

# ERRORS IN SPREADSHEET USE

by

**Barry D. Floyd**

and

**Jisurk Pyun**

Information Systems Area  
Graduate School of Business Administration  
New York University  
90 Trinity Place  
New York, N.Y. 10006

October 1987

Center for Research on Information Systems  
Information Systems Area  
Graduate School of Business Administration  
New York University

## Working Paper Series

CRIS #167  
GBA #87-111

## **Abstract**

Fourteen experienced users of two commercial spreadsheet packages, Lotus 123 and Multiplan, performed four tasks - two of entering spreadsheets and two of modifying those same spreadsheets. Their actions were videotaped and analyzed for incidents of errors. Over 450 errors were made, the majority of them centered around the visual properties of the spreadsheet packages. A classification of the errors is presented with an analysis of the causes governing the production of the errors. A discussion of the choices in the design of the interface which facilitated the production of these errors is also presented.

## Table of Contents

1. Introduction	1
2. What is a spreadsheet?	2
3. The Experiment	4
4. Results	6
4.1. Classes of errors	6
4.2. Errors in contrast	10
4.3. Time and error performance	11
5. Discussion	12
6. Future Research	14

## 1. Introduction

The task of entering a model into the world of the computerized spreadsheet is one performed thousands of times a day. Decisions of material importance to the firm are made from the analysis using these models entered into computerized spreadsheet programs. However, errors have also found their way into the spreadsheet representation of these models. While system use doesn't appear to be diminishing, concern over the accuracy of these models is increasing. A recurring topic in the popular literature on spreadsheets is a discussion of the decisions which have been made based upon incorrect models and the disastrous results which followed.

A necessary step towards reducing these errors in spreadsheet models is an understanding of the type and frequency of these errors. Given the type of error and the frequency of its occurrence in the performance of various subtasks associated with spreadsheet use (e.g., specifying a formula), we can ask whether it possesses a causal relationship with some aspect of the system design. We can then focus on determining what this underlying cause may be and the psychological principles involved.

In a paper on the cognition involved in interacting with computer based spreadsheets, Olson and Nilsen (1986) identify two major components of system usage: planning the task to be performed and then executing the subtasks associated with the planned task. Our research focusses on the latter component of spreadsheet use: executing the task (i.e., entering and modifying a spreadsheet model) - and the difficulties one faces in doing so. We have focused on task execution because the type of interaction the user experiences with electronic spreadsheets is qualitatively different from one's interactions with most of the systems available in the past. Those systems relied on a user's memory to recall commands and command syntax. The mode of interaction in executing tasks in today's systems, such as electronic spreadsheets, is moving towards the style of direct manipulation. The interaction with these systems is dominated by our perceptual processes which leads to an interesting set of issues in system design.

The nature of computers today restricts the size of displays and thus the amount of

information which can be presented to the user at one time. Spreadsheets are by design a visual interface moderated by the size of the screen in the computer display. This fact coupled with the constraints on the human information processing system, such as limited short term memory and a limited effective field of vision (Mackworth, 1976), calls for a synthesis in design information between the two systems (user and spreadsheet) with an emphasis on how the visual properties of the spreadsheet are managed. However, our perception is that many spreadsheet design choices place stress on the user's ability to perform error free behavior in entering a spreadsheet model by failing to compensate for these visual and memory limitations. The s of today separate the entry of the information from the area in which it is used. They provide few and relatively distant landmarks for visual reference. An overview perspective of the spreadsheet is seldom provided. Furthermore, much of the information contained in the spreadsheet is hidden from view - even when the cell is shown on the screen (i.e., formula specifications).

Our initial work then, centers on the visual properties of the spreadsheet package and on how well the user performs in this complex environment. The performance metric of interest is that of error production rather than, say, speed of model entry. We focus on errors because we believe that, unlike word processing where speed is of key interest, the number of errors and, more importantly, the type of errors are a more fundamental issue in system acceptance. In this paper we report the results of a study where users performed a series of relatively simple tasks with a spreadsheet and in performing these tasks made a significant number of errors. We classify these errors and discuss the psychological principles behind the errors and the design decisions which we believe facilitated their occurrence. Before beginning however, we provide a brief description of some of the salient properties of a popular implementation of an electronic spreadsheet.

## **2. What is a spreadsheet?**

The prototypical spreadsheet provides a two dimensional grid of cell locations with column and row labels so that each cell can be referenced (see Figure 1). This grid contains thousands of cells with only a hundred or so visible to the user at any one

time. The user interacts with this two dimensional grid by moving a pointer over the cell whose contents he would like to define (or to modify if there already is a cell specification). Moving to a particular cell can be accomplished in a number of ways. Locally, one can move a cell at a time using one of four directional keys. One can also use page commands to move more than one cell at a time. Other more powerful options exist at the command level where you can jump to a particular cell or group of cells.

