other	28	17.7

[a]Country status and region according to WHO classification [60].

[b]Full functionality means the webpage is equivalent in the different languages.

[c]Reduced functionality means the webpage is available in additional languages but with less information and functionalities compared to the main language(s).

[d]According to WHO classification [3].

Uses and Users of COVID-19 Dashboards

A quarter of dashboards (45/158, 28.5%) explicitly stated the intended purpose of their reporting. Of these 45 dashboards, the statements spanned three main themes: (i) high-level reporting to create trust and aid overall compliance (25/45, 55.6%); (ii) sub-national reporting targeting policy interventions including benchmarking (12/45, 26.7%); and (iii) individual-risk assessment (8/45, 17.8%).

Only 14.6% (23/158) of dashboards explicitly stated the intended audience (end-users). Target users predominately included the general public (20/23, 86.9%) and, in few instances included more specific audiences such as travelers or subject matter experts (6/23, 26.1%). When looked at by the level of reporting, national-level dashboards were less likely to explicitly state the intended audience (9/93, 9.7%), while international and municipal-level dashboards were more likely to do so (7/25, 28.0% and 2/7, 28.6%, respectively).

Of the 158 dashboards assessed, 20 (12.7%) reported both the purpose and intended user explicitly. The profile of these dashboards, in terms of their level of reporting and the type of organisation that developed it, did not differ from the characteristics of the general sample.

Content and Data of COVID-19 Dashboards

Key Performance Indicators

Table 3 summarizes the frequency of indicator themes reported by the dashboards. See Multimedia Appendix 4 for illustrative examples of indicator titles. On average, dashboards reported on 5.3 indicator themes (max=15, min=1). Almost all dashboards reported public health and epidemiological indicators (155/158, 98.1%), particularly those on cases and deaths. These account for the only high-frequency indicator themes (indicators present in more than two-thirds of assessed dashboards). Medium-frequency indicator themes (themes reported in more than a third but less than two-thirds of dashboards), were related to hospital care (hospitalizations, admissions to infection control units), testing (total tests, testing rates), and spread and death (recovered, active cases).

Only 4% of dashboards (7/158) reported indicators related to social and economic impacts. Indicator themes included employment and hardship relief (e.g. [28,76]) and transport, trade and international travel (e.g. [28,76]). Indicators on behavioral insights were also infrequently reported (8/158, 5.1%). Indicator themes included two main types: self-reported adherence related to restrictions (e.g. [77,78]) or health and well-being status (e.g. [76]); and observed public adherence to restrictions assessed through mobility data or reported breaches of restrictions (e.g. [61,79]).

Some use of composite scores to signal overall risk levels or the current status by sector (e.g. health, economy) was identified, though infrequently used (e.g. [28,62,80]).

Table 3. Frequency of indicator themes reported by 158 dashboards assessed.

Low (≤33%) Medium (≥34%≤ 66%) High (≥67%)

Information type	Cluster	Indicator themes	Total (n)	Percent (%)
Public health and epidemiological	Spread and death	Cases (all confirmed cases)	150	95
		Deaths	136	86
		Recovered (healed, cured)	91	58
		Active cases	56	35
		Mortality rate (case fatality rate)	24	15
		Reproduction rates (attack rate)	12	8
		Future projections/risk models	5	3
		Doubling rate	3	2
	Testing	Testing (total number tested, PCR[a] tests)	80	51
		Testing rates (positivity, negative tests)	43	51
		Tests-pending results	17	11
		COVID-19 antibody tests (serology tests)	1	1
	Risk management	Self-quarantine (isolation notices)	18	11
		Contact tracing	6	4
Health system management	Hospital care	Hospitalized (admissions, discharges)	74	47
		Admitted to ICU[b] (critical condition)	47	30
		On a ventilator	14	9
	Health system capacity	Hospital bed capacity (availability)	12	8
		ICU bed capacity	10	6
		Ventilator capacity (available ventilators)	5	3
		Non-COVID-19 service usage	4	3
		Personal protective equipment stock	2	1
		Testing stock	2	1
Social and economic impact		Employment and hardship relief	7	4
		Transport, trade and international travel	3	2
Behavioural insights		Observed public adherence to restrictions	4	3
		Self-reported adherence to restrictions	2	1
		Self-reported health and well-being status	2	1

[a]PCR: polymerase chain reaction.
[b]ICU: intensive care units.

