The Use of Timed Directional Link Analysis to Improve User Interaction during Universal Remote Control Setup Procedures

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Abstract. The universal television remote control is one of the most common pieces of household technology in the industrialized world. In spite of the ubiquity of the television remote, the complexity of the device often means that consumers find universal remotes to be confusing to operate, particularly when programming the remote to operate a new device or piece of technology. The present study employed an advanced version of a technique called link analysis in order to decompose how a typical user would go about programming a remote control in order to better understand where users might become confused during a standard setup procedure. Next, the authors worked with a project development team at Universal Electronics Incorporated (UEI) to produce a new model of the remote that was easier to use. Finally, the setup procedures of the new version of the remote control were tested against the previous version in a short usability test. The results of the study confirmed that programming new devices using the redesigned remote was faster, less error prone, and subjectively rated by users as easier to accomplish. These findings suggest that timed directional link analysis may be a viable technique that designers and human factors psychologists can utilize to improve the user experience of consumer electronics.

Keywords: Remote Control; Usability Testing; Link Analysis; Product Design.

1 Introduction

Developed in 1956 by Eugene Polly and Robert Adler, the television remote is a special type of technology, one that has become truly ubiquitous in the homes of industrialized societies. The success of the television remote control led to the development of additional remote controls for other types of home entertainment (e.g., the stereo receiver, the DVD player). As home entertainment systems grew in scope and complexity, many consumers realized that having a different remote control for each device confusing. In the wake of the influx of numerous specialized remote controls, demand grew for a 'universal' remote control, one that could control many different devices regardless of their function or manufacturing origin [1]. Consumers and electronics manufacturers alike thought that by replacing multiple

D. Harris (Ed.): EPCE/HCII 2013, Part I, LNAI 8019, pp. 104–113, 2013.

dedicated remote controls with just one device, they could make user interactions with home entertainment systems faster, easier, and more intuitive.

Universal remotes have certainly accomplished some of the goals of their many developers set out. Not only have universal designs helped to unclutter coffee tables everywhere, but they have also allowed consumers to learn how to operate one remote rather than the many that may accompany each component of a complex home entertainment system. The ‘Atlas’ universal remote, developed by Universal Electronics Inc. (UEI), can be programmed to control several hundred models of home entertainment equipment regardless of their manufacturer or year of production. Because of its reliability and relatively low cost, the Atlas has become one of the most common universal remote controls available in the Unites States.

Fig. 1. Universal Electronics’ Atlas universal remote control model

Although universal remote controls are commonplace, users do not always find remote controls to be user friendly. The Duke of Edinburgh, a famous advocate for usability in technology, quipped in 2009 that “to work out how to operate a TV set you practically have to make love to the thing,” and an online search will quickly yield reviews, blogs, and even designers’ personal websites that point to remote control designs as very good examples of very poor human factors. One of the major barriers that seems to limit designing user friendly universal remotes is that the remotes, by definition, are intended to control an incredible variety of different products that have been developed by other product design teams. As a consequence, universal remote control designers must try to balance the demands of supporting a great many products and systems with the demands of creating user-friendly products.

The work reported here represents one attempt by one of the world’s leading manufacturers to strike a better balance between product support and ease of use while redesigning one of their most popular universal remote controls, the Atlas. To improve the human factors of the Atlas remote, the product development team employed multiple task analysis techniques, but this paper focuses specifically on a technique called *link analysis*, a technique that is particularly useful for analyzing the links between parts of a system as a person shifts her focus of attention between them [2]. Specifically, the link analysis reported here investigated how people shift their attention between printed instructions and the button clusters of the remote control while programming the device to control new products and systems.

