

## Improving the U.S. Adult Immunization Schedule by Applying Usability Principles

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Human factors (HF) can be implemented in various domains to improve usability, and healthcare is no exception. A student team from Georgia Tech was consulted by the Centers for Disease Control (CDC) about performing a straightforward user-centered redesign of the CDC's immunization schedule. Using classic design principles (e.g., consistency, simplicity, clarity), the team created a prototype schedule that aims to produce HF-driven efficiency of use while maintaining a form that fits with end-user expectations of the schedule. The CDC implemented some of the team's design recommendations in its 2017 immunization schedule, and more changes could be implemented in the 2018 version of the schedule.

### INTRODUCTION

The application of human factors (HF) in healthcare is relatively new, originating primarily out of efforts to reduce medical error and improve patient safety (e.g., Cook & Woods, 1992; critical incident analyses, Cooper, 1984). In medicine, and other fields, HF principles diverge from the notion that humans are primarily at fault when errors are made during the use of a socio-technical system; rather, errors are likely more attributable to the design of the system (Cafazzo & St-Cyr, 2012). Healthcare is a complex domain with many usability issues (Leape, 2004) stemming from the relationship between humans, technology, and processes that range from the mundane (e.g., hand hygiene; Vicente, 1998) to the complex (e.g., patient-controlled analgesia pump; Lin et al., 1998). Another example of this relationship can be found in the adult immunization schedule in the United States. The Centers for Disease Control and Prevention (CDC) annually publishes the Advisory Committee on Immunization Practices-recommended adult immunization schedule (Kim, 2016). It is designed for use by healthcare providers to determine the vaccines routinely needed by adults with respect to age and medical, occupational, or other indications.

Vaccines protect people from diseases and save lives. However, diseases that can be prevented by vaccines remain major causes of illness and death. In the United States, vaccine-preventable diseases result in the deaths of an estimated 60,000 adults and 300 children each year in the United States (Institute of Medicine, 2000) and cause excess medical visits, hospitalizations, missed school/work, and lower quality of life. The adult immunization schedule, two figures that are designed to be read with accompanying footnotes, provides a cohesive and comprehensive summary of recommendations for the use of fourteen licensed vaccines routinely recommended for adults. It is designed for use by healthcare providers and updated annually to include changes in vaccination recommendations (e.g., new vaccines, dosage, frequencies, intervals, and indications). A well-designed immunization schedule plays a critical role in effectively communicating with healthcare providers who implement immunization recommendations.

### PRACTICE INNOVATION

Over time, the adult immunization schedule has become more difficult to read as the number of recommended vaccines has increased and the details of their use have become more complex (Centers for Disease Control and Prevention, 2016). Although the current schedule is functional, many issues keep the current schedule from being as usable as it could be.

The student chapter of the Human Factors and Ergonomics Society at the Georgia Institute of Technology (HFES-GT) collaborated with the CDC to evaluate the current design of the adult immunization schedule and, based on HF principles, recommend changes to improve the schedule's usability. Using classic usability principles, HFES-GT produced a recommended prototype schedule that aimed for easier information extraction (particularly for common use cases) and structural consistency, all while considering the expectations of end-users and the feasibility of using the prototype in healthcare settings.

### FINDINGS AND PRACTICE APPLICATION

The existing issues and corresponding recommended solutions are summarized below and illustrated in Figure 1 (main schedule figures) and Figure 2 (footnotes).

#### Improving the adult immunization schedule figures

- A. **Issue:** The indication bar corresponding to the measles, mumps, and rubella (MMR) vaccine (upper schedule figure) is targeted only at those born in 1957 or later and therefore incrementally lengthens by one year as each version of the schedule is released annually. This method potentially creates confusion regarding the ages of applicability for the MMR vaccination; users must decipher the applicable age by estimating how much of a given cell (e.g., "50-59 years", "60-64 years") it occupies. **Solution:** Text is included within the MMR indication bar to indicate the exact age range through which the vaccine is recommended. Now users will never have to rely on their absolute perceptual judgment for this information, even during future years in which the MMR indication

bar will lengthen and extend into the next cell (corresponding to 60-64 years of age).