Data Sources and Metadata

A quarter of dashboards did not explicitly report the source of data (39/158, 24.7%). National, regional and municipal-level government-run dashboards predominately reported to use data sourced from official public health authorities. International dashboards predominately reported to use data sourced from WHO [25] or Johns Hopkins Centre for Systems Science and Engineering [26].

Less than half of the dashboards (63/158, 39.9%) specified metadata (data dictionaries, indicator specifications) in the format of notes, footnotes or linked additional webpages to provide further information on the methodology of an indicator's calculation. Thirty-nine dashboards (24.7%) did not report sources of data nor metadata details. The majority of dashboards updated data daily and stated explicitly the frequency and time of the last update.

Types of Analysis and Presentation of Data on COVID-19 Dashboards

Table 4 summarizes the types of analysis and presentation of data. Dashboards predominately reported indicators over time (138/158, 87.4%) and of these breakdowns were most often 'by day' (128/138, 92.8%). Forty percent of the dashboards reported data on two geographic levels (e.g. national and regional or regional and municipal). In the case of national-level dashboards (n=93), geographic breakdowns predominately

included regional comparisons (73/93, 78.5%), with some municipal-level (28/93, 30.1%) and international-level (25/93, 26.9%) comparisons. In only a few instances were breakdowns by neighborhood (post code-level) (4/93, 4.3%) reported.

In addition to geographic breakdowns, more than half of the dashboards (96/158, 60.8) analyzed data by other breakdowns: on average three types of breakdowns were included. of these 96 dashboards, the most common breakdowns included by age (79/96, 82.3%), sex (71/96, 74.0%), and mode of transmission (26/96, 27.1%). Other breakdowns, though less frequently reported, included race, ethnicity, long-term care facilities, healthcare workers, comorbidities and socio-economic status.

As per our inclusion criteria, all dashboards used some form of visualization. On average, two types of visualizations were included per dashboard. These included graphs or charts (134/158, 84.8%), maps (111/158, 70.3%) and tables (95/158, 60.1%). Almost half of the dashboards (76/158, 48.1%) did not include written descriptions to clarify either the quality of the data or its meaning, while 31 dashboards (19.6%) provided both.

More than half of the dashboards (104/158, 65.8%) used some technique to simplify data. Of these 104 dashboards, color-coding was most often used (93/104, 89.4%), followed by size variation (40/104, 38.5%). The majority of dashboards (126/158, 79.7%) included some element of user interaction. This was mostly the possibility to present more information (e.g. pop-up windows), change the information (e.g. different breakdowns) or change the display (e.g. switch from table to map).

Table 4. Summary of analysis and presentation of dashboard information.

Considerations	Total (n)	Percent (%)
Time trend analysis availability	**158**	100.0
Time trend analysis available	138	87.3
No time trend analysis	20	12.7
Use of time trend analysis	**138**[a]	–[b]
By day	128	92.8
By week	33	23.9
By month	19	13.8
Geographic levels (scales) of analysis	**158**	–[b]
International (multi-country)	54	34.2
National	118	74.7
Regional	117	74.1
Municipal	54	34.2
Neighborhood	13	8.2
Other	5	3.2
Number of levels (scales) of analysis per dashboard	**158**	100.0
1 level	34	21.5
2 levels	65	41.1
3 and more levels	59	37.3
Disaggregation availability per dashboard	**158**	100.0
1 or 2 types of disaggregation	48	30.4
3 or 4 types of disaggregation	42	26.6
5 or more types of disaggregation	6	3.8
No disaggregation options	62	39.2
Disaggregation options	**96**[a]	–[b]
Age	79	82.3
Sex	71	74.0
Mode of transmission	26	27.1
Long-term care facilities	16	16.7
Ethnicity	12	12.5
Race	10	10.4
Health workers	9	9.4
Comorbidities	9	9.4
Socio-economic status	2	2.1
Other	23	24.0
Visualization features	**158**	–[b]
Graphs/charts	134	84.8
Maps	111	70.3
Tables	95	60.1
Video/animations	10	6.3
Use of narratives to interpret data	**158**	100.0
Yes, to clarify the quality of the data only	28	17.7
Yes, to clarify the meaning of the data only	23	14.6
Yes, to clarify both the quality and the meaning	31	19.6
None	76	48.1
Simplification techniques used	**104**[a]	–[b]
Use of color-coding	93	89.4
Size variation	40	38.5
Icons	6	5.8
Interactive options	**126**[a]	–[b]
More information	115	91.3
Change of information	61	48.4
Change of display	44	34.9

[a]Subset of applicable dashboards (i.e. 138 dashboards that *do* use time trends).