To provide a specification for the cell, information is typed in a separate window located at the top left hand side of the screen for packages such as Lotus 123 (see Figure 1) and in the bottom of the left hand side of the screen for other packages such as Multiplan (see Figure 2). The contents of the cell can be labels, numeric data, formulas or commands (a series of stored commands defines a macro). The power of the spreadsheet is derived from the specification of formulas which reference the contents of other cells. However, this power is also accompanied by an extremely complex scenario of information.

What the user sees as a result of his cell specifications depends on the type of information entered. For numeric data the user sees the data that has been entered but modified by any formatting instructions such as rounding. For labels and spreadsheet commands, the user only sees the characters entered except for the beginning character which is used for indicating that the entry consists of characters and/or for indicating the format of the cell. The specification of this additional character is optional for Lotus users. However, the system defaults to (1) left justified alpha fields and right justified numeric fields and (2) numeric defaults for character strings which begin with a number or an arithmetic character (including parentheses and @ signs). In Multiplan, the user must enter a character indicating either alpha mode or value mode. For formulas, the user sees the results obtained from the execution of the formula. To view the formula itself, the user must position the cursor over the cell. When this is done, the contents of the cell are displayed to the user in a window located near the one used for cell entry.

The user may also interact with the system via a set of commands. These commands allow the user to perform a variety of functions such as copying or moving cells, naming cells, protecting cells from modification, modifying the physical nature of the spreadsheet such as adding rows and columns, changing cell widths, etc. In general, these commands are useful in operating on groups of cells, reconfiguring the spreadsheet, and in interacting with the outside world (e.g., printing the spreadsheet or retrieving files). Although there are other more complex aspects of a spreadsheet such as database and graphics functions, these characterize much of the system the user interacts with.

### **3. The Experiment**

Videotapes were made of fourteen subjects performing four tasks using one of two different (but very similar) electronic spreadsheets: Lotus 123 and Multiplan. The fourteen subjects were full-time MBA students at The University of Michigan Graduate School of Business Administration. They were also experienced users of either Lotus 123 or Multiplan, using one of the packages both in and outside of a classroom environment. Many had used electronic spreadsheets in their work environments.

The four tasks were designed from two basic spreadsheets (see Figure 3 and Figure 5). The first spreadsheet is a comparative balance sheet for a fictitious company called the XYZ Company, and the second is a compilation of annual net income and sales data for two decades for another fictitious company called Inland. The four tasks consisted of entering and subsequently modifying (see Figures 4 and 6) each of these two spreadsheets (i.e., entering XYZ Company, modifying XYZ Company, entering Inland Steel, and modifying Inland Steel). The spreadsheets used in these tasks were chosen to be relatively small but still representative of spreadsheets used in industry and ones the subjects were likely to be familiar with.

The task of entering a spreadsheet requires the use of basic spreadsheet skills such as changing column widths, formatting items in columns, entering numbers, labels, and formulas, saving and printing the spreadsheet. A summary of a normative analysis

towards accomplishing our four experimental tasks is shown in Figure 7. In performing these tasks, the subjects were not provided any direction on which commands to use or how to approach the problem. The spreadsheet was designed however, to allow subjects to use some of the more powerful commands such as COPY - although one could perform the task without using these commands.

In modifying the spreadsheet we asked the subjects to reaccess the spreadsheet, add another column with formulas, insert rows and columns, change column widths, justify columns or titles, change a value and report how a related value changed, print a part of the spreadsheet, move a portion of the spreadsheet to another area, and finally to save the spreadsheet.

Our experimental procedure was designed to induce the subjects to solve the problems with the spreadsheet software in the way that they normally would follow. We didn't tell the subjects the sequence of subtasks to perform. At the beginning of each task, the subjects were given two sheets of paper. One sheet contained the model's results that should appear when the task was completed, and the other had a list of instructions about what we want them to do. We asked the subjects to make notes from their reading of the instruction sheet onto the model's result sheet. The instruction sheet was then removed for the duration of the experiment. To insure that the subjects understood the task, we asked them to describe the task completely. They were reminded of any omissions or misconceptions, asked to modify their notes, and then were allowed to proceed with the task.

All subjects performed the four tasks. The presentation of the tasks was counterbalanced by model. Half the subjects worked on the XYZ Company model (initial entry followed by the modification task) and then the Inland model (entry followed by modification). The other half worked on the tasks in the reverse model order. To warmup, all subjects entered a short balance sheet at the beginning of the session.



## 4. Results

We analyzed the video tapes made during the experimental session of the subjects performing our four tasks for incidents of errors. We define an error as an action which results in a misspecification of the spreadsheet model. For example, an incorrect range used in a formula specification is considered an error. In addition to looking for errors in subject performance, we also noted incidents of overshooting in cursor movements. We felt this would give some indication of difficulties (and/or strategies) in using the spreadsheet representation. For example, attempting to move the cursor outside of the spreadsheet boundary and having the system respond with its overly familiar "beep" is overshooting the desired cell.

We discuss our collectifferent perspectives. The first is a classification of the errors users made in performing their assigned tasks. We accompany this classification with a presentation of the frequency of errors in each class. The second perspective contrasts the number of errors along various dimensions such as package type and order of task presentation.

