LINK: THE PRINCIPLED DESIGN OF A COMPUTER ASSISTED LEARNING PROGRAM FOR CORRELATION

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A study that identified students' misconceptions in correlation informed the development of a computer assisted learning program. Link is to be used by psychology students and is designed to address and remedy students' misconceptions in correlation. A formative evaluation of this program was conducted with students to assess its usability and possible instructional effectiveness. The findings of this evaluation indicated that students' understanding of correlation was significantly improved after using Link. This evaluation study and an expert evaluation of Link provided data this was used to improve its design. Further research in the form of a summative evaluation of the completed program will be undertaken.

INTRODUCTION

It is recognised that computer assisted learning programs can be designed and used to address students' misconceptions in statistics (e.g., Thomason, Cumming and Zangari, 1994). Accordingly, the design of these programs must be based on empirical studies concerning students' understanding of particular areas in statistics. In addition, the design of interactive learning materials must involve formative evaluation with students and experts.

THE DESIGN OF *LINK*

The design of *Link* was based on research that found that students held misconceptions that concerned causality, negative correlations and the strength of correlations (Morris, 1997a). This research was part of a wider research project that has looked at misconceptions in correlation that are held by students taking psychology at university (Morris, 1997b). Estepa and Batanero (1996) report findings concerning pre-university students' preconceptions about correlation.

A first version of the program was developed which provided learner activities that were designed to address: students' inferring causality from correlation, the conception that a negative correlation does not indicate a relationship between two variables, and the conception that a negative correlation is stronger than a positive correlation when this is not the case.

THE FORMATIVE EVALUATION OF *LINK*

One aim of the evaluation study was to provide a formative evaluation of the program's learner activities. In addition, the study was designed to investigate whether *Link* contributed to students' understanding of correlation and whether the program addressed students' misconceptions in correlation.

A framework, which was devised for the empirical evaluation of computer assisted learning programs (Jones et al, 1996), was employed for this study. Jones et al (1996) recommend that students must be involved in the process of evaluation and that a variety of quantitative and qualitative data must be generated and collected in an evaluation study.

Eighteen students who were studying psychology participated in the study. The average age of this group was 38 years (range 24 - 56). Seventeen participants had completed an introductory psychology course that covered the topic correlation, and one participant had completed a degree course in psychology.

To investigate whether the program contributed to students' understanding of correlation two equivalent tests were developed which were both designed to provide an assessment of a student's understanding in this area. Participants were randomly assigned to either complete test A prior to using the program and to complete test B after they had used the program, or vice versa. The participants were set pre defined tasks and were asked to think aloud whilst they used the program. Participants were observed whilst they worked with the program and observation and audio records were made for later analyses.

FINDINGS OF THE FORMATIVE EVALUATION

The evaluation study provided valuable data concerning students' interactions with the program. Analysis of the pre and post test data showed that *Link* contributed to students' general understanding of correlation. It was not clear whether the program specifically remedied particular misconceptions that students held.

Students' interactions

Activity 2 is used to illustrate students' interactions with the program. This activity was designed to address the conception 'that a negative correlation does not indicate a relationship between two variables' (figure 1). Students were asked to select the correlation coefficient in the table that represented the target scatter plot displayed on the screen. If a student selected any of the correlations in the table, then a scatter plot that

represented the correlation coefficient was displayed alongside the target scatter plot on the screen.

Only two of the participants selected the correlation, -0.65 that represented the target scatter plot almost immediately. Four of the eighteen participants appeared at first not to be able to attempt the activity, but then they completed it and worked out that the negative correlation of -0.65 represented the scatter plot in question. One of these participants said “I’m puzzled, I’m afraid” and was prompted to select a correlation as instructed by the program. She selected the correlation 0.64 and then commented “oh no, so it’s the other way” and selected the correlation -0.65. Another participant approached this activity in a similar way where initially she remarked “don’t like these scatter graphs” and went on to say that she could not “picture it in a graph form like that”. This participant then said she would guess and selected the correlation 0.64 and said “so that’s [a] positive correlation and “so we need a negative correlation” and she then selected -0.65. This participant did, however, comment further “I have to say I still don’t understand why it represents what it says it does on the graph”.