[b]Percentages for these considerations do not total to 100% as multiple considerations could be present per dashboard.

Features of Actionable Dashboards

In the first round of scoring, 21 of the 158 dashboards assessed (13.3%) were scored with the highest actionability score (score=5) and 18 dashboards (11.4%) with the lowest score (score=1) for a mean score of 3.01. The second round resulted in a final total of 20 dashboards scored most actionable. A quarter of dashboards (40/158, 25.3%) were scored differently: 24 lower, and 16 higher. All 17 panelists completed both rounds of scoring. Details on the distribution of scoring by panelist and between rounds are summarized in Multimedia Appendix 5.

The panel workshop following the first round of scoring resulted in a total of 18 features that characterize highly actionable dashboards. After rescoring, these features were further discussed among the panel to consolidate the list in terms of their description and importance as well as its consistency and completeness as a set. A final total of seven key features common to highly actionable dashboards were agreed upon (Table 5). There was consensus among the panelists that some dashboards excelled on certain features over others. These dashboards are noted as illustrative examples.

Table 5. Seven features of highly actionable COVID-19 dashboards.

#	Feature	Explanation	Examples
1	**Know the audience and their information needs**	Dashboards with a known audience and explicit aim had focus and continuity in their content, analysis and delivery. Techniques such as guiding key questions or overall composite scores communicated clearly the decision they intended to support. Multi-language functionality and exact timing of updating signaled an awareness and intent to encourage their regular use by the intended decision-maker.	#HowsMyFlattening [61], Covid Act Now [62], California, USA [80].
2	**Manage the type, volume and flow of information**	The selection of a concise number of indicators brought focus and importance to the information and the possibility to view indicators together, at-a-glance. The use of indicators in moderation, yet still spanning varied types of information, was especially effective. The ordering of information, from general to specific or in sections based on theme, made the flow of information intuitive.	Covid Act Now [62] reports on five key indicators. Deloitte [28], Vancouver, Canada [79] include a range in types of information.
3	**Make data sources and methods clear**	A clear source of data and explanation of an indicator's construction, including potential limitations, was found an important component of trust in the dashboard and clarity in its reporting. This information can be provided in short narratives that support users to understand what is in fact being presented.	Denmark [81], France [77], Spain [82] and media pages CBC [83] and New York Times [84] are attentive to narrate the calculation of indicators.
4	**Link time trends to policy (decisions)**	Reporting data over time together with the introduction of key infection control measures facilitated an understanding of their effect (or lack of). This was found conducive to generating public support for infection control measures.	ABC News [85], Sledilnik [63], embed policy measures over time. Toronto, Canada [86] reports city targets.
5	**Provide data 'close to home'**	To inform individuals of risks in their immediate surroundings, granular geographic breakdowns are needed. Data that is highly aggregated was difficult to understand. Maps (over tables and charts) were most effective for geographic information.	United Kingdom [87] offers post code-level breakdowns. Germany [88] – city and borough-level in Berlin.
6	**Breakdown the population to relevant sub-groups**	Providing data with the possibility to explore varied population characteristics made indicators relatable to individual users. It allows an understanding of risks and trends based on one's own demographics. It also can facilitate equity-driven decision-making by exposing differences among the population.	Ethnicity and race breakdowns in New Zealand [76], various USA dashboards [80,89-93]. #HowsMyFlattening [61] on economic status.
7	**Use story-telling and visual cues**	A concise narrative explaining the significance of a trend supports users to understand the importance of the information. Bare statistics without a narrated analysis leave the burden of interpretation solely to the user. Brief explanations on the meaning of trends used in combination with visual techniques, such as intuitive color schemes and icons, supported ease of interpretation.	Covid Act Now [62] narrates the significance of trends. Colorado, USA [89] uses colored icons to signal the direction of trends.

DISCUSSION

Principal Findings

With this study, we set out to assess the state-of-the-art of public, web-based COVID-19 dashboards globally during the initial stage of the pandemic (July 2020) and identify features common to those found highly actionable. We assessed 158 dashboards, each operating in a different context. Their differences aside, the dashboards analyzed in this study ultimately share a common aim: to serve as both a communication tool and call for individual and collective action to respond to the COVID-19 pandemic. Despite their contextual differences (or because of these), our results indicate that some dashboards fulfill their function of communicating, informing decision-making and supporting behavior change better than others. And, while it is also clear there is no single approach to developing a dashboard, our results suggest that introducing certain features may enhance a dashboard's actionability.

