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The Persistence of Content Knowledge

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Abstract

Research has shown that changes in the way a website works or how it is laid out affects how well people are able to use that website. This study examined how changes in the content and procedures of a website-like system affect the way people recover from not being able to find information in that system. Participants were placed in one of four learning conditions, differing by the content and procedures taught for a simple website-like system. They were then tasked with finding certain pages in that system or systems with different procedures, content, or both. The first test (System B Online Test) showed that participants who had to learn new content were less efficient at finding that content, while participants who had to learn new content *and* procedures were the only ones slowed down. The second test (System C Online Test) showed that participants who had experienced a previous change in content responded to the new change faster, whereas people who started with inconsistent procedures (as compared to consistent) made fewer errors towards the end.

INTRODUCTION

One of the most prevalent concerns in designing any website is making it easy to use. “Ease of use” is the idea that to navigate the website efficiently, the user must be able to comprehend where things are. Researchers in both the computer science field and the psychology field have conducted numerous research projects to understand how to make websites more usable and accessible (e.g., Farris, 2003; Montgomery & Faloutsos, 2001; Richardson, Dominowska, & Ragno, 2007; Stronge, 2002).

To stay popular, websites must conform to some style. Between two sites that carry the same functionality, the new user would no doubt gravitate toward the more visually appealing site. Designers, therefore, are pulled in both directions; they have to make websites that work well but that continuously stay in line with the current style sensibilities. This updating of styles may require changes in the way the site navigates and where certain things are found within the site’s structure.

Previous studies (e.g., Farris, 2003) have shown that changing how a website is designed may negatively affect the ability of users who learned on the old website to transfer their knowledge to the new one. This study focuses on that problem from the purview of training by asking the following question: Does the manner in which people learn the way system works (the procedures of the system) and where things are (the content of the system) affect their ability to recover when that system changes?

Content and Procedures Knowledge

The focus of this study was on understanding if and how knowledge of a system transfers when the system changes. The goal was to assess what and how people learn after a relatively short interaction with a novel system. We examined two aspects of knowledge: content and procedures. Content knowledge was defined as the knowledge of the location of all the information in the system. This is the “where” of the system: the specific location of each piece of information in the system in relation to other pieces of information. Procedures knowledge was defined as the knowledge of how to navigate the system. This is the “how” of the system: what the user has to do to navigate the system to find each of the pieces of information.

Content, Procedures, and System Use

Both content and procedures knowledge have been previously linked to effects on system use. Specificity (Ehret, 2002) and consistency (Jones, Farris, & Johnson, 2005) of content have both been shown to aid system use, but even consistent content must be deemed “useful” to be considered; the user must believe the consistent content would help them achieve the new task (Payne, Richardson, & Howes, 2000).

Procedurally different (rather than similar) systems (Singley & Anderson, 1987) have been shown to cause less of a negative effect of efficiency and speed because similar systems take longer to be judged as different, so the small changes cause more problems until the user notices that the two systems have differences. There are also procedure effects when the system goes from simple to complex (rather than complex to simple) because the basic functionality of the simple system is easier to understand when learned *first*: the complex functionality masks the basic functions if given at the beginning (Franzke & Rieman, 1993).

Knowledge: Head vs. World

Norman (1988) postulated that humans have two different sources of knowledge: “knowledge in the world” and “knowledge in the head”. Knowledge in the world is the information available to the user from external sources. Knowledge in the head is the information the users have stored in their memory. Factors such as access cost (Gray & Fu, 2004) affect the participant’s choice to use one type of knowledge over the other. For example, knowledge in the world may cost more to access than knowledge in the head, causing the participant to use what is in their head rather than what is in the world. This has an effect on system usage and could affect how the user responds when the system (knowledge in the world) changes.

Overview of Present Study

The goal of the present study was to assess whether and how inconsistencies of content and procedures affect the use of a novel system. We compared the effects of different types of training on user performance for a new system that was content or procedure inconsistent.

In the first System Test (System B Online Test), if the content change affected the participants, we hypothesized that the change would have been likely to cause more errors at the beginning when the different content had to be searched for and found in the new

locations. It might also have caused the person to visit more pages which would take more time. If procedure changes affected the participants, we expected that it would only have lengthened the time taken to find the new content locations, as the participants would still have looked in the same places they would with the original procedures, it would just have taken longer for them to get there because of the time it took to learn the new procedures.