1.1 Link Analysis

Link analysis is a task analysis method that identifies patterns of interactions between a human and systems ranging from small handheld interfaces to large-scale work environments. The "links" in the analysis represent one of three types of actions: mental shifts in operator attention, physical movements in operator behavior, or verbal communications between multiple operators (see [2]). In a traditional link analysis, the analyst tallies the sequential shifts in actions between these three types of interactions during normal system operation, and in doing so, he or she learns how an operator interacts with a system during a given procedure. Connection frequency data is then typically displayed on a resulting 'link table,' which forms a tabular representation of the task in a way that highlights areas of frequent system-user interaction. While link analysis is a useful task decomposition method in many domains, link analyses are perhaps most useful when link tables of the interactions allow the analyst to consider complicated interactions in a tabular format that may highlight frequent actions that are potentially complicated or frustrating for a user. In doing so, those interactions may be flagged for redesign when a product or system is upgraded, modified, or redesigned.

In spite of link analysis' usefulness, researchers have recently addressed limitations in this task decomposition method by modifying the traditional link analysis technique itself. For example, some researchers have developed computer-based link analysis techniques that allow algorithms for describing user interactions to optimize an interface layout for maximum efficiency [3]. Other researchers have noted that traditional link tables lack both directionality, information about whether a link represents an action that is moving towards or away from a given part of a system, and weighting, information about how relatively complicated or time consuming any given action is to complete.

Lin and Wu [3] addressed the lack of directionality and timing data by developing a directional link analysis, a technique whereby the direction of actions are recorded by an analyst and used to populate a modified link table [4]. As shown in Figure 3, a directional link analysis table represents system sub-areas along the side and top of the table, but the starting points of user interactions are always represented on the left vertical column, while the targets that the user's actions move towards are represented in the top horizontal row. Lin and Wu also addressed the issue of how different actions can affect usability by proposing a system whereby computer modeling is used to establish weighting variables that are assigned to links, although this process also requires that the analyst use a computerized version of link analysis.

Because link analysis was initially designed to be a relatively simple task decomposition method that can be achieved with paper and a pencil [2], we devised a simpler method in the study reported here called Timed Directional Link Analysis (TDLA), a link analysis technique that combines the directionality of the link tables used by Lin and Wu [3] with basic time information about each action sequence similar to those used during keystroke level modeling techniques [5]. By measuring or estimating the average time it would take a user to complete an action, essentially the time it takes for them to move from a start position to a target position, each link in the bi-directional table can be weighted with time information which will allow an analyst to determine which actions may be most burdensome to the user. As a result, the analyst can make recommendations to designers to either decrease the frequency of a cumbersome action, decrease the time it takes to complete a cumbersome action, or both, thereby improving the human factors considerations of the product or system.

2 Methods

To complete a TDLA of the Atlas remote, it was first necessary to define specific areas of the remote control and instruction manual. We identified four main areas used during new product setup: 1) the 'Setup' located at the top of the remote that consisted of the mode keys and setup button, 2) the numeric keypad located near the bottom of the remote control, 3) the step-by-step instructions found in the user manual, and 4) the list of numerical codes printed in the back of the user manual that corresponded to the hundreds of programmable brands and models that were supported by the universal remote. We reasoned that these were the major areas that a typical user would be required to successfully setup a new product that could be controlled by the Atlas remote (see Figure 2).

PROGRAMMING DEVICE CONTROL

The Atlas OCAP 5-Device Remote Control with Learning is preprogrammed to operate the cable box (converter) provided by your cable system, an RCA TV, a Toshiba DVD player, an RCA VCR, and a Pioneer audio receiver. To control devices other than the default brands, perform the following steps; otherwise skip this section.

NOTES: For control of a Combo device (for example, a TV/VCR combo), skip this section and perform the instructions on "Setting Up a Combo Unit" on page 11. Also refer to "Device Table" on page 8 to find out which devices can be programmed onto each device key.

If you have another brand of cable converter or a satellite receiver you would like to control, you'll need to unlock the cable ID Lock before changing the converter code (see "Programming Cable ID Lock" on page 20).

1. Turn on a device and, if applicable, insert video media, (e.g., cassette or disc).

NOTE: Please read steps 2 through 4 completely before proceeding. Highlight or write down the codes and device you wish to program before moving on to step 2.