Knowing the audience and their information needs was identified as a key actionability feature, which corresponds with Lasswell's model for effective communication [1,41,43]. Nevertheless, the clear reporting of a dashboard's purpose (its 'why') and audience (for 'whom') was infrequent. This may be explained in part by the fact that the majority of dashboards were developed by public authorities and hosted on existing webpages. Hence, the target audience (citizens) and the aim (constitutional mandate to protect health) may be considered implicit. However, without clarity on the intended use and user of a dashboard, its development is steered by the *potential* to be useful, rather than addressing a specific information need [32,94-96].

'What' a dashboard communicates through its content, is not a neutral window into the available data. It is the result of judgment, discernment and choice [14]. The average of five indicator themes reported per dashboards can be considered a manageable volume and in line with the evidence that 'less is more' [33,48]. It is the breadth in types of information presented that is concerningly narrow, with only a handful of dashboards addressing the WHO-recommended four types of information needed for a complete picture of the pandemic [3]. For example, indicators reporting on population behavioral insights gauge the compliance of citizens with infection control measures, making them an important tool for maintaining public trust. However, in our sample this type of information was rarely reported on. This may be due to data infrastructure limitations and the limited availability of such data, especially in the early phases of the pandemic. Similarly, less than half of the dashboards reported on health system management indicators, despite their importance to inform the management of both COVID-19 and non-COVID-19 services. Dashboards that did report on these non-epidemiological types of information, may serve as inspiration for drawing on innovative data sources and indicators [28,61].

Clarity around data sources and indicator calculations (metadata) are critical for overall quality, credibility and trustworthiness of reporting [47,49,50]. For transparency on how data was collected and insights into 'what lies behind' the reported indicators, explicit data sources and calculations should be considered a minimum requirement. Nonetheless, our findings signal that doing so is not a given. Further efforts are needed internationally and nationally to standardize indicator calculations and set requirements of what constitutes good practice in public reporting of pandemic-related data.

In terms of 'how' content gets presented, dashboards should be viewed as a tool for making a clear link between current trends and past policy decisions and individual behavior. Doing so connects change-points and actions, which has been found to contribute to an indicator's use [97,98]. It also serves to leverage the two-way communication potential of dashboards. Dashboards that fail to make the connection between the past and present, miss the opportunity to communicate back to users the effects of their decision-making. Beyond describing the past and present, only a handful of dashboards went further and employed predictive analytics by illustrating different future scenarios of 'what could happen'. The lack of precision of predictive models and simulations early in the pandemic likely stunted their use. Use of both descriptive and predictive approaches to dashboard design and tighter links between infection control policies and their effects and should be further explored into the next phases of the pandemic.

We found frequent use of different display options and interactive techniques among the dashboards assessed. However, the analysis of data by location and by population sub-groups were limited overall, which may restrict their utility for individual-level decision-making purposes. The challenge to report data locally and disaggregated by relevant breakdowns such as age, sex, socio-economic status, ethnic or racial groups, may be in large part due to data infrastructure limitations and perceived legal obstacles [99]. Without collecting, registering and using data about meaningful population sub-groups, there is the risk of not being informed about these important (and modifiable) differences [99].

Lastly, an actionable dashboard is based on complete, timely, and transparent data, prepared, contextualized and presented such that it can be used as information [100]. Our assessment finds an overall underuse of known and proven delivery techniques, in particular, the use of explanatory narratives. Plain language text to clarify complicated information has proven to make end-users more motivated and confident in using information in their decision-making [1,48,55]. While commonly-used software for the development of dashboards (e.g. ArcGIS) have served to optimize their single-screen design, the embedding of narratives into templates may be useful for improving interpretation.

Future research could explore the following. First, recognizing the highly dynamic nature of COVID-19 dashboards, a follow-up study could give insights into how dashboards have evolved over time, given improvements in disease prevention, testing and treatment as well as data infrastructure. Second, exploring across official municipal, regional and national dashboards in a given context was beyond the scope of this study, however, doing so may offer insights into the possibility for tailoring dashboards at different levels to specific purposes and audiences. Third, this study has pursued a theoretically-informed expert-based appraisal of actionability. A study from the perspective of the target audience is, therefore, merited and needed for insights from firsthand use. Lastly, the assessment tool developed could be used within a specific country context to analyze actions needed in order to implement the features identified.