In the second System Test (System C Online Test), we expected that those who had already seen one content change would have been faster to recover from a second one. This means that the originally content inconsistent participants would have had fewer errors and been faster than content consistent participants. We did not expect procedures to make a difference in this second System Test, as, by this time, each participant had some experience with the online procedures.

METHOD

Participants

The participants in the study were twenty-nine undergraduate students from the Georgia Institute of Technology. One participant's data were not used due to computer error, leaving seven in each of the four conditions. The participants' ages ranged from 18 to 23 with a mean age of 19.75.

Materials

The stimuli were presented on Windows-based PCs using the psychology experiment program E-Prime 2 (Psychology Software Tools, 2008). Participants' navigation through the system (location and rate) was recorded by E-Prime. The stimuli used in this experiment were the fauna of Cyrus, an imaginary planet created for a biological learning study (Shapiro, 1999) and also used in Jones, Farris, and Johnson (2005). These eighteen fauna were arranged by two different characteristics: their prevalence (Extinct, Endangered, and Populous) and scientific grouping (Herding Animal, Meat Eater, or Bird). The fauna were organized into both paper outlines and websites for the participants to learn. Each outline listed the animal names arranged by these classifications. Each web site used these classifications to lay out the different animal-specific web pages.

Design

The different learning conditions were presented between-subjects in a 2×2 content by procedures design. Content condition was operationalized as whether or not the content presented in the learning system was consistent with System B. Procedure condition was operationalized as the procedures the participant was presented with (outline or online). The experiment flow for each condition is shown in Table 1.

There were two dependent variables. The first was interaction efficiency index (IEI), calculated by taking the number of page views the participant took to accomplish the task minus the minimum required (Jones, Farris, & Johnson, 2005). The second was task time, defined as the time (in seconds) between when the home page was presented and when the participant clicked on the correct animal's picture.

Procedure

The experiment took approximately two hours to complete. Participants signed a consent form, performed one of the four learning tasks, completed System B Online Test, completed System C Online Test, and then were debriefed. Participants were tested in groups of four or fewer. After consent, participants were given a small briefing on the imaginary planet Cyrus and its inhabitants. The participants were then given their learning system (either an outline or the online database) and a checklist with all 18 animals' names. The procedure flow for each of the four conditions and how each condition differs at each stage is outlined in Table 1.

In the learning phase, the participants received their prescribed learning system and were instructed to "find each of the individual animals on the checklist." After ten minutes, participants were given a paper assessment to assess their content knowledge of Cyrian fauna. This assessment comprised 20 multiple choice questions asking about the prevalence or animal type of one animal in the system. Twelve of the questions were about the six target animals, whereas the other eight were randomly chosen from the other twelve animals. Each of these assessments was on the system the participant had just used. This learning-assessing process was then repeated four more times to ensure system retention, with the participant given five minutes to learn in four subsequent cycles.

Before the System Tests, the participant was informed that a new transmission from Cyrus with updated information about life on the planet had been received. The method used for the System Tests was adapted from Jones et al. (2005) and is as follows.

In the System B Online Test, the participants were asked to find the page of a specific animal in the online version of System B. Six animals were chosen randomly as targets from the original eighteen. Each animal was searched for ten times for a total of sixty trials on System B. Each set of six trials (one per animal) comprised a block. These ten blocks comprised System B Online Test.

In each trial, participants navigated the system similar to a website to find the target animal. Once participants found the correct page, they were instructed to click the animal's picture to complete the trial. The system would then present the next animal to find and return them to the homepage. If participants gave up or forgot which animal they were searching for, they were navigated to the right animal by the experimenter. Once all six tasks had been completed, the order of those six tasks was randomized and the participant completed them again.

For the System C Online Test participants completed ten blocks of trials (sixty total) on System C. The six target animals in System C Online Test were the same ones found in System B Online Test. There were also paper assessments similar to the ones taken during learning after each System Test, but these will not be discussed in this paper.

RESULTS

The data were analyzed to answer the following questions. First, how does the way people learn the content and procedures of a system affect the way people respond when that system changes? Second, how does a second system change affect these differences? To this end, we analyzed three of the ten six-trial blocks in each of the two System Tests for both dependent variables (Interaction Efficiency Index (IEI) and Task Time). To assess initial differences between conditions, we analyzed blocks one and two of each System Test. For differences after practice with the system, block ten was analyzed. All tests were two-way fixed-effects ANOVAs with content and procedures crossed. Before any analyses were conducted, all data were checked for outliers. All trials with data two standard deviations outside the mean of Interaction Efficiency Index were eliminated. This eliminated 58 data points out of 3360 or 1.73% of all data.