**Principles:** Conveyed information should not depend on physical discrimination at fine level (Wickens, Gordon, Liu, & Lee, 1998).

- B. **Issue:** Wordy and repetitive text within indication bars (e.g., “Depending on indication”, and “Depending on vaccine”) creates unnecessary visual clutter  
**Solution:** Symbols are used to denote the two common phrases, which reduces clutter in some indication bars (a key was added at the top to provide symbol meanings)  
**Principles:** Minimalist design (Nielsen & Molich, 1990).
- C. **Issue:** Indication bar borders and their respective row borders are spaced inconsistently – users might interpret different spacing amounts to imply different meanings.  
**Solution:** All indication bars have been re-formatted to completely fill their respective rows/cells so all spacing is consistent; therefore, users will not have to guess whether different spacing amounts imply different meanings. The overall design also features fewer lines (because bars and rows/cells now share borders) and is therefore cleaner.  
**Principles:** Consistency of structure (e.g., Shneiderman & Plaisant, 2009); simplicity of design (Stone et al., 2005).
- D. **Issue:** The two current legends are mostly redundant and create visual clutter (the second legend merely has one additional item not in the first legend).  
**Solution:** One all-encompassing legend was placed at the top of the page to reduce clutter; placement at the top indicates the legend’s general applicability.  
**Principles:** Simplicity of design (e.g., Stone et al., 2005).
- E. **Issue:** Legal/policy information is not grouped together (some in middle of page, some on bottom) and is not formatted consistently, creating search difficulty for users.  
**Solution:** All legal and policy information has been moved to the bottom of the page and is outlined by yellow boxes, in accordance with user expectations.  
**Principles:** Consistency of structure (e.g., Shneiderman & Plaisant, 2009); easy accessibility (Norman, 1983).
- F. **Issue:** Text that straddles colors might be confusing regarding its applicability. Some might believe that text only applies to the specific color(s) they overlay (particularly for dosage numbers; e.g., for the Hepatitis A vaccination in the lower figure, “2” is on the yellow segment of the indication bar and “3” is on the purple), when the text actually applies to all of the colors within the indication bar unless a thick line separates the colors.  
**Solution:** Text should straddle colors when possible to indicate that the text applies across indication bar colors. However, to solve the stated issue, it is possible to at least ensure that the dosage numbers are all overlaid onto one color to minimize confusion about the applicability of the dosage numbers.  
**Principles:** Prevent errors in the first place, as opposed to

correcting them afterward (e.g., Nielsen & Molich, 1990); design for common cases, not edge cases (Johnson, 2007).

- G. **Issue:** In the last row of the lower figure, the indication bar for *Haemophilus influenza* type b vaccination containing the text “3 doses post-HSCT recipients only” is not separated in a way that is consistent with the way other indication bars are separated from each other when there is a difference in immunization recommendation (e.g., “contraindicated” indication bar for varicella vaccination and its adjacent bar).  
**Solution:** In addition to re-formatting indication bars to completely fill their respective cells and rows (see letter C above), a thick line has been inserted to separate the indication bar segment containing the text “3 doses post-HSCT recipients only” from the rest of the indication bar, a format consistent with the way other indication bar segments are separated from each other (i.e., not reliant on just a color change as separation).  
**Principles:** Consistency of structure (e.g., Shneiderman & Plaisant, 2009).

**Improving the adult immunization schedule footnotes**

- A. **Issue:** Patient demographic information (age, sex, pregnancy status, etc.) was not easily searchable within bullets, forcing users to read each bullet point in full and therefore resulting in time wasted reading bullets that were irrelevant for a given use case.  
**Solution:** All patient demographic information was set in bold so that users could easily find relevant bullets.  
**Principles:** Contrast (Sanders & McCormick, 1998).
- B. **Issue:** Headings of each major section (in bold) were no longer as salient after demographic information was also set in bold (letter A above), making search more difficult.  
**Solution:** The existing bold headings for each major section were also underlined to facilitate search processes.  
**Principles:** Contrast (Sanders & McCormick, 1998).
- C. **Issue:** The continuousness of the footnotes text (across pages and columns) and the proximity of the major sections (not enough white space between sections) creates reading difficulty, and together these issues can cause users to be overwhelmed.  
**Solution:** The major sections were alternately shaded and additional spacing was added between sections. Alternate shading is a common method used in APA-style tables that visually distinguishes sections and enables users to quickly gauge the height of a row. Increased spacing between sections reinforces divisions between sections.  
**Principles:** Separation of sections (Wickens & Carswell, 1995); redundancy gain (Wickens, Hollands, Banbury, & Parasuraman, 2015).