Strengths and Limitations

To our knowledge, this is the most comprehensive summary of COVID-19 dashboards and assessment of their actionability published to-date. The search of COVID-19 dashboards was wide-reaching and used multiple methods to amass a global sample. The approach tapped into a unique and highly specialized international network dedicated to health care performance intelligence, allowing for an expert, context-aware and multicultural team. The multilanguage competencies of the panel made it possible for dashboards to be reviewed in their original languages for high-quality data extraction. Through detailed data extraction and a structured process of scoring with joint deliberation, we have identified a set of timely and pragmatic features for optimizing dashboards. This is also the first study to our knowledge on the use of dashboards for public reporting from a communication and health care performance intelligence perspective. Importantly, the study was conducted at pace with the ongoing pandemic to ensure the potential for findings to inform the continued development of dashboards in combination with other communication tools.

We acknowledge the following potential limitations. First, the sample of dashboards is ultimately a subset of publicly available web-based COVID-19 reporting. The sample is also skewed to locations in the European and Pan-American region – accounting for two-thirds of the dashboards reviewed. This may be attributed in part to factors including: the thorough though not exhaustive sampling strategy applied; the exclusion of dashboards beyond the 22 language competencies of the panel (i.e. Arabic, Hindi); and the focus on web-based dashboards to the exclusion of those exclusively on mobile applications (common to Asian countries). As an exploratory study, reasonable diversity in locations, in combination with different levels (scales) of focus and type of organizations, took precedent and was achieved. Nonetheless, the findings may not be generalizable to all contexts. Second, despite our best efforts for a snapshot of COVID-19 dashboards in a common two-week period, the severity and specific phase of the pandemic inevitably varied greatly on the date of the review as described. Our approach to assess, rather than evaluate (the impact of) COVID-19 dashboards, mitigates the significance of these differences on our findings. Third, the appraised actionability of dashboards ultimately does not confirm their use in practice and doing so was beyond the scope of this

study.

Conclusion

This study has taken stock of the vast public, web-based COVID-19 dashboard landscape: a testament to the advancements in health information systems and digitalization of our societies, coupled with the responsibility and imperative to publicly report health information. As could be expected, the 158 dashboards in our sample, spanning a total of 53 countries, are diverse. They have different contexts and levels of focus, purposes and audiences. They draw from various data sources, offer different content and use a range of ways – albeit at times limited – to breakdown data, visualize, simplify and interact with information. Their actionability also differs, signaling that their fitness for use by decision-makers is not a guarantee. In the period of July 2020 when dashboards in this study were assessed, the number of dashboards appraised as highly actionable signals the work still needed to optimize a dashboard's use. There is no one-size-fits-all template or model to do so. Dashboards must be purpose-driven and context-specific. We urge those working on COVID-19 dashboards to consider the seven features identified in our study and adopt these as called for. By doing so, we stand to fully leverage the potential advantages of public reporting and its use for decision-making and behavior change needed to address the current pandemic.

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Authors' Contributions
DI, EB, SA, NK and DK were involved in the design of the study. DI and EB coordinated sampling of dashboards, defining inclusion and exclusion criteria and the initial screening. DI and EB developed the dashboard assessment tool, which was piloted and validated by all authors. The panel of scorers (DI, EB, VB, OBF, KJG, TS, PK, NL, SL, BMT, JM, MP, AR, SW, CW, YY, ZY) participated in data extraction, two rounds of scoring and two consensus workshops. DI and EB coordinated data extraction and organized and moderated consensus workshops. DI and EB cleaned and analyzed the data and drafted the manuscript, with supervision of SA, NK and DK. All authors contributed to the interpretation of the results, provided critical comments and edited, revised, and approved the manuscript in its final form for submission.

Conflict of Interest
None to declare.