System B Online Test – IEI

The Interaction Efficiency Index (IEI) was measured by subtracting the optimum number of pages needed to get to the animal from the amount of pages the participant actually took to get to that animal. This means that an IEI of zero would denote a perfect trial and that the lower the IEI, the more efficient the participant was at finding the animal. The IEI data for all four conditions on System B Online Test are shown in Figure 1.

The two System A conditions, where the participant learned on a system that was content inconsistent from the one they were tested on, performed worse throughout than those in the System B conditions wherein the content was consistent with the learning phase. This benefit of content learning was reflected by significant differences between content conditions at blocks one, two, and ten ($F = 131.79, 26.48, \text{ and } 9.46, p = < .001, < .001, \text{ and } .002$, respectively). These data were consistent with Jones, Farris, and Johnson (2005). The procedures conditions did not differ from each other in any block (all $ps > .05$), suggesting that having to learn the procedures of the system had no significant effect on participant efficiency. There were no significant interactions between the content and procedure conditions at blocks one, two, or ten (all $ps > .05$).

System B Online Test – Task Time

Task time was defined as the time between the instant the home page was shown and the instant the participant clicked on the target animal. The task time results (in milliseconds) for System B Online Test are shown in Figure 2.

As expected, the participants who learned on System A had a high task time for longer. Because they were also less efficient, much of this could be due to the significant correlation between task time and IEI ($r = .72, p < .001$). It took longer for the participants who had learned on the content inconsistent system (System A) than those who had learned on the content consistent system (System B). The differences between content conditions were significant in blocks one and two ($F = 43.58 \text{ and } 21.69, p = < .001 \text{ and } < .001$, respectively). By block ten, though, both content conditions were performing at the same rate ($F = 3.42, p = .066$).

Procedures also made a difference, as users who learned from an outline had a harder time at the beginning. There were significant differences between procedures conditions in block one ($F = 12.28, p = .001$). Both procedures conditions reached to a similar level by the end, however ($p > .05$ for blocks two and ten). Most interesting, however, was the interaction between content and procedures at block one ($F = 5.79, p = .017$). Post-hoc Tukey t-tests were done at familywise alpha = .05 and Bonferroni corrected across all four conditions at block one. The results were as follows: The participants in the content and procedure inconsistent condition (Outline, System A) were significantly slower than any of the other three conditions (p 's $< .001$). There were no significant differences between any of the other three groups. The results suggest that the combination of inconsistent procedures *and* inconsistent content was what made these participants so slow to start. There were no significant interactions between content and procedure conditions at blocks two and ten (both p 's $> .05$).

System C Online Test – IEI

The System C Online Test required all participants to transfer to new content. The IEI results for System C Online Test are shown in Figure 3.

Participants who learned System A originally started with higher efficiency (low IEI) than those with System B. The participants were told that the system had been updated before both testing phases, so the second time, the System A participants might have been primed by this information. This was supported by the main effect of content at block one ($F = 9.05, p = .003$). Blocks two and ten were not significant ($p > .05$ for both). Second, the two outline conditions ended lower than the two online conditions, showing a significant difference in procedures. This was evident in significant differences between procedures conditions at block ten ($F = 8.46, p = .004$). This effect could be due to a difference in how participants internalized the information they learned. Those who learned from a procedure-inconsistent system (the outline) may have arranged the information in the system differently and been better able to change the information to make fewer errors. There were no significant procedures differences at blocks one and two ($p > .05$ for both). There were also no significant interactions of content and procedures at blocks one, two, or ten (all p 's $> .05$).

System C Online Test – Task Time

The task time results for System C Online Test are shown in Figure 4.

The results at the beginning of System C Online Test for task time mirror those from the System C Online Test IEI data, probably again due to a high correlation between the two ($r = .77, p < .001$). The people who originally learned inconsistent content (System A) were significantly faster than those that learned consistent content (System B) at block one ($F = 11.48, p = .001$). The results for block two and ten, however, do not show the same differences between content conditions ($p > .05$ for both). There were significant differences between procedures conditions at block two ($F = 4.10, p = .045$), but it is not clear whether this is meaningful, as there were no differences at block one or ten. There were no significant interactions between content and procedures at blocks one, two, or ten (all p 's $> .05$).

DISCUSSION

The main goal of this study was to determine whether the consistency of content and procedures knowledge gained while learning a system affects how people perform when that system changes. These findings could have implications on how people react to changes in the way data are organized and presented on websites or any similar digital data repositories.

