# Application of Cognitive Engineering Principles to the Redesign of a Dichotomous Identification Key for Parasitology

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## Abstract

*Dichotomous identification keys are used throughout biology for identification of plants, insects, and parasites. However, correct use of identification keys can be difficult as they are not usually intended for novice users who may not be familiar with the terminology used or with the morphology of the organism being identified. Therefore, we applied cognitive engineering principles to redesign a parasitology identification key for the Internet. We addressed issues of visual clutter and spatial distance by displaying a single question couplet at a time and by switching to the appropriate next couplet after the user made a choice. Our analysis of the original paper-based key versus the Web-based approach found that of 26 applicable cognitive engineering principles, the paper key did not meet 4 (15%) and partially met 11 (42%). In contrast, the redesigned key met 100% of 32 applicable cognitive engineering principles.*

***Keywords***
*Classification, microcomputers, software, internet, veterinary, parasitology*

## Introduction

Worldwide, a wide variety of parasites afflict humans and animals. Proper identification of parasites is necessary for applying appropriate control measures and to reduce the illness and economic loss caused by parasite infection and control. Workers responsible for identifying immature and adult stages of parasites and vectors typically use a dichotomous identification key (Figure 1), which is a sequence of "either / or" questions that are designed to help the user identify a particular object or structure. However, even though detailed keys are available to aid in the identification of various parasites [1,2,3], using them correctly can be difficult as they are not usually intended for users who are not experts in the nuances of morphological features of the organism being identified, and a mistake at any point will produce an incorrect identification [4]. Since the available keys are typically paper-based, non-interactive, and linear in structure, there is no functionality to assist the user in performing the task. Further, while a variety of interactive identification key programs are available for other domains, such as botany, a review of the literature indicates that work on such keys seems to be concentrated on the database structure and design [5,6], not on the usability or design analysis of interactive keys. Therefore, an interactive identification key that incorporates cognitive engineering principles for usability and that allows the user to display additional photographs, line drawings, and definitions would help the user reach the correct identification. Thus, the purpose of this paper is to describe the application of cognitive engineering principles to the redesign of a paper parasitology identification key for the Internet, and to provide guidance for those who wish to develop such keys on their own.