2. On the remote control, press a device key once (i.e., **VCR, DVD, AUD, TV,** or **CBL**); it will blink once. Then press and hold **SETUP** until the selected mode key blinks twice.

3. Use the "Manufacturer's Codes" starting on page 28) to locate the type of device and brand name and then enter the first four-digit code for your device. If performed correctly, the selected mode key will blink twice.

NOTE: If the selected mode key emits a long blink, the entry is invalid. Repeat steps 2 through 3 and try entering the same code again.

4. Aim the remote control at the device and press **PWR** once. The device should turn off. If it does not, repeat steps 2 through 3, trying each code for your brand until you find one that works. If it still does not respond, try searching for the code (see "Searching for Your Code" on page 13).

NOTE: If the device does not have a **PWR** key, press the ▶ (Play) key.

Setup Codes for DVD Recorders

Apex Digital	1056
Aspire Digital	1168
Coby	1086
CyberHome	1129, 1502
Funai	0675, 1334
Gateway	1073, 1158
Go Video	0741, 1158, 1304, 1730
iLo	1348
JVC	1164, 1275
Kreisen	1421
LG	0741
LiteOn	1158, 1416, 1440
Magnavox	0646, 1506
Panasonic	0490
Philips	0646
Pioneer	0631
Polaroid	1086
RCA	0522
Samsung	0490
Sensory Science	1158
Sharp	0675
Sony	1033, 1431, 1432, 1433
Sylvania	0675
Zenith	0741

Setup Codes for DVD Combos (LCD)

Akai	0695
Audiovox	1071, 1121, 1122
iLo	1472
Initial	1472
LG	1526
Mintek	1472
RCA	1193

Fig. 2. The numeric keypad (rectangle) and setup (oval) portions of the remote, plus the instructions and an example of a code page from the instruction manual. Shifts between these four areas are represented by 'links' on the TDLA table shown in Figure 3.

Using the instructions and estimated action times, we then populated a TDLA table to illustrate orders of actions and the times necessary to complete them. We made two assumptions about how a user would interact with the product in order to complete the link analysis. First, we assumed that the average user would need to look up 2 codes before they found the code that correctly controlled his or her device. Second, we assumed that the user would not make any mistakes during the setup process. In reality, we note that both assumptions may be too optimistic – certainly users make errors or own products that cannot be controlled by the first or second code supplied by UEI. Reasonable assumptions made by the analysts that are held constant across product comparisons are necessary for an analyst to make while completing TDLA tables and many other task decomposition techniques [2]. With these assumptions in mind, we developed the TDLA table shown in Figure 3 representing the actions of a typical user who is using the Atlas instruction manual and remote to setup a new device that succeeds after the second code and makes no errors.

	T_{SETUP}	$T_{NUMBERS}$	$T_{INSTRUCTIONS}$	T_{CODES}
S_{SETUP}			2 (1.2 sec.)	…
$S_{NUMBERS}$	2 (1.2 sec.)		…	
$S_{INSTRUCTIONS}$	1 (1.2 sec.)	2 (6.7 sec.)		2 (37.6 sec.)
S_{CODES}	…		2 (1.2 sec.)	

Fig. 3. A TDLA table representing an average user as they attempt to program the Atlas remote while making no errors and cycling through two possible remote codes

2.1 Interpreting the TDLA Table

Two primary user-interaction observations were made following the TDLA of the Atlas remote. First, the Atlas redesign team realized that there were a total of 11 action links, a relatively large number, representing the various interactions that a user needed to make in order to setup a new device. Second, the team realized that one directional action link, users who finished reading the instruction and went to look up a code, was taking users much longer than they had anticipated. As shown in the grey cell in Figure 4, users took approximately 37.6 seconds to shift their attention away from the instruction set to the proper code listed in the back of the instruction manual. The problem was made worse because of the large numbers of codes that the user needed to search through, and because the codes were listed on multiple pages of the manual.