In the first test, the System B Online Test, we assessed the influence of changed content and procedures on performance. We found that participants were more efficient when the system was consistent with the content they know, regardless of whether it uses the same procedures. When both were changed, however, people performed significantly slower. This would suggest that changing both at the same time would limit the users' abilities to update their knowledge in a short period of time. These results mirror those findings in Jones, Farris and Johnson (2005).

The System C Online Test measured whether prior exposure to content or procedure change improved adaption to another change. The first trend, that people who were used to content change responded and recovered faster, seems to show that users that are more ready for content to change respond faster when it does.

The second trend, that people who originally learn from another set of procedures outpace those who learn from a similar system after a time, could suggest many different things. First, it could be that the outline was a better way to learn the system, but participants in both procedures conditions performed similarly on the paper assessments at the end of the learning phase, showing that there were no significant differences in how much of the content different procedures allowed the participant to learn. The other possibility was that the participants who learned using an outline have better content knowledge of the system, having learned it in two ways. Learning from one way and then being tested on another may have given them a better internal model from which to recall.

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References

- Blackler A, Popovic V, Mahar D. The nature of intuitive use of products: an experimental approach. *Design Studies*. 2003; 24(6):491–506.
- Cooke NJ, Salas E, Cannon-Bowers JA, Stout R. Measuring team knowledge. *Human Factors*. 2000; 42:151–173. [PubMed: 10917151]
- Ehret, BD. CHI 2002. Minneapolis, Minnesota: CHI; 2002. Learning where to look: Location learning in graphical user interfaces; p. 237-288.
- Farris, JS. Unpublished Doctoral Dissertation. Kansas State University; Manhattan, Kansas: 2003. The human-web interaction cycle: A proposed and tested framework of perception, cognition, and action on the web.
- Franzke, M., Rieman, J. Vienna Conference on Human computer Interaction. Vienna, Austria: Springer-Verlag; 1993. Natural training wheels: Learning and transfer between two versions of a computer application; p. 317-328.

- Gray WD, Fu WT. Soft constraints in interactive behavior: The case of ignoring perfect knowledge in-the-world for imperfect knowledge in-the-head. *Cognitive Science: A Multidisciplinary Journal*. 2004; 28(3):359–382.
- Jones KS, Farris JS, Johnson BR. Why does the negative impact of inconsistent knowledge on web navigation persist? *International Journal of Human-Computer Interaction*. 2005; 19(2):201–221.
- Montgomery AL, Faloutsos C. Identifying web browsing trends and patterns. *Computer*. 2001; 34:94–95.
- Norman, D. *Design of everyday things*. New York: Basic Books; 1988.
- Payne SJ, Richardson J, Howes A. Strategic use of familiarity in display-based problem solving. *Journal of Experimental Psychology: Learning, Memory, and Cognition*. 2000; 26(6):1685–1701.
- Psychology Software Tools, I. *E-Prime 2.0 (Version 2.0)*. Pittsburgh, PA: Psychology Software Tools, Inc; 2008.
- Richardson, M., Dominowska, E., Ragno, R. Predicting clicks: Estimating the click-through rate for new ads. 16th International Conference on the World Wide Web; Banff, Alberta, Canada: ACM; 2007. p. 521-529.
- Shapiro AM. The relevance of hierarchies to learning biology from hypertext. *Journal of Learning Sciences*. 1999; 8:215–243.
- Shipley, W. *Shipley Institute of Living Scale*. Los Angeles: Western Psychological Press; 1940.
- Singley MK, Anderson JR. A keystroke analysis of learning and transfer in text editing. *Human-Computer Interaction*. 1987; 3(3):223–274.
- Stronge AJ, Rogers WA, Fisk AD. Web-Based Information Search and Retrieval: Effects of Strategy Use and Age on Search Success. *Human Factors*. 2006; 3(48):434–446.
- Wechsler, D. *Wechsler Memory Scale III*. 3. San Antonio, TX: The Psychological Corporation; 1997.

Figure 1.
Interaction Efficiency Index in System B Online Test.

Figure 2.
Task Time in System B Online Test.

Figure 3.
Interaction Efficiency Index in System C Online Test.

Figure 4.
Task Time in System C Online Test.

Table 1

Procedure flow by condition.

Learning Phase	System B Online Test	System C Online Test
Outline of System A	Inconsistent Procedures Inconsistent Content	New Content
Outline of System B	Inconsistent Procedures Consistent Content	New Content
Online with System A	Consistent Procedures Inconsistent Content	New Content
Online with System B	Consistent Procedures Consistent Content	New Content