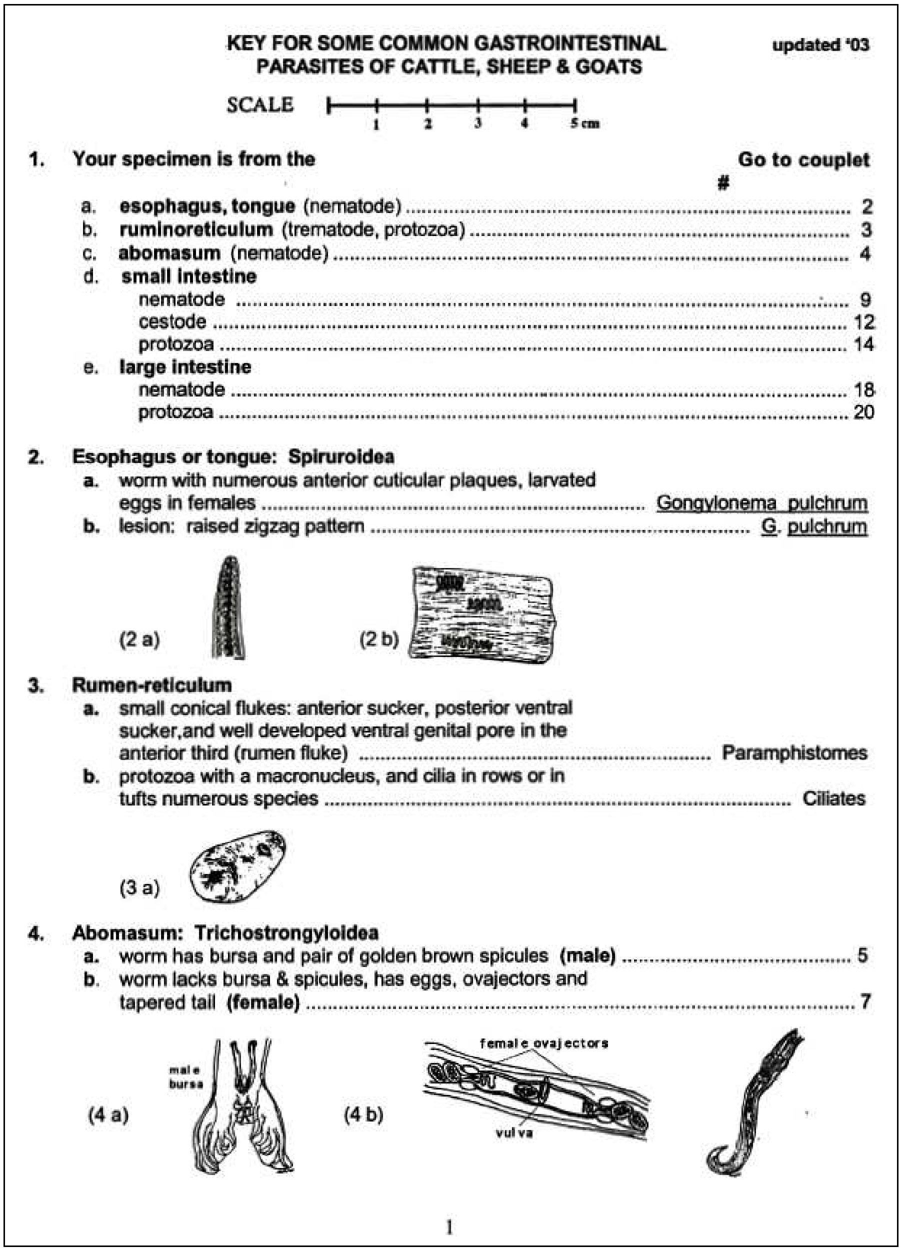
## Previous Work

Dallwitz et al. list several advantages of interactive keys over conventional ones. A few of the most notable features include the ability to use any characteristic in any order, illustrations of characteristics, and inclusion of glossaries, explanatory notes, and terms for assistance in interpreting characteristics [7]. In fact, the International Consortium on Ticks and Tick-Borne Diseases decided in July 2000 that due to the difficulty of using standard keys for livestock tick identification, a computerized key should be developed [8].

## Method

***Scope.*** Veterinary parasitology is a vast subject, because of the matrix of host species and parasites that infect those hosts. For this reason, we chose to use a veterinary parasitology identification key for this research. In order to restrict this project to a manageable level, we focused specifically on gastrointestinal parasites of ruminants (cattle, sheep, goats) and further restricted the scope to those commonly found in the southeastern United States.

***User analysis.*** We performed a user analysis (Table 1), based on Hackos and Redish [9]. This user analysis identified three target groups of people who may be responsible for identification of parasites in the context of this project: parasitologists, veterinarians and veterinary students.



KEY FOR SOME COMMON GASTROINTESTINAL PARASITES OF CATTLE, SHEEP & GOATS

updated '03

SCALE 1 2 3 4 5 cm

**1. Your specimen is from the** — **Go to couplet #**

a. **esophagus, tongue** (nematode) .......... 2
b. **ruminoreticulum** (trematode, protozoa) .......... 3
c. **abomasum** (nematode) .......... 4
d. **small intestine**
   nematode .......... 9
   cestode .......... 12
   protozoa .......... 14
e. **large intestine**
   nematode .......... 18
   protozoa .......... 20

**2. Esophagus or tongue: Spiruroidea**

**a.** worm with numerous anterior cuticular plaques, larvated eggs in females .......... Gongylonema pulchrum
**b.** lesion: raised zigzag pattern .......... G. pulchrum

(2 a) (2 b)

