CDS Hooks: It is Written in the Cards

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Clinical decision support (CDS) systems implement point of care information to assist with decision-making by providing the right information, to the right person, at the right time (Agency for Healthcare Research and Quality [AHRQ], 2019; Office of the National Coordinator for Health Information Technology [ONC], 2017). CDS Hooks is an emerging CDS standard with the potential to transform the nature of decision support by enabling automatic connections with external CDS systems (Spineth, Rappelsberger, & Adlassnig, 2018).

**Objectives**

In order to maintain a manageable scope for this project, the investigators chose three main objectives. First, the initial objective was to develop a foundational understanding of the CDS Hooks standard and discuss some of its key aspects including functionality, implementation, and current hooks. For their second objective, the investigators proposed three new hooks that could be added to the CDS Hooks specification. Lastly, the final objective was to present a discussion of several identified advantages and disadvantages of CDS Hooks.

**Background and Significance**

CDS Hooks “is a hook-based pattern for automatically invoking CDS functions from within a physician’s EHR workflow” (Spineth et al., 2018, p. 166). As events occur, the EHR sends notifications to an external CDS service. The service learns what is occurring and can then return information in the form of a card to be displayed inside the EHR. Contrary to prior CDS methods, CDS Hooks runs automatic checks ahead of time, so the clinician does not need to manually select an appropriate application to run (Raths, 2016). While CDS Hooks does not fix the “curly braces problem” seen in Arden Syntax (Kawamoto, Shekleton, Doyle, Rhodes, & Strasberg, 2017), it provides a completely different way of implementing decision support. CDS Hooks is an up-and-coming standard with limited published research and has even been described as having “scant literature” (Dolin, Boxwala, & Shalaby, 2018, e116). Therefore, a deeper exploration of the topic was necessary to address this gap.

**Methods**

Four distinct methods were used to gather information for this project. The researchers did not identify any ethical, legal, privacy, or security issues with this approach.

**Published Literature Search**

First, a literature search was conducted using the databases of PubMed and CINAHL. Due to the limited published literature available, only one search term of “CDS Hooks” was used to prevent further limiting of the results. However, to ensure relevancy, the results were filtered to only include studies written in the English language and published within the last five years. Both PubMed and CINAHL returned six articles each; a summary of these search strategies may be found in Table 1 and Table 2, respectively. After duplicate articles were removed and the articles were reviewed, three articles remained as sources to use for the project. This process is depicted in the PRISMA Diagram found in Figure 1.

**Systematic Google Search**

The second method was a systematic Google search. Although this is not a conventional search method for a scholarly investigation, it was necessary due to the limited published literature. As in the previous search, the phrase “CDS Hooks” was the only term used. For each page of results, the investigators independently screened the articles for eligibility, and any discrepancies were resolved through discussion between the two of them. The articles were reviewed in two phases; first, the articles were screened by reading the article title and summary of information presented under each result. The only exclusion criteria applied in this phase was if the article did not address CDS Hooks, or the file was a video. Video files were excluded due to the added complexity and lack of credibility that could potentially result. The second round of article elimination involved a closer review of each article by skimming through its entire content. The investigators continued this two-phase process with each page of search results until most articles were being eliminated, thus indicating the results were becoming less relevant. Therefore, the search process ended after reviewing four complete pages of Google search results. The total number of articles eliminated at each phase are presented in Table 3, and the reasons for such elimination are presented in Table 4.

**Additional Focused Google Search**

Next, the third method used to gather information was through an additional focusedGoogle search. This allowed for the retrieval of other articles to inform gaps of information the investigators wished to address. Four additional sources were obtained through these focused searches; more detailed information regarding these topics is provided in Table 5.

**Open Interview**

Lastly, an open interview was conducted with Dr. Josh Mandel on the CDS Hooks channel of the Fast Healthcare Interoperability Resources (FHIR) community. The researchers became familiar with Dr. Mandel when they came across one of his presentations on YouTube (Mandel, 2019) as they were first learning about CDS Hooks. Dr. Mandel wrote the initial CDS Hooks specification in 2015, and he continues to work on the development of the standard alongside several other colleagues (J. Mandel, personal communication, February 27, 2020). Therefore, he is an expert in the field and served as an excellent resource. Of note, his recorded presentation on YouTube (Mandel, 2019) was the only video used to inform this project, as its validity could be verified. All eight interview questions are listed in the Appendix.