### 4.1. Classes of errors

Error classification is our initial perspective on the error population. One caveat before we continue is that the nature of our tasks dictates the types of errors the user could make. The spreadsheets under study are relatively simple in contrast to many of those found in industry. Both spreadsheets were fairly homogeneous, there were no separate "subspreadsheets" which needed to be connected in either a physical or a logical way. The small size of the spreadsheet did not push the subject to space allocation problems nor require him to jump about the spreadsheet. However, the number of errors which were found indicates that even with these considerations, experienced users found difficulty in using the spreadsheet programs under study.

Our procedure for classifying the errors was data driven. We began with an initial listing of many different types of errors and then consolidated similar errors into the

categories listed in Figure 8. This figure lists the class name along with the different types of errors we mapped into each class.

The way in which we counted the number of errors was a function of the subtask (e.g., entering a formula) and not of the keystrokes. For example, if the subject entered " Net Income" into cell A20 in the XYZ Company spreadsheet when the title should be "net income", we count two errors: one error for incorrect capitalization and the second error for incorrect indentation. A different method of counting focusing on keystrokes would count four errors, one for each incorrect space in the indentation and one for each incorrect capital letter.

Our subjects made quite a few errors in performing their assigned tasks. Overall, 488 errors were made and 258 unnecessary cursor movements. The largest class of errors was typographical with 157 errors closely followed by the class labeled "Incorrect format" with 119 errors. Figure 9 shows the number of errors for each of our classes. We discuss each of these errors in more detail in the following paragraphs.

Subjects made 62 "Exclusion" errors in interacting with the spreadsheets. This class of error denotes forgetting to include either (1) a required item in one of the label fields of the task such as one of the words or phrases or the closing parenthesis (see Figure 3, cell A15) or (2) forgetting to include some part of a command. We believe the difficulty behind these two types of errors to be different. In the first error situation, the subject misses seeing an item in the complex display of information such as one of the labels in a multiline label. This error is similar to one typists make in omitting a line of text. In the second error situation, a typical error was forgetting to place the closing parenthesis on formula specification. An example formula is:

@SUM(B8..B15)

The error occurred usually when the subject was pointing to indicate the last cell to be included in a formula. After moving the cursor to this location (B15 in our example), the subject would press the ENTER key. However, the system requires that the formula specification end with a closing parenthesis. The system expects at this point a closing parenthesis to indicate (1) that the cursor is over the closing cell and (2) that the

@SUM formula is complete. For the user, a common interaction is specifying ranges for copying or moving cells. In doing so, the user must press the ENTER key after the cursor is over the last cell of the range. This action sequence is very similar to the formula specification just described. In one case you simply press ENTER, in another very similar situation you do not only press ENTER, you press a closing parenthesis first. We view this error as a lack of consistency in the dialogue. It is also an example of what Norman (1983) refers to as a capture error; two similar scenarios with different endings.

The second class of errors, "Incorrect format" ( $n = 119$ ), includes the incorrect formatting of cells (e.g., an incorrect indentation or centering) and the incorrect format of the spreadsheet (e.g., incorrect number of blank rows between groups of cells). Subjects experienced extensive difficulty in entering the correct indentation for the labels located on the left hand side of the spreadsheet for task 1 (see Figure 3). The indentation scheme was fairly complex to begin with. We believe that the task of aligning these labels can be accomplished easily if the labels are in close proximity, one directly over the next. However, to enter label values into the spreadsheet, the location of entry is located in the top (or bottom for Multiplan) part of the screen, away from the location where it will end up. The task then changes from one of visually aligning the cells to one of counting (or some other strategy) the correct number of blanks to precede each label. These other strategies appear to be error prone. (We will return to this discussion later when we contrast Lotus 123 to Multiplan).

The next class, "Incorrect location", ( $n = 39$ ) describes those errors where the subject entered data into the wrong cell. In performing this subtask the subject moves the cursor over to the cell in which the data is to be entered and types the data. We found that subjects in attempting to find the correct cell had difficulty in finding the correct row. One aspect of this subtask is that our labels are variable in the number of rows they take up. The subject then does not have any additional cues such as putting data in every other row to assist him in locating the correct row. In some instances the subject would move the cursor over to the label and then move the cursor along the row

to the appropriate column.

Our next category of errors, "Incorrect reference", ( $n = 20$ ) is similar to placing data in the wrong location. In this error, the intention of the user is to tell the system the location of a cell or group of cells he wants to be included in a formula specification or in some other function operating on cells such as a MOVE. For our tasks, subjects were either specifying formulas or providing boundary ranges for moves, copies or cell formats when they produced this error. We found two different versions of this type of error. The first version occurred when the subject was formatting cells for information which was later entered, such as in formatting the cells where the contents were centered. The second version of this error type is when the data has been entered and the subject is defining a range which includes a particular group of cells such as in copying a formula. We believe both of these errors, and the ones described in "Incorrect location", are the result of insufficient visual feedback to the subject in letting him know where he is in the display.