2.2 Redesigning the Atlas Remote

Data from the TDLA task decomposition method was provided to designers at Universal Electronics, who were also given the results of some past usability tests that suggested that users frequently committed errors while attempting to setup new products using the Atlas remote control. On the basis of this feedback, the designers were tasked with incorporating these findings into a large Atlas redesign effort. Virtual and physical prototypes were created based on the results of the TDLA and other forms of user testing, but the designers placed an emphasis on improving the setup functions of the remote. As shown in Figure 4, the result of the redesign effort was a new universal remote control named ‘Champion,’ which was released publically in June of 2011.

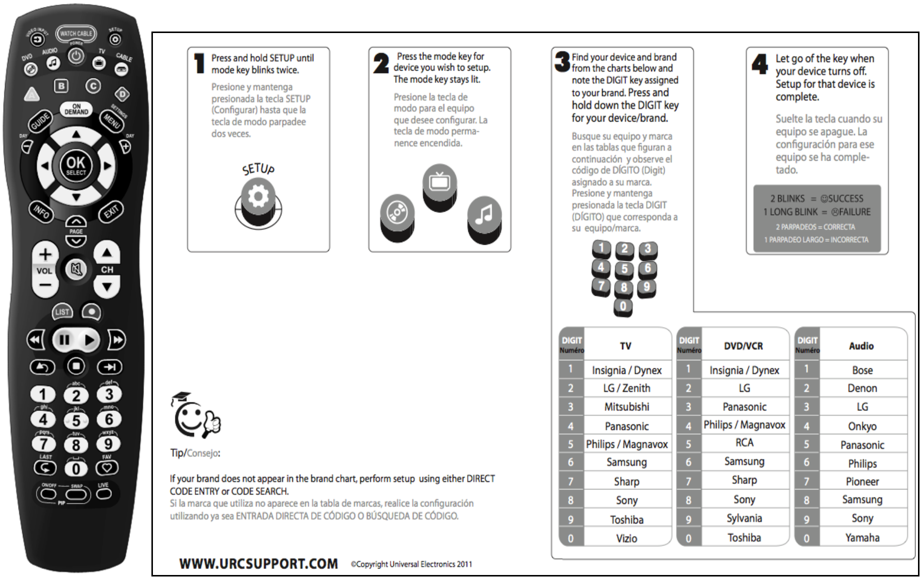

Fig. 4. The Champion universal remote (left) and the simplified ‘Popular Brands’ instruction set (right). Both were created to eliminate problems with Atlas setup found via TDLA.

Many new features have been included in the Champion, but two were specifically designed to improve on some of the problems during the setup procedure that the TDLA had identified. First, the designers recognized that a setup procedure that required fewer user action links (i.e., fewer shifts in action or attention) might make the setup procedure less overwhelming to the user. Second, the designers recognized that the time involved in looking up codes from the back of the Atlas manual should somehow be reduced. The primary solution that the designers reached was to develop a shortcut method for programming most new devices, which the designers called the ‘Popular Brand’ method. Using the Popular Brand setup method, users followed a greatly simplified procedure that required fewer actions (see Figure 4). Users were much less likely to need to look up codes because 10 of the most popular television, DVD player, and audio receiver brands were pre-programmed into the remote.

A second change made by UEI designers addressed situations where users needed to still use codes because a device was not among the 10 most popular brands. The original Atlas instruction manual was a small 59-page booklet, which created large delays when users flipped through pages to look up codes listed in the back of the manual. To address this, the designers decided that the Champion's user manual would be printed on one large double-sided 13 x 18 inch instruction sheet. The resulting instructions were much larger, but users did not have to flip between pages to look up codes using the new manual.

2.3 Comparison Testing of the Existing and New Remotes

Participants. Fifty-nine students from George Mason University volunteered to participate in a new usability test comparing the setup procedure of the Atlas and Champion remote controls. Participants ranged in age between 18 and 50 years of age, with a mean age of 20.8 years. Forty-seven percent of the participants in the sample identified themselves as female.