**Results**

**Overview of CDS Hooks**

**How it works.** CDS Hooks is unique due to how it enables the EHR to interact with external CDS services (Spineth et al., 2018). When a clinician performs an action in the EHR, CDS Hooks can invoke all the CDS services that may be able to provide relevant decision support (HL7 & Boston Children’s Hospital, 2018). A hook is sent out via a JSON message that contains information regarding the nature of the hook and relevant contextual information (Mandel, 2019). In certain situations, CDS services may have requested to have access to “pre-fetch” data in order to speed up the response time. Pre-fetch data is data such as a patient’s demographic information or most recent lab values that an EHR may agree to share with the CDS service ahead of time (GitHub, n.d.). This eliminates the need for the CDS service to gain access to this additional data from the EHR via its own FHIR application programming interface (API) call utilizing an access token (Mandel, 2019; Hay, 2019). Once the CDS service has all the information it needs, it returns its recommendation in the form of cards to the EHR via another JSON message (Mandel, 2019). There are three types of cards that may be returned: information, suggestion, or app link (HL7 & Boston Children’s Hospital, 2018). As the name suggests, an information card provides additional information about the situation, such as the cost of a medication that is being prescribed. A suggestion card may offer a recommendation for a clinician to take, such as switching from a brand name to a generic drug. Lastly, an app link card provides a link to a SMART app that a clinician can use to supply additional information to help come to an informed decision (HL7 & Boston Children’s Hospital, 2018). A summary of this process is depicted visually in Figure 2. Of note, the entire CDS Hooks 1.0 specification is published and available to the public (HL7 & Boston Children’s Hospital, 2018).

**Current implementation.** The investigators found there to be a lack of clarity with identifying the institutions that are currently implementing CDS Hooks. Dr. Mandel (2020) stated that certain organizations are implementing this standard as part of the Argonaut Project, but specific information was not readily provided. However, despite the lack of transparency, there is evidence that both Epic and Cerner support the development and advancement of CDS Hooks (Kawamoto et al., 2017). Through a search of all identified literature, a few specific use-cases were identified. For example, an international use-case of CDS Hooks was identified with an alert being fired as a reminder to complete HIV screening for patients in Argentina (Rubin et al., 2019). Furthermore, the ArdenSuite CDS service has implemented the use of the Hepaxpert app for interpretation of Hepatitis A, B, and C results when an EHR connects to this app via CDS Hooks (Spineth et al., 2018). Lastly, Boston Children’s Hospital has been trialing CDS Hooks to trigger alerts to adjust azathioprine medication dosage orders based on a patient’s genetic information via the PGx app (ONC, 2017).

**Current hooks.** In Version 1.0 of the CDS Hooks standard, there are currently eight hooks: patient-view, medication-prescribe, order-review, order-select, order-sign, appointment-book, encounters-start, and encounters-discharge (Burger, 2019). Each hook may move through four maturity levels, or it may become deprecated in favor of another hook. Of note, the order-review and medication-prescribe hooks have been deprecated for the order-select and order-sign hooks. On the maturity scale, level one indicates that a hook has been submitted, level two indicates testing, level three indicates consideration, and level four indicates documentation (HL7 & Boston Children’s Hospital, 2018). Currently the patient-view hook is the only formally standardized hook with a maturity level of four, but it is not the only hook being used (Mandel, 2020). There is a necessary delay between the time when hooks are being tested to when formal standardization occurs. This allows for any unanticipated challenges to be worked out when the hook is being used with real patient data, as opposed to only speculative data (Mandel, 2020). Dr. Mandel stated that ensuring this quality is a consistent challenge, but FHIR and CDS Hooks are committed to achieving real-world application for the maturity of the standard (2020).

**Proposal of New Hooks**

After researching the limited number of hooks that are currently created, the investigators felt it was essential to address several ideas for future hooks in order to promote the development of the standard. Notably, anyone in the informatics community can build hooks; it is marketed as an “open set” (Mandel, 2019). However, all hooks must be formally proposed using the “New Hook Template” as provided by HL7 and Boston Children’s Hospital (2018). Furthermore, all proposed hooks must be agreed upon by members of the GitHub community before any testing of the hook is completed (Hay, 2019). According to the “New Hook Template,” all hook names must follow the pattern of “noun-verb” (HL7 & Boston Children’s Hospital, 2018). Additionally, new hook proposals must address where in a clinician’s workflow the hook would be relevant, as well as provide a table of any contextual data that is necessary for the hook to function. This contextual data includes field, optionality, prefetch token, type, and description (HL7 & Boston Children’s Hospital, 2018). The investigators have proposed three hooks: medication-link, diagnosis-educate, and patient-travel.