**3. Rumen-reticulum**

**a.** small conical flukes: anterior sucker, posterior ventral sucker,and well developed ventral genital pore in the anterior third (rumen fluke) .......... Paramphistomes
**b.** protozoa with a macronucleus, and cilia in rows or in tufts numerous species .......... Ciliates

(3 a)

**4. Abomasum: Trichostrongyloidea**

**a.** worm has bursa and pair of golden brown spicules **(male)** .......... 5
**b.** worm lacks bursa & spicules, has eggs, ovajectors and tapered tail **(female)** .......... 7

(4 a) (4 b)



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**Figure 1:** Page 1 from Texas A&M University's identification key for common gastrointestinal parasites of ruminants

**Table 1:** User Analysis

| | **Parasitologist** | **Veterinarian** | **Veterinary Student** |
|---|---|---|---|
| **Domain knowledge** | Expert, detailed | Advanced to expert | Limited |
| **Skill** | Expert | Moderate to expert | Novice to moderate |
| **Education** | Advanced; DVM; post-doctorate | Advanced; DVM | Advanced |
| **Cognitive capacity** | Moderate to high | Moderate to high | Moderate to high |
| **Limitations** | Busy | Busy; does not routinely perform task | Busy |

***Functionality.*** Using the user analysis and literature review as a guide, we determined specific functions to be incorporated into our design. These included:

- Reorganization of basic structure to support basic human cognitive processes.
- Display of photographs of the suspect parasite to aid in identification.
- A basic synopsis of the identified parasite. This will help users determine if the identification is reasonable or possibly erroneous.
- The ability to click on terms and then display additional information such as definitions, line drawings, and photographs to aid the user in understanding terminology and vocabulary.
- A method to allow users to retrace their steps in the identification process.

***Prototype Development.*** We used Microsoft FrontPage 2003 (Redmond, WA) and JavaScript to create a working prototype. An example of an entry from the paper key and its corresponding Web-based version at http://www.kimberlysmith-akin.com/ID_key, are shown in Figures 2 and 3, respectively.

***Prototype Review***. We demonstrated four iterations of the prototype to graduate students enrolled in a cognitive engineering course in a graduate-level health informatics program. After each demonstration, the prototype was modified to incorporate suggested changes.