The next class of errors are "Mode errors" ( $n = 28$ ). The predominant error in this category was made by Multiplan users. In Multiplan, users are initially in command mode. To enter data they must select either a numeric field type or an alpha field type before entering the data. Multiplan users forgot to enter this selection on 26 occasions. By forgetting to enter this selection the system interpreted the characters as command selections. If the character corresponded to a correct command, this command was then invoked; if there was no command which the character was mapped to, the system responded with an auditory signal indicating an error in command selection. We discuss this error in more detail in a later section.

The next two categories of errors, "Incorrect logic" and "Lack of knowledge" ( $n = 41$  and  $n = 22$ ) are indicative of the skill the users have in both formulating the formulas used in our tasks and in knowing the command structure of the spreadsheet. (In some instances the subject entered the help facility). We are in the midst of analyzing these errors. We anticipate that the nature of these errors along with the approach the

subjects took to perform the tasks, we can discover metrics to assess a user's level of expertise by monitoring his choice of methods and approaches towards model specification.

Our last error category, "Typos", reflects, among other things, the typing skills of our subjects. They made 157 errors in typing the labels and the numbers entered into the spreadsheet. There are 92 labels and numbers in the four tasks for a total of 1288 instances of cells. This relates to about 1 error for every 8 cells.

Finally, our subjects moved around the spreadsheet quite a bit "Unnecessarily" ( $n = 258$ ). This category includes instances where the subject appears to be centering a particular cell, bringing other cells into view, or in attempting to determine the correct row for a cell. It also includes movements where the subject attempts to move outside the boundary of the spreadsheet such as in attempting to move past the top of the spreadsheet. We are not able to assess intention in many of these movements but include them here as an indication of the difficulty subjects had in moving around and viewing information in the spreadsheet.

#### **4.2. Errors in contrast**

In looking at our errors we were also interested in whether there were any effects due to the type of spreadsheet package the subject used or if our order of tasks we presented to the user affected the subjects' performance. Our analysis showed no significant difference ( $t(12) = 1.29$ ,  $\alpha = .05$ ) in the number of errors for any of our classes as a result of the order of presentation of the tasks (see Figure 10). However, we did find some differences based upon the type of spreadsheet which was used.

Our analysis found that the packages differed significantly in the number of errors produced for the classes of "Incorrect mode" ( $t(12) = 4.50$ ,  $\alpha = .05$ ) and within the "Incorrect format" class, "Incorrect indentation" ( $t(12) = 2.18$ ,  $\alpha = .05$ ). In both instances, Multiplan users made the larger number of errors. The reasoning behind the difference in errors for the "Incorrect mode" class was fairly clear. As



mentioned earlier, Multiplan users are required to select a mode for entering character data into the spreadsheet; Lotus 123 users do not have to specify this mode selection. We found that the Multiplan users would forget to enter the alpha mode with the result being that the system interpreted the characters to be a command selection. A reason why Multiplan users could forget to enter this character is that it is not required every time the user enters a character field. A user can enter the alpha mode and move from cell to cell entering characters strings. However, once he leaves alpha mode, to enter another character string, he must begin with the character designation. Therefore, this decision choice (Am I in alpha mode?) results in user errors. We suspect however, that users forget that they even have this decision choice to make.

The larger number of "Incorrect indentation" errors for Multiplan users is less easy to understand. In both systems, the data entry for the cells is located away from the cell of interest. One difference between the two systems is that the location for cell entry for LOTUS 123 is in the top left hand corner and for Multiplan is in the bottom left hand corner. We can see no rationale for why this would affect user performance, we expected them to do poorly, but equally so. One insight we have into this error condition is that the task of indenting labels in spreadsheets is not one where the subject can easily align the label visually; the current cell is out of context. The task then becomes one of either trial and error (i.e., type it in, see if its ok, edit, etc.) or one of counting the number of blank spaces. If the subjects perform this counting strategy for entering in labels, it becomes more complex for the Multiplan user. The Multiplan user must remember to enter the character to select the alpha mode in addition to counting the preceding blank spaces, but also to not count this character. This added complexity potentially increases the likelihood of an error.

### **4.3. Time and error performance**

As a final bit of analysis for our errors we were interested in the relationship between speed of performance and the production of errors. Generally it's expected that increased speed relates to an increase in the number of errors produced.

The amount of time it took subjects to perform each task varied from an average of 15.6 minutes for task 1 to 8.41 minutes for task 4 as shown in Figure 12. For the longest task the number of errors is the largest. For the shortest task the number of errors was the smallest. However, for the two tasks in between the relationship is reversed. To account for the time to perform all our tasks, we would need to include in our analysis, in addition to the number and type of error made, the strategy and methods the subject used to perform the task (see Olson and Nilsen, 1986), as well as the number and type of subtasks (e.g., entering a formula). This analysis is not the focus of our paper and is not pursued further, however, it remains an interesting question.