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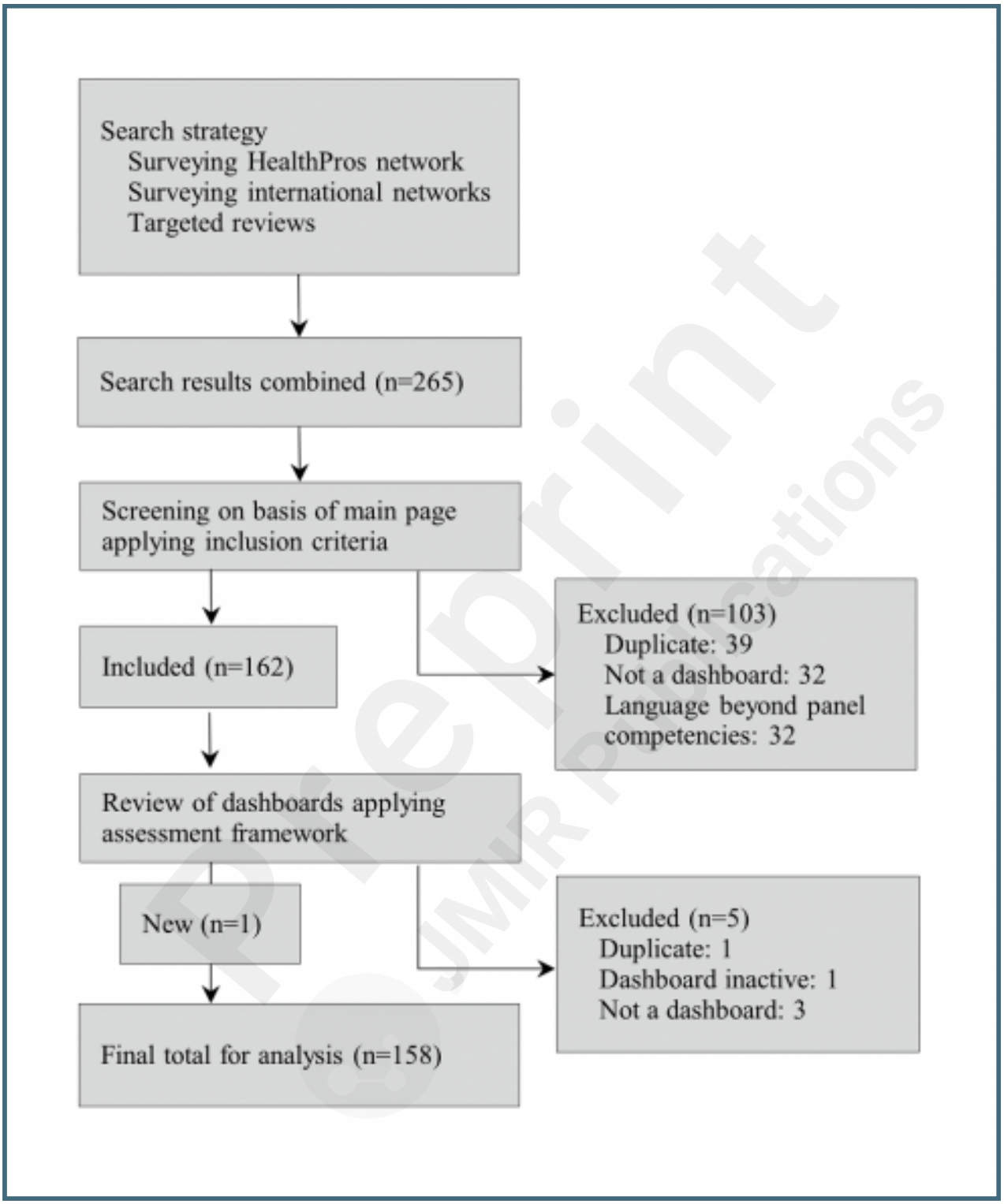
Abbreviations

NA – not applicable
NGT – Nominal Group Technique
ICU – intensive care unit
PCR – polymerase chain reaction
WHO – World Health Organization

Supplementary Files

Figures

Flow diagram of COVID-19 dashboard sampling.



Multimedia Appendixes

Dashboard Sampling Survey.
URL: https://asset.jmir.pub/assets/13d043eeab2ff6c1beabeb80754f6079.docx

Assessment Tool.
URL: https://asset.jmir.pub/assets/c79d0ab28afecb9d5b30d61b84efc3d9.docx

Public, Web-Based COVID-19 Dashboards Assessed.
URL: https://asset.jmir.pub/assets/71fd9027996cdc552bbedbbdee2a3000.docx

Illustrative Indicator Titles by Themes.
URL: https://asset.jmir.pub/assets/57898916dfbbaaf104cfa7f8716cd02d.docx

Summary of Dashboard Scoring.
URL: https://asset.jmir.pub/assets/2d115ac5bdf728d17ef344448cae3312.docx

TOC/Feature image for homepages

A woman viewing a COVID-19 dashboard on her laptop.