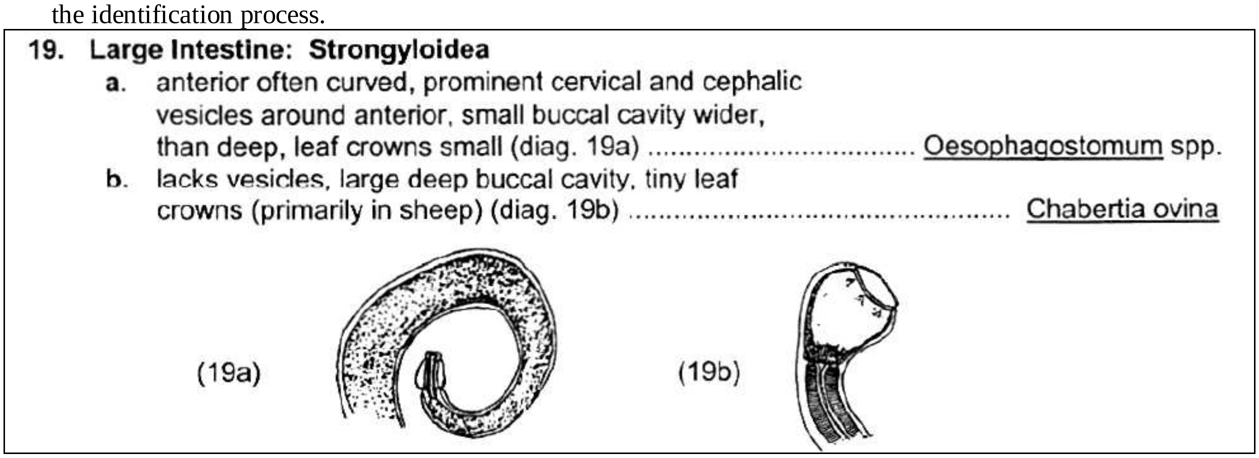


**Figure 2:** Original entry from paper-based key

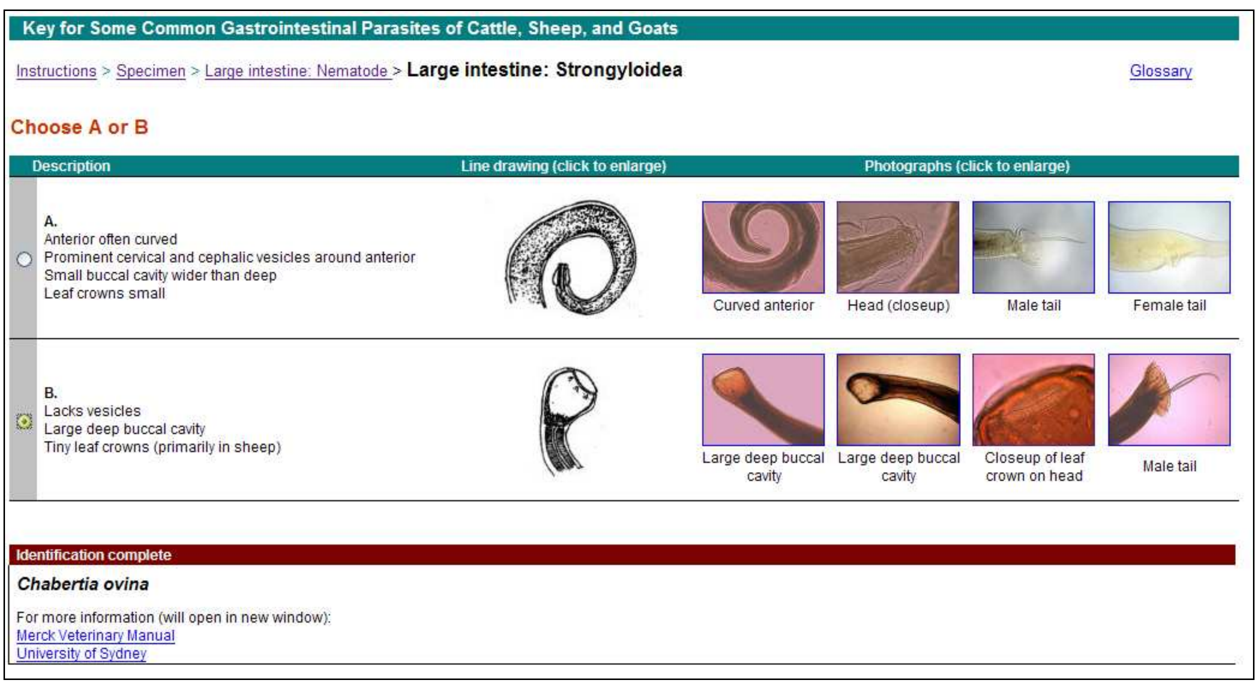


**Figure 3:** Redesigned entry from Web-based key

***Prototype Evaluation***. We developed a matrix of 32 cognitive engineering principles, based on Wickens [10]. These principles are listed in Table 2.

**Table 2:** Identified Cognitive Engineering Principles

| | |
|---|---|
| Chunking | Landmarks |
| Codes | Memory span |
| Color coding | Object-centered cues |
| Conflict and focused attention | Organizational distance |
| Cognitive distance | Overview map |
| Comprehension | Physical locations in display and edge effect |
| Consistency | Pictorial realism |
| Consistent labels | Picture integration |
| Continuously viewable fixed perspective map | Previewing information |
| Data-ink ratio | Print case |
| Diagnosticity | Proximity compatibility |
| Distance vs. clutter | Reliability |
| Environmental expectancy | Sampling arrangement |
| Highlight anchors for user orientation | Spatial structure |
| Intelligent cueing | Structured search |
| Items per menu | Symbol response |

Using this matrix, we evaluated both the original paper key and the Web-based prototype, scoring each principle as 'Present', 'Sometimes Present', or 'Not Present'. The total for each of the three categories was added for the two keys. Some principles, such as Web-based features, were not applicable to the paper key, and these were marked as 'N/A' and were not considered in its total. The total possible score for each key was calculated, as was the percentage of 'Present', 'Sometimes Present', 'Not Present'.