## **5. Discussion**

Our work was directed towards understanding user behavior in spreadsheet system use by focusing on the nature of the errors people made. We chose a relatively simple set of tasks as a beginning step in this understanding. What we found was that subjects made in our estimation a large number of errors. We believe that the design of the system failed to accommodate some of the characteristics of the user. In this section we discuss some of those characteristics and present alternative designs which we predict would reduce, if not eliminate some classes of the errors we found to exist.

Our largest class of errors which we believe are a result of the particular design of the spreadsheet packages under study is the one of incorrect formatting, particularly indentation. Work on vision has found the useful range of sight to be relatively small (3-5 degrees) for complex displays (Mackworth, 1976), such as those found in spreadsheets. The design decision to separate the cell for entry from the cell where the data will reside is a decision to not allow the cell and those about it to be in the useful field of vision at the same time. As a result, the user must use other strategies (such as counting or scanning back and forth) to include the information from the cells nearby in the process of defining the current cell of interest. Our results show that these other strategies are error prone.

While we do not have data which suggests that moving the site of entry into its location of context is the optimal choice, we believe that it would reduce the number of errors for those situations where the cell's context is important and the task is a visual one. This was true for the labels in task 1 of our experiment. We also believe that context is an important feature in the pointing method for range specifications. Both Lotus 123 and Multiplan provide this type of context by returning to the cell being defined when each of the range endpoints are indicated rather than to the entry cell located at the top (or bottom for Multiplan) of the screen.

A second source of error in our experimental tasks is that of knowing exactly where the cursor is pointing to in the cells shown on the screen. Attempting to align a cell with one on the other side of the screen is a difficult task. Labels, while useful as indicators of aligned adjacent cells, are poor in providing the direction to follow for those cells located on the far side of the screen. The physical layout of words make them a poor arrow for assessing direction. Furthermore, our useful field of vision is limited and requires the subject to use eye movements in attempting to align data items. These eye movements provide potential for errors. While experimental work on vision has shown that our ability to detect differences in alignment (vernier acuity) is very good for displays where there is no interference, the displays of the spreadsheet are usually complex and not interference free (although, some provide nice landmarks for reference, e.g., no errors of this type were made in column C of task 1 when the subject had already entered completely column B). The visual points of reference on the top and sides of the display are inadequate according to our data. Our subjects experienced difficulties with fairly simple spreadsheets where most of the data was available on one screen.

We believe that an answer to these difficulties is to provide better visual feedback to the user for his location on a screen. A simple way of providing this feedback is to provide crosshairs which follow the cursor around the screen (see Figure 13). These crosshairs would be excellent indicators of row and column locations and also clearly indicate all items currently in view and aligned on these axes. We believe this type of



visual feedback is also important for pointing to the desired cell in formula specifications or in commands requiring range specifications such as copy or move (see Figure 14).

We see other areas where visual feedback can assist the user. For example, one of our logic errors was the copying of a formula which was inappropriate to the cell it was copied to. In task 1, the formula totalling the differences for "Total Current Assets" between years 1984 (column B) and 1983 (column C) can be calculated either as the sum of the differences in column C from Cash to Prepaid Expenses or the difference between the two sums in columns B and C (i.e., values 145500 and 122200). If this formula was entered as the difference between B and C, then it could be correctly copied to the cell calculating the difference between 1984 and 1983 Property, Plant and Equipment.

One subject copied the formula as described but had defined the formula as the sum of column C from Cash to Prepaid Expenses, not the differences, resulting in an error. However, if in moving to the cell from which he copied the formula, the system had provided visual feedback by highlighting the range of cells referenced by this formula, then this error may not have occurred. In fact, many of the auditing programs for spreadsheets provide this highlighting feedback information to assist in examining the spreadsheet for errors.

In brief, there is insufficient visual feedback to the user in performing many of the tasks associated with spreadsheet entry and modification.

## **6. Future Research**

Our current work is an initial step in understanding how users interact with computerized spreadsheet packages. Our tasks show some of the errors users make.

<sup>1</sup> Other more complex tasks using multiscreen spreadsheets will illustrate the difficulties users have with moving about in such a larger space. Furthermore, the difficulties in commands which have a global effect such as adding a row, become more troublesome when there are parts of the spreadsheet out there, out of view, but open for destruction. It is not the case that if you can't see it, it's ok. We believe that more complex spreadsheets will illustrate these other more deadly errors in system use. We suspect that most of these errors result from the visual properties of the system and that better feedback to the user will assist in reducing the frequency of these errors. Some of the newer packages offer visual feedback which assists the user in interacting with the system. We intend to explore these packages as well as user performance with more complex spreadsheets to achieve a better understanding of how people perform this difficult task.