Design and Procedure. Participants in this study were randomly assigned to use either the Atlas or Champion, and their accompanying instructions, to complete a series usability tests. In the first usability test, participants programmed their remote to control a 2011 model LG television. The television model used in the first test was selected because it appeared on the Champion's list of the 10 most popular brands, and therefore was an appropriate test of whether the UEI designers' improvements to the setup procedure had been effective.

In the second usability test, participants programmed the remote to control an audio receiver. The audio receiver used in the second test was selected because it did not appear on the Champion's list of the 10 most popular brands, and was therefore a test that focused on the Champion's redesigned code-based setup procedure.

Measures. During usability testing, participants sat in a small laboratory in a comfortable chair facing a table that held the television and audio receiver. When the participant was ready to begin, he or she programmed the remote to control the television or audio device, and the experimenter timed how long it took participants to do so successfully. The experimenter also made note of any overt errors that the participants made, and these were tallied for later comparisons. At the conclusion of each usability test, participants were asked 'now that you have completed this task, please rate how easy you felt it was to accomplish using the remote control and instructions that you were provided?' Participants answered on a 7-point Likert like scale. A response of 1 indicated the procedure was 'not very easy,' 4 indicated that the procedure's ease was 'average,' and 7 indicated the procedure was 'easy to accomplish.' The rating procedure was adopted from those outlined by Lewis (1995).

3 Results

Two multivariate analysis of variance tests (MANOVAs) were conducted to test for reliable differences between the time, number of errors, and participants' ease-of-use ratings when participants were using the Atlas or Champion remotes. The first

MANOVA tested whether the 'Major Brands' setup procedure that was incorporated into the Champion remote setup procedure had resulted in a faster and more error-free setup procedure. As shown in Figure 5, the MANOVA revealed an overall significant effect of the remote condition, $F(58, 2) = 5.65$, $p < .01$. Champion users completed the setup procedure more quickly, $F(58, 2) = 17.07$, $p < .001$, and with fewer errors, $F(58, 2) = 10.68$, $p < .01$.

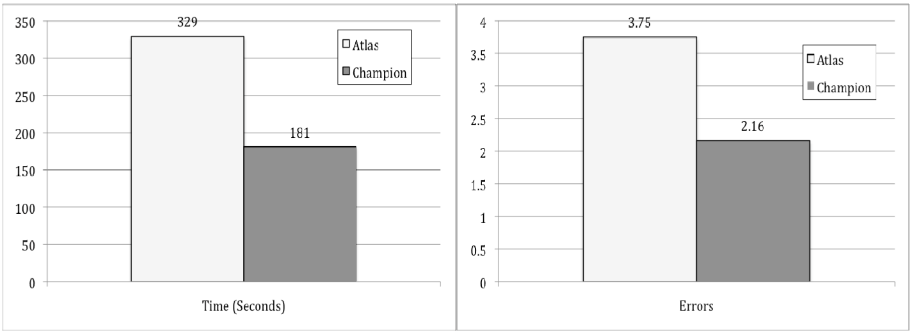

Fig. 5. Time to complete setup and error data, split by remote condition

The second MANOVA tested whether the simplification of the Champion instructions would improve the code-based setup procedure that had to be used when programming the remote to control a non-major brand. But before we could do so, we needed to address a large heterogeneous practice effect that was discovered in the Atlas condition. Because participants in the Atlas condition had already been asked to setup a television using coded entry during their first usability test, Atlas testers had already 'practiced' the coded entry method in the previous round of testing. Although they were being asked to find a new code that matched the audio receiver in the second test, we found that they were completing the task much more quickly, likely because they had memorized some of the procedure from the previous round of testing. This made direct comparisons against Champion users problematic because they were using coded entry procedures for the first time. Because of the practice effects, we decided that best test of whether the coded entry method was improved on the Champion remote was to compare the data we had gathered during the first round of Atlas testing against the data from the second round of Champion testing. In doing so, we more accurately compared how a new user would react to the different coded entry procedures the first time they used them, which was the focus of the testing.