**Medication-link.** This hook would fire when the clinician is scanning an IV medication to administer through a line that has already been electronically linked with another IV medication. It is important to note that this hook would only be relevant if the nurse is using an EHR that has been equipped with the technology to link medications to lines. When fired, this hook would use external medication compatibility information and alert a nurse via an informational card if he or she is about to run a medication that would be incompatible with what is currently running in the line. The contextual data is presented in Table 7 (HL7.org, 2019).

**Diagnosis-educate.** This hook would fire whenever a new diagnosis is added to a patient’s chart. Upon firing, different educational materials that are relevant to the specific diagnosis could be located and returned to the clinician in the form of links provided in SMART app link cards. This information could then be accessed and shared either electronically or in print form to the patient or family. The contextual data is presented in Table 8 (HL7.org, 2019).

**Patient-travel.** This final hook proposed by the investigators, inspired by the COVID-19 pandemic, would fire when a clinician is documenting information about the patient’s recent travel history. The hook would connect with external sources of information about current regions presenting an elevated infection risk. This data could be relayed to the clinician either as an informational card or as a suggestion card offering a recommendation for further screening or isolation. The contextual data is presented in Table 9 (HL7.org, 2019).

**Advantages and Disadvantages**

**Advantages.** Overall, CDS Hooks works to incorporate new technologies that allow for simpler methods to integrate external CDS tools into EHRs. This not only allows for the utilization of standards for information exchange, but it also enables a more efficient health care model (Rubin et al., 2019). The main advantage of CDS Hooks is the ability to have the appropriate application launch automatically without the user having to launch it manually or even know that the application exists (Freeman, 2018; Kawamoto et al., 2017; Mandel, 2020). Moreover, CDS Hooks developers are adding functionality to decrease alert fatigue. For example, the system can remember when a clinician dismissed a card and not show it again the subsequent time (Burger, 2019). Lastly, this standard also has the advantage over vendor-specific models of CDS due to the integration of a consistent set of APIs and the ability to target the user experience around this single set (Mandel, 2020). The benefits of this phenomenon extend to EHRs by allowing the developers to focus on what they provide best, as opposed to also having to develop internal CDS support (Raths, 2016).

**Disadvantages.** Despite the numerous advantages of this standard, there are still several disadvantages worthy of discussion. For example,since CDS Hooks is at an early phase of development with limited technical support, this is one of the obvious disadvantages (Mandel, 2020; Raths, 2016). In addition, Dr. Mandel (2020) explained another disadvantage is the tension faced between API features that are used as a universal standard in CDS Hooks versus API features that are implemented into a specific vendor product. A vendor-specific product that is highly advanced in a certain area may initially offer better functionality than the standardized CDS Hooks function (Mandel, 2020). Another disadvantage is related to a specific feature of the CDS Hooks 1.0 specification. Currently, if a clinician is directed to a flowchart via an app link card, there is no way for the EHR to automatically capture the decision made from the flowchart; the clinician must manually enter the appropriate action in the EHR (Mandel, 2019). A final disadvantage discussed by Hay (2019) is the potential for security threats. Due to the unique nature of CDS Hooks, both the EHR and CDS service must be able to trust each other and ensure that patient data will be kept secure. Although specific security measures have been put into place, such as the usage of the transport layer security (TLS) to communicate information, potential security breaches are not miniscule concerns (Hay, 2019).

**Discussion**

Based on the findings presented above, it is evident CDS Hooks has the potential to significantly impact decision support. One strength of this project was the ability to clearly present information surrounding a little-known standard. Additionally, the investigators’ proposal of new hooks added a unique contribution to the topic. However, this project was not without weaknesses. For instance, the lack of published literature was problematic, as many of the data sources relied on websites and blogs. Moreover, having only two researchers available to search the literature was not the best practice. Despite these weaknesses, this work still provides a relevant contribution to national efforts in supporting adoption of decision support tools. The use of CDS has been included in the 2018 Modified Stage 3 Meaningful Use criteria (AFMC Health IT, 2018). With the adoption of CDS tools becoming mandatory, the exploration of the newest developments in the field, such as CDS Hooks, offers significant insight into this national effort. Additionally, with advanced CDS tools enabling the clinician to have the timeliest access to information, this exploration also has the potential to impact clinical practice and the quality of patient care (AHRQ, 2019; ONC, 2017).