**DISCUSSION**

The adult immunization schedule illustrates how a straightforward application of classic human factors principles

could improve messaging and lower cognitive load for healthcare providers. Past versions of the schedule had incorporated some basic usability principles, but many opportunities remain for more improvement in this realm.

While some significant changes were made between the current and prototype schedules, the team members also recognized the need to weigh the benefits of any changes against the potential disruption of those changes to end-user expectations. As a result, some proposed ideas were excluded from this prototype in favor of maintaining the status quo. For example, it was thought that the axes could be reversed in the lower schedule figure (indications on the Y-axis, vaccines on the X-axis) because healthcare personnel might be more likely to search the figure using a patient's indications. Such an orientation would cause this information to be indexed at a convenient location where users could naturally read left to right for all of the information associated with a given patient indication. However, such a significant change would likely require a difficult adjustment for healthcare personnel who are experienced with the existing format, and the change would have created inconsistency between the two schedule figures. Depending on an organization's goals and willingness to re-train, fundamental changes might or might not be feasible.

Other proposed ideas were excluded because of potential conflicts between human factors principles (i.e., solving one issue created another). For example, enlarging the type size of the footnotes would increase the readability of the text, which is important for a document frequently hung on office walls. However, enlarging type size also increases the length of the document and sometimes forced the separation of information that would often be needed simultaneously (healthcare personnel would have to re-learn locations of information), leading to problematic increases in working memory load (Shneiderman & Plaisant, 2009). Therefore, all proposed prototype changes were confined to those that would keep intact the document's overall structure and color schemes.

The process of improving the adult immunization schedule will be iterative. The CDC has implemented some of the recommended changes in the 2017 version of the schedule and interviewed about 40 physicians, nurse practitioners, physician assistants, pharmacists, nurses, and medical assistants, about this version. The team is currently working with the CDC to make further changes to the 2018 version. However, as of now, the proposed prototypes are merely proofs of concept. Future work should include empirical usability testing with end users to quantitatively assess the effectiveness of the solutions described in the current paper.

### PRACTITIONER TAKE-AWAYS

- The goals of providing a clean interface and providing every necessary piece of information are often in conflict with each other. It is easy to say that no more than just the necessary information should be provided, but some information is important enough to be repeated, and defining what is "necessary" can be difficult because various use cases can differ in importance and frequency (particularly in medicine).

- If a practitioner desires wholesale changes to a system, process, or interface, he or she should account for whether the benefits associated with the change outweigh the costs (e.g., training, equipment, employee morale), even though the costs might not be HF-related.
- Consistent structures and patterns can decrease the apparent amount of clutter on an interface, even without explicit removal of items from the interface.
- Before beginning work with a client, it is important to clearly understand the scope, objectives, and parameters of the work – a clear understanding will help the practitioner avoid performing unnecessary or unusable work.