As shown in Figure 6, the second MANOVA revealed an overall significant effect of the remote condition, $F(58, 2) = 5.92$, $p < .001$. Champion users again completed the setup procedure more quickly, $F(58, 2) = 18.37$, $p < .001$, and with fewer errors, $F(58, 2) = 7.49$, $p < .01$.

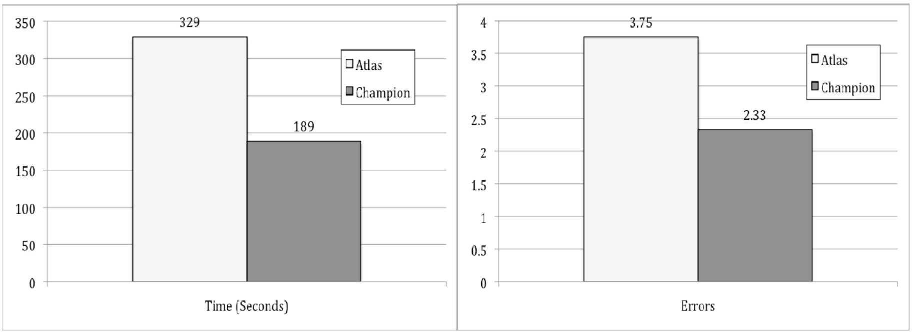

Fig. 6. Time to complete setup and error data, split by remote condition, during the second usability test

4 Discussion

The results of the usability tests revealed that the changes that UEI designers made to improve the user experience of programming the remote to control a new device were largely successful. Champion users completed the major brand setup procedure more quickly and with fewer errors than Atlas users, and Champion users anecdotally indicated that they felt that it was easy to operate the when using the major brands procedure. The designers were also successful at improving the time and error rates for using coded-based setup procedures.

Remotes that are produced at UEI are designed to control literally hundreds of manufactured products, and can be programmed to support thousands of different product models produced by those manufacturers. In a competitive marketplace, the adaptability of these remotes is clearly paramount. But companies like UEI who are committed to improving their products' human factors properties may indicate a shift in the remote control market, one where human factors will play a greater role. For example, as the technology behind home entertainment equipment continues to evolve, many products will gain Internet connectivity, an advance that will allow remote control systems to connect to devices regardless of their make or model. Given a market where all remote control systems are truly 'universal,' the adaptability of remotes may become something that users simply assume, making the human factors of remote controls just as important as they have become in the cellular telephone, gaming, and personal computer industries.

We believe that the choice whether or not to invest time and resources towards human factors considerations may make the difference between those companies that succeed and those that diminish as the marketplace for home entertainment electronics continues to evolve. UEI shipped an astonishing 200 million remote controls worldwide in 2011. We hope that our work with UEI will add human factors value to their product line, and also that it will decrease a few of the headaches that customers will experience as they program them to operate their home entertainment equipment.

Irrespective of remote control design, this project highlights the utility of link analysis as a useful task decomposition method for human factors analysts who are working to improve interactive technology. The technique requires relatively little training, and requires few resources to employ beyond detailed access to a product or system and a stopwatch. The modifications that we have introduced here to basic link analysis also should allow an analyst to recognize that not all actions, or even directions of actions, are created equal. In this study, our participants took longer to look up codes than to return to the instructions after finding them, but this same principle extends to many other domains where link analysis would be made more effective if weighting and directionality were taken into account. Employees take longer to go up stairs than to go down them, baggage screeners use more effort to begin visual searches than to complete them, and doctors can leave an operating room in seconds, but are required to complete a lengthy 'scrub in' procedure before they can return. These and many other interactive tasks can therefore be better analyzed when the analyst has the directional and weighting abilities that TDLA affords.

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