The investigators found several areas for future recommendations and plans. First, it will be important to test CDS Hooks in more real-world environments. This will enable developers to gain a better understanding of what is functioning appropriately (Dolin et al., 2018). Feedback from users will help improve functionality over time and help build new features that have high priority (Mandel, 2020). Dr. Mandel (2020) also stated that the “big picture” for the future of CDS Hooks is improving support for existing functionality and potentially adding hooks for a particular care context. Furthermore, CDS Hooks is working to standardize features for the 1.1 specification, such as more feedback regarding why and how advice is taken by clinicians. This would enable the CDS developers to know if their suggestions are useful for the end-users (Mandel, 2020). Finally, another recommendation includes the need for more HIPAA regulatory guidance to ensure the security of data shared across the network (Kawamoto, 2019).

Despite the important conclusions that were drawn from this project, a more comprehensive exploration of CDS Hooks would still be valuable. For example, interviews with more key stakeholders, especially individuals whose organizations are currently implementing CDS Hooks would add vital information. Beyond the traditional means of journal publication, the authors envision the deliberate sharing of information presented in this project via word of mouth to be an important next step. Spreading the knowledge with other informatics professionals, who may then share this knowledge with their colleagues, may rapidly spread insight about this otherwise little-known standard. Furthermore, members of the FHIR community on the CDS Hooks channel have requested the investigators share the information presented in this project back to the forum, so this is another planned method of dissemination.

**Conclusion**

Overall, this project shed light on several aspects of CDS Hooks, including a general overview of the standard, ideas for new hook development, and some key advantages and disadvantages. Due to the integration of information from a variety of sources, the investigators consider the project to have been a successful exploration and dissemination of a standard still in initial stages. Being that CDS Hooks has little published literature, the investigators feel that having composed a written document with much of the available knowledge in one cohesive location could lead to the project having a significant impact. Although the process will be time consuming, CDS Hooks appears to show great promise in bringing a new dimension to the CDS arena. According to Dr. Mandel (2020), “…a new standard only ‘wins’ over that time period if it’s solving a real-world problem. I think CDS Hooks is going to meet that bar.”

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Table 1

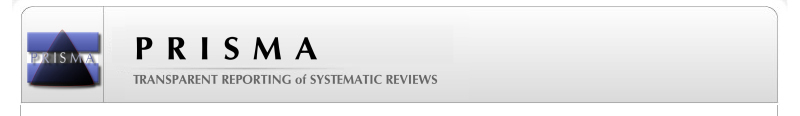
*Summary of PubMed Search Strategy*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Date** | **Search Term** | **Publication Limit** | **Language Filter** | **Number of Results** |
| 3/9/2020 | CDS Hooks | 5 years | English | 6 |

Table 2

*Summary of CINAHL Search Strategy*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Date** | **Search Term** | **Publication Limit** | **Language Filter** | **Number of Results** |
| 3/9/2020 | CDS Hooks | 5 years | English | 6 |

**PRISMA 2009 Flow Diagram**

## Identification

Records identified through database searching  
(n = 12)

Additional records identified through other sources  
(n =1)

## Screening

## Eligibility

## Included

Records screened  
(n = 8)

Records after duplicates removed  
(n = 8)

Records excluded,

with reasons

(n = 2)

-Wrong study topic (n = 2)

Full-text articles excluded, with reasons  
(n = 3)

-Wrong study topic (n = 3)

Full-text articles assessed for eligibility  
(n = 6)

Studies included in literature review (n = 3)

*Figure 1.* PRISMA Flow Diagram used in CDS Hooks project. Adapted from ‘Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRIMSA Statement,’ by D. Moher, A. Liberati, J. Tetzlaff, and D. G. Altman, 2009, PLoS Med, 6(6): e1000097. Open Access.

|  |  |
| --- | --- |
|  |  |
| Table 3  *Summary of Systematic Google Search Strategy* |  |
|  |  |
| Search Results by Page | Number of Websites |
| **Page One** |  |
| Initially keep | 9 |
| Initially eliminate | 0 |
| Second elimination | 4 |
| *Total remaining* | **5** |
| **Page Two** |  |
| Initially keep | 9 |
| Initially eliminate | 1 |
| Second elimination | 7 |
| *Total remaining* | **2** |
| **Page Three** |  |
| Initially keep | 10 |
| Initially eliminate | 0 |
| Second elimination | 9 |
| *Total remaining* | **1** |
| **Page Four** |  |
| Initially keep | 9 |
| Initially eliminate | 1 |
| Second elimination | 8 |
| *Total remaining* | **1** |
| **Total Websites to Review** | **9** |