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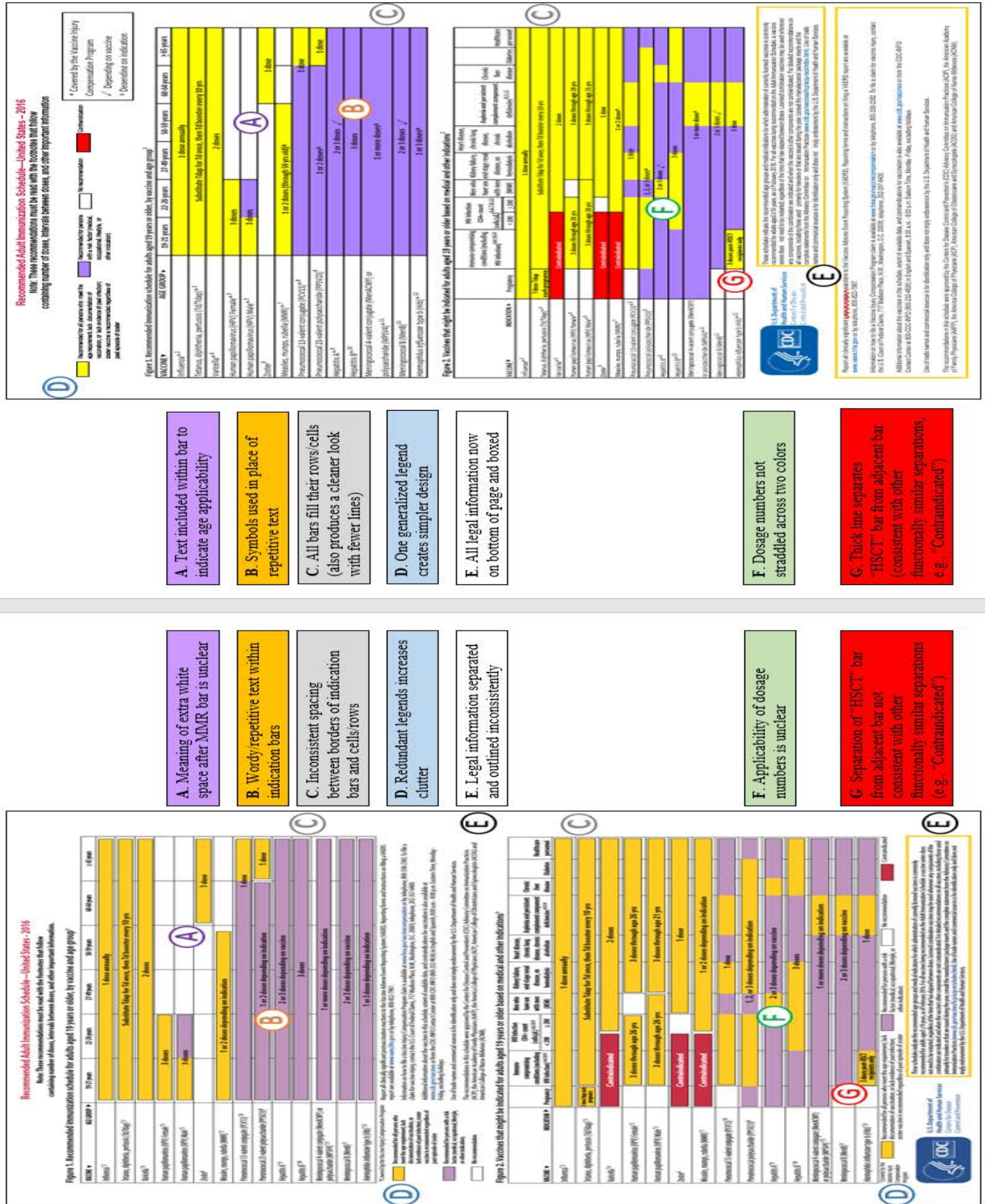


Figure 1. Comparison of current (left) and prototype (right) schedule figure pages

Figure 2 illustrates a comparison between current and prototype footnotes sections. The figure is divided into two main columns: 'Current' on the left and 'Prototype' on the right. Each column contains several sections, labeled A, B, and C, which represent different areas of text. The 'Current' version shows standard text formatting, while the 'Prototype' version implements several design changes to improve readability and searchability. These changes include:
 

- Section A:** Patient demographic information is now bolded in the prototype, making it more prominent and easier to identify.
- Section B:** Section headings are underlined in the prototype to distinguish them from the rest of the text.
- Section C:** Alternate shading and increased space between sections are used in the prototype to visually separate different parts of the text.

 The overall layout in the prototype is more structured and easier to navigate, with clear visual cues for identifying key information like patient demographics and section boundaries.

Figure 2. Comparison of current (left) and prototype (right) footnotes sections