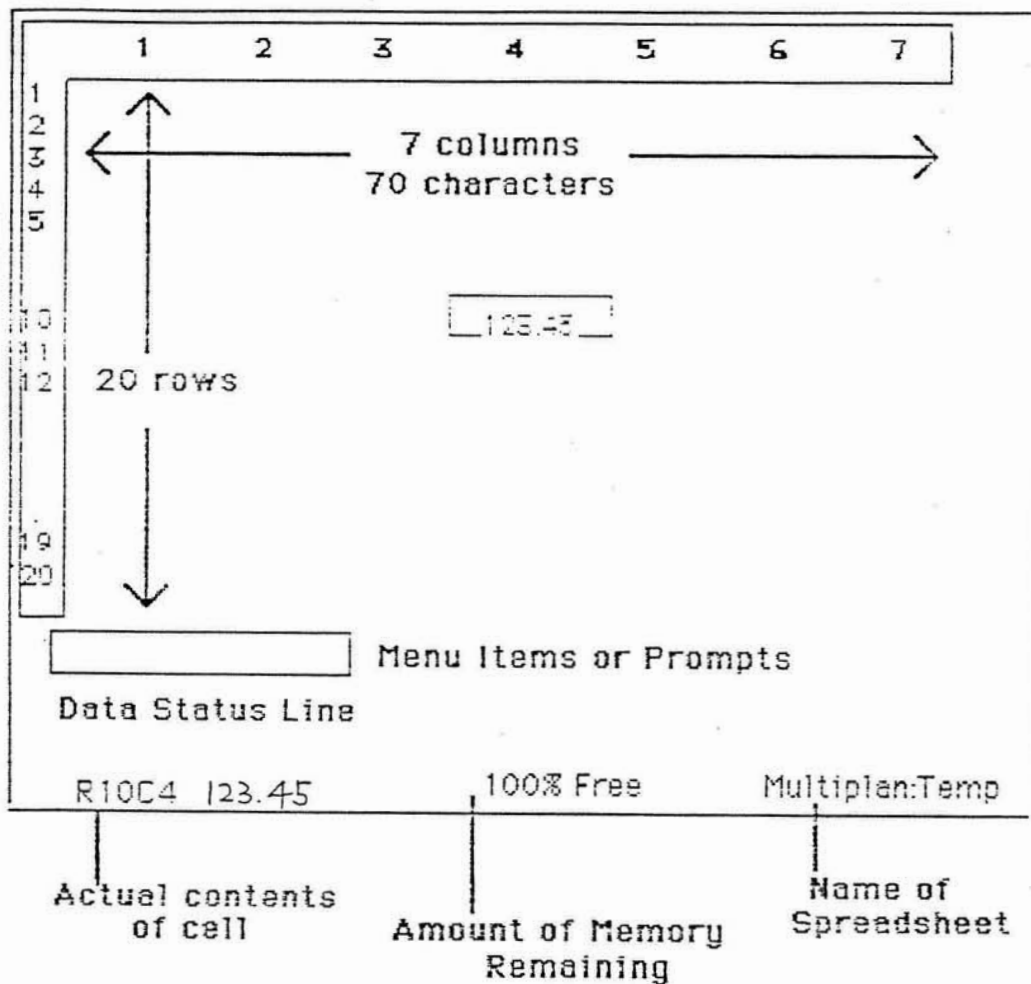
---

<sup>1</sup>We have gathered a number of error types discussed in the popular literature and through interactions with students learning the tasks and through contacts of experts using spreadsheet software in hopes of developing a more complete taxonomy of errors in spreadsheet use to aid in understanding system use more fully via an analysis of error production.

## BIBLIOGRAPHY

- Dember, W. N. *The psychology of perception*. New York, NY: Holt, Rinehart and Winston, 1964.
- Mackworth, N. H. *Stimulus density limits the useful field of views*. In R.A. Monty and J. W. Senders (Eds.), *Eye movements and psychological processes*. Hillsdale, NJ: Lawrence Erlbaum Associates, 1976, 307-321.
- Monty, R. A. and Senders, J. W. (Eds.) *Eye movements and psychological processes*. Hillsdale, NJ: Lawrence Erlbaum Associates, 1976.
- Norman, D. A. *Design rules based on analyses of human error*. *Communications of ACM* 26, 4 (April 1983), 254-258.
- Olson, J. R. and Nilsen, E. *Analysis of the Cognition Involved in Spreadsheet Software Interaction*. (forthcoming in *Human Computer Interaction*), 1986.

Figure 2: Multiplan Worksheet



**Figure 3: Task of Entering XYZ Company Model: Task 1**

XYZ COMPANY  
COMPARATIVE BALANCE SHEET

Assets	December 31, 1984	December 31, 1983	Increase or Decrease
<b>Current Assets:</b>			
Cash	5500	4200	1300
Marketable Securities	1500	2400	-900
Accounts Receivable (less allowance for uncollectible accounts of \$2,000 in 1983) and \$2,000 in 1983)	61600	52000	9600
Inventories (lower of cost (FIFO or market))	76000	63000	13000
Prepaid Expenses	900	600	300
<b>Total Current Assets</b>	<b>145500</b>	<b>122200</b>	<b>2300</b>
<b>Long-term Assets:</b>			
Property, Plant & Equipment (net of accumulated depreciation)	45000	40000	5000
Investments	1800	1600	200
<b>Total Long-term Assets</b>	<b>46800</b>	<b>41600</b>	<b>5200</b>
<b>TOTAL ASSETS</b>	<b>192300</b>	<b>163800</b>	<b>285000</b>