## Results

Evaluation of the two keys revealed that the Web-based key met 100% of the 32 identified cognitive engineering principles. For the paper-based key, 26 of the principles were applicable. Of these, the paper-based key consistently met 11 (42%), sometimes met 11 (42%), and did not meet 4 (15%). Principles not met by the paper key included:

***1. Distance vs. clutter,*** or the trade-off between scanning distance and visual clutter. This is a limitation of the paper medium, as all identification questions must be printed, causing visual clutter that can distract the user. The user must also look for the next step in the coding process and may forget the intended target number, requiring the user to go back to the previous step. The Web-based approach resolves this issue by displaying only one pair of questions at a time, and displays the appropriate next set of questions in response to the user's selection.

***2. Comprehension***, which can be improved by defining words that may be unfamiliar. The paper-based key does not provide a glossary, while the Web-based key provides both popup definitions and hyperlinks to glossary, and provides hyperlinks to other Internet-based resources.

3. ***Color-coding***. This was also a limitation of the paper medium, as all information was displayed in black and white. The Web-based version uses standard blue hyperlinks; changes the title bar color when an identification has been achieved; and utilizes red sparingly to draw the user's visual focus to important instructions. Finally, the variety of color photographs provides greater granularity.

4. ***Previewing information***. Again, the inability to preview information is a limitation of the paper medium. The Web-based key provides a short description of additional resources, such as thumbnails of pictures, which lets users know what to expect and helps them determine if they want to view the additional resource.

## Discussion

Distance versus clutter is perhaps the most significant drawback of paper-based keys. We minimized both visual clutter and spatial distance by displaying only one couplet at a time, and we used radio buttons with hyperlinks to display the next appropriate couplet when the user made a selection (Figure 3).

We reorganized the basic structure to support human cognitive processes. We grouped the most important data (the textual description) to the left of the screen and placed supporting line drawings and photographs immediately to the right, instead of below the textual description, to allow for more efficient horizontal eye movement. We minimized the use of colors and utilized red only to draw attention to important instructions and to indicate when a final identification had been obtained. Standard colors were used for hyperlinks. We incorporated the display of photographs of the suspect parasite to aid in identification. In order to allow the key to remain visible, we displayed the photograph in a "pop-up" window.

We improved comprehension by adding the ability to click on terms to access a glossary, which could also incorporate additional information such as definitions, line drawings, and photographs to aid the user in understanding terminology and vocabulary. To help the user determine if the identification is reasonable or possibly erroneous, we provided links to external Web pages that contained additional information about the identified parasite.

We also needed to provide a method to allow users to retrace their steps in the identification process. With a paper key, the user can simply use a pencil to mark each step; however, repeated erasures can degrade the quality of the key for the next use. We addressed this functionality by providing a "breadcrumb" trail along the top of each page showing the path that was used to reach the current point in the key. In addition, each step is hyperlinked, allowing the user to instantly go back to any point in the identification process.

In contrast to the paper-based key, we purposely did not display the identification until the user made a choice at the final step, as we felt this would assist the user in the learning process. The identification was then displayed at the bottom of the same screen, allowing the user to review their choices that led to the identification, and to make adjustments in their selection if necessary.

## Conclusion

We recognize that a Web-based key such as the one we describe is not appropriate for all uses and is in no way intended to replace more robust applications intended for researchers. However, we have identified specific drawbacks of the traditional printed key format, and have further provided suggestions for how this format could benefit by leveraging current multimedia technology.

While our analysis involved only a single identification key, we believe that these cognitive engineering principles are applicable to many other types of keys. The thoughtful application of these principles can improve both the usability and functionality of identification keys and we encourage further work in this area.

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