Table 4

*Reasons for Website Elimination from Systematic Google Search*

|  |  |
| --- | --- |
| Reasons by Round | Number of Websites |
| **Initial Elimination** |  |
| Video file | 2 |
| *Total eliminated* | **2** |
| **Secondary Elimination** |  |
| Video file | 1 |
| Duplicate information | 7 |
| Journal article identified elsewhere | 1 |
| Too technical/ geared toward CDS developers | 5 |
| Lack of site trustworthiness | 2 |
| Too specific for one use-case | 1 |
| Does not provide substantial information | 8 |
| Requires account creation | 3 |
| *Total eliminated* | **28** |
| **Total Eliminated Websites** | **30** |

Table 5

*Topics for Additional Focused Google Searches*

|  |  |
| --- | --- |
| Topic | Number of Sources |
| CDS background information | 1 |
| FHIR resources data | 1 |
| Meaningful Use criteria | 1 |
| Dr. Mandel YouTube video | 1 |
| **Total Additional Websites** | **4** |

Table 6

*Final Counts of Sources Used*

|  |  |
| --- | --- |
| Number of Sources Used Per Category | Number of Sources |
| Journal articles | 3 |
| Websites from initial systematic Google search | 9 |
| Websites from additional focused Google searches | 4 |
| Interview | 1 |
| **Total Sources Used** | **17** |

**A picture containing screenshot

Description automatically generated**

*Figure 2.* Diagram depicting the process of CDS Hooks. Reprinted from ‘CDS Hooks,’ by HL7 & Boston Children’s Hospital, 2018, Retrieved from https://cds-hooks.org/

Table 7

*Contextual Data for Medication-link Proposed Hook*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Field | Optionality | Prefetch Token | Type | Description |
| userId | REQUIRED | Yes | *string* | The id of the current practitioner |
| patientId | REQUIRED | Yes | *string* | The FHIR “patient.id” of the current patient being viewed |
| encounterId | OPTIONAL | Yes | *string* | The FHIR “encounter.id” of the current encounter |
| medications | REQUIRED | No | *object* | The FHIR bundles of “MedicationAdministration” and “MedicationKnowledge” |

*Note:* Resources taken from https://www.hl7.org/fhir/resourcelist.html, 2019.

Table 8

*Contextual Data for Diagnosis-educate Proposed Hook*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Field | Optionality | Prefetch Token | Type | Description |
| userId | REQUIRED | Yes | *string* | The id of the current practitioner |
| patientId | REQUIRED | Yes | *string* | The FHIR “patient.id” of the current patient being viewed |
| encounterId | OPTIONAL | Yes | *string* | The FHIR “encounter.id” of the current encounter |
| diagnosis | REQUIRED | No | *string* | The FHIR bundles of “DiagnosticReport” “CarePlan,” and “Goal” |

*Note:* Resources taken from https://www.hl7.org/fhir/resourcelist.html, 2019.

Table 9

*Contextual data for Patient-travel Proposed Hook*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Field | Optionality | Prefetch Token | Type | Description |
| userId | REQUIRED | Yes | *string* | The id of the current practitioner |
| patientId | REQUIRED | Yes | *string* | The FHIR “patient.id” of the current patient being viewed |
| encounterId | OPTIONAL | Yes | *string* | The FHIR “encounter.id” of the current encounter |
| travel | REQUIRED | No | *string* | The FHIR bundles of “Condition” and “ImmunizationRecommendation” |

*Note:* Resources taken from https://www.hl7.org/fhir/resourcelist.html, 2019.

**Appendix**

**Interview Questions**

1. What do you see as the main advantage to using CDS Hooks?
2. What do you see as the main disadvantage or challenge to using CDS Hooks?
3. Do you know of any hospitals that are currently using CDS Hooks either as a pilot or in actual production mode?
4. Piggybacking off of our last question, it looks like only one hook is currently beyond a maturity level of 1, “patient-view.” Is this the only hook that has been tested by any actual CDS clients/hospitals?
5. Can you provide any specific examples of the external CDS services that may be evoked when an EHR triggers a hook? Are they different from previous CDS services used in internal systems?
6. We did a previous class project on Arden Syntax and learned more about the “curly braces” problem. From our understanding, CDS Hooks is not a solution to the curly braces problem. Instead, it offers a different approach entirely that is able to bypass the “curly braces” because the external CDS systems may use FHIR APIs to obtain any institution/patient specific information. Are we correct in our thinking here?
7. Do you think hospitals will be quick or hesitant to adopt CDS Hooks?
8. What do you see as the next steps for the advancement of this standard? Do you think it will eventually replace some of the older internal CDS systems?