Figure 4: Task of Modifying XYZ Company Model: Task 2

XYZ COMPANY  
COMPARATIVE BALANCE SHEET

Current Assets:				
Cash	5500	4200	1300	0.31
Marketable Securities	1500	2400	-900	-0.38
Accounts Receivable (less allowance for uncollectible accounts of \$2,000 in 1983 and \$2,000 in 1983)	61600	52000	9600	0.18
Inventories (lower of cost (FIFO or market)	76000	63000	13000	0.21
Prepaid Expenses	900	600	300	0.50
Total Current Assets	145500	122200	23300	0.19
Long-term Assets:				
Property, Plant & Equipment (net of accumulated depreciation)	45000	40000	5000	0.13
Investments	1800	1600	200	0.13
Total Long-term Assets	46800	41600	5200	0.13
TOTAL ASSETS	192300	163800	28500	0.17

Assets	December 31, 1984	December 31, 1983	Increase or Decrease	Percent Change
--------	-------------------	-------------------	----------------------	----------------

**Figure 5:** Task of Entering Inland Steel Company Model: Task 3

Inland Steel

Year	Net Income (\$000's)	Sales (\$000's)	Net Income /Sales
1950	9300	62000	0.15
1951	7800	54000	0.14
1952	6700	82000	0.08
1953	5300	46000	0.12
1954	6800	78000	0.09
1955	6300	93000	0.07
1956	5800	67000	0.09
1957	9400	98000	0.10
1958	5100	75000	0.07
1959	6200	53000	0.12
1960	6400	90000	0.07
1961	7000	48000	0.15
1962	7400	83000	0.09
1963	5600	43000	0.13
1964	-130	21000	-0.01
1965	-240	36000	-0.01
1966	1200	51000	0.02
1967	3400	49000	0.07
1968	5400	76000	0.07
1969	6800	89000	0.08

**Figure 6:** Task of Modifying Inland Steel Company Model: Task 4

Inland Steel

1950	9300	62000	0.15	
1951	7800	54000	0.14	
1952	6700	82000	0.08	
1953	5300	46000	0.12	
1954	6800	78000	0.09	
1955	6300	93000	0.07	
1956	5800	67000	0.09	
1957	9400	98000	0.10	
1958	5100	75000	0.07	
1959	6200	53000	0.12	0.10
1960	6400	90000	0.07	
1961	7000	48000	0.15	
1962	7400	83000	0.09	
1963	5600	43000	0.13	
1964	-130	21000	-0.01	
1965	-240	36000	-0.01	
1966	1200	51000	0.02	
1967	3400	49000	0.07	
1968	5400	76000	0.07	
1969	6800	89000	0.08	0.07
Year	Net Income (\$000's)	Sales (\$000's)	Net Income /Sales	Decade Average



**Figure 7:** Normative Analysis of Each Task

Subtask Type	Task1	Task2	Task3	Task4	Total
Entering label	27	2	8	2	39 *
Entering number	12	1	40	-	53 *
Entering formula	4	1	1	1	7 *
Execution of command					
Retrieving file	1	1	1	1	4 **
Formating field	4	2	5	2	13 **
Altering format		1		1	2 **
Inserting column/row		2		2	4 **
Changing value		1		1	2 **
Moving range		1		1	2 **
Erasing cell		8			8 **
Copying	4	1	1	1	7 **
Saving file	1	1	1	1	4 **
Printing	1	1	1	1	4 **
	-----	-----	-----	-----	-----
Total	54	23	58	14	149
(%)	36.2	15.4	39.0	9.4	100.0
	=====	=====	=====	=====	=====

NOTE> \*       Number of cells  
 \*\*       Number of command executions

**Figure 8:** Classes of Errors

- (1) Exclusion: omits part of a field label, formula, multiline label, or command parameter or portion of command (e.g., closing parenthesis)
- (2) Incorrect format: incorrect indentation, labels not centered, incorrect number of blank rows between spreadsheet segments.
- (3) Incorrect location: enters data into the wrong cell location, i.e., the wrong row or the wrong column.
- (4) Incorrect reference: incorrect range specification for formulas or for commands (such as print or copy).
- (5) Incorrect mode: enters a number while in alpha mode or vice versa.
- (6) Incorrect logic: enters incorrect formula, selects incorrect command, copies incorrect formula.
- (7) Lack of knowledge: enters help mode, doesn't use efficient command, searches through command menu.
- (8) Typo: misspells word, incorrect capitalization.
- (9) Unnecessary cursor movement: runs into physical spreadsheet border, overshoots desired cell within spreadsheet, backs up too far while editing cell data, presses home key when not desired.

**Figure 9:** Frequency of Errors

<u>Error type:</u>	<u>Frequency of Errors</u>
Exclusion	62
Incorrect format	119
Incorrect location	39
Incorrect reference	20
Incorrect mode	28
Incorrect logic	41
Lack of Knowledge	22
Typos	157
Unnecessary cursor movement	258
	<u>746</u>
	=====

**Figure 10:** Frequency of Errors by The Order of The Task Presentation

Error type:	XYZ first	Inland first	Total
Exclusion	36	26	62
Incorrect format	65	54	119
Incorrect location	21	18	39
Incorrect reference	11	9	20
Incorrect mode	11	17	28
Incorrect logic	22	19	41
Lack of knowledge	14	8	22
Typos	94	63	157
Unnecessary cursor movement	126	132	258
Total	400	346	746

**Figure 11:** Frequency of Errors by Package Type

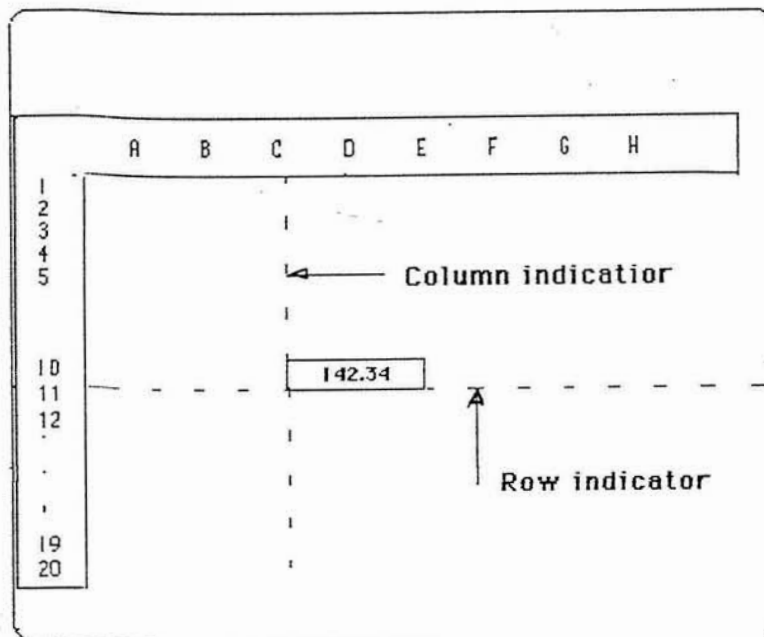
<u>Error type:</u>	<u>Lotus 123</u>	<u>Multiplan</u>	<u>Total</u>
Exclusion	39	23	62
Incorrect format	34	85	119
Incorrect location	23	16	39
Incorrect reference	10	10	20
Incorrect mode	2	26	28
Incorrect logic	27	14	41
Lack of Knowledge	15	7	22
Typos	75	82	157
Unnecessary cursor movement	114	144	258
	<u>-----</u>	<u>-----</u>	<u>-----</u>
Total	<u>339</u>	<u>407</u>	<u>746</u>

**Figure 12:** Time to Perform Task by the Order of Experiment

Experimental task	XYZ first	Inland first	Average
Task 1	16.32	14.89	15.60
Task 2	11.33	6.66	9.00
Task 3	11.41	11.29	11.35
Task 4	8.53	8.30	8.41
	-----	-----	-----
Total	47.59	41.14	44.36
	=====	=====	=====

Note> Time indicated in minutes.

**Figure 13:** Lotus 123 Worksheet with Crosshairs



**Figure 14:** Lotus 123 Worksheet with Range Specification and Crosshairs

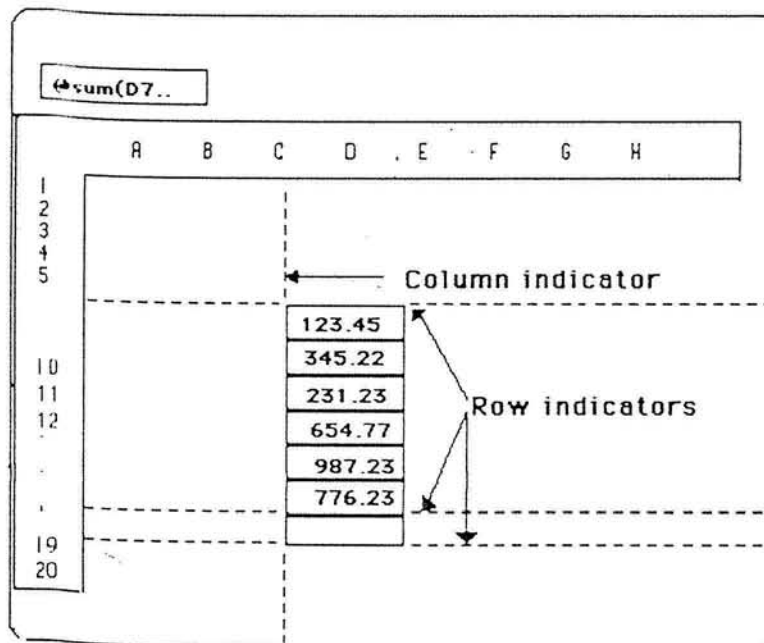




Figure 1: Lotus 1-2-3 Worksheet