Four of the participants found activity 2 difficult and tended to guess by selecting several of the correlations in the table until they selected -0.65. For example, one of these participants said “I haven’t a clue. I’ve never clapped eyes on a scatter plot before” and remarked how he was guessing when he selected the following correlations in the table in turn: -0.07, 0.12, 0.64, -0.65.

Four of the participants did not mention that they found the activity difficult and that, for example, they were stuck or confused, but they did select several correlations in the table including the negative correlation that represented the target scatter plot. For example, one of these participants selected the correlations 0.18, 0.12, -0.07, 0.55 in turn and then said “tried four out of the six now. It’s none of them” and then selected the coefficient of -0.65.

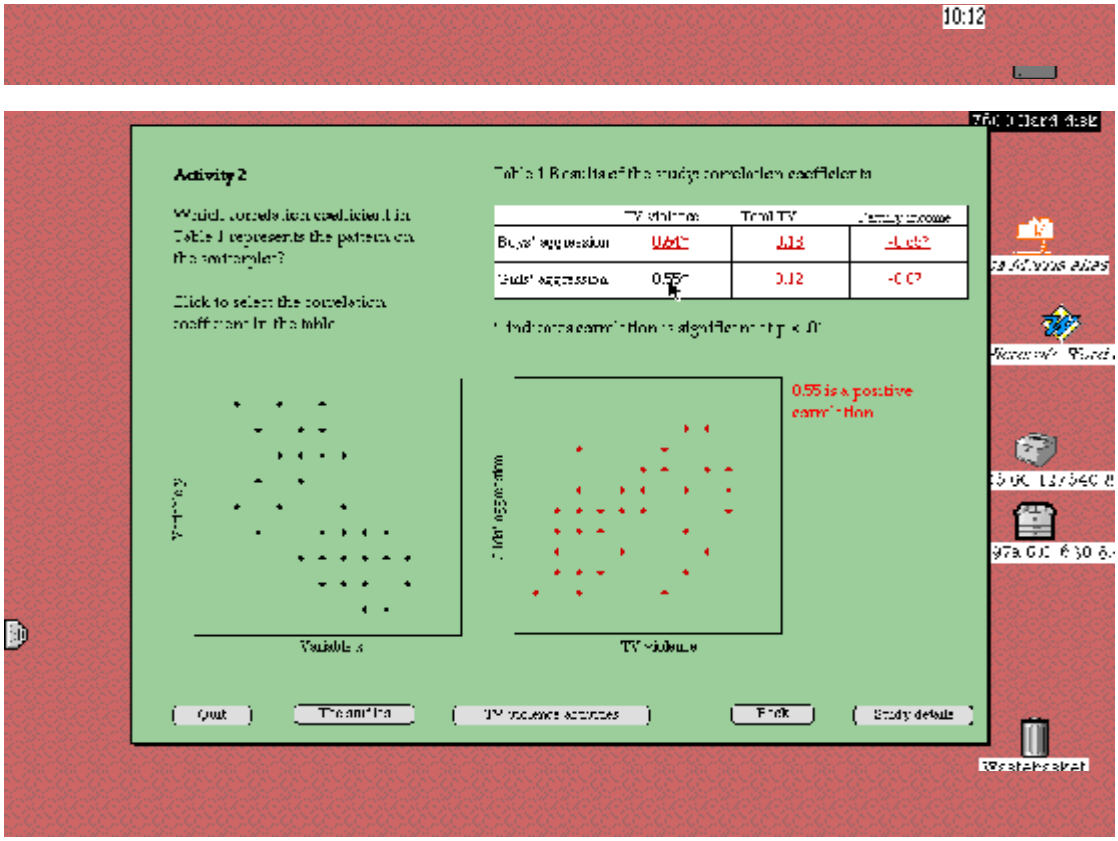

Figure 1. Activity 2. The correctation 0.55 has been selected.

LEARNING OUTCOMES

The tests that were completed before and after the participants used the program were designed to assess a student's understanding of correlation and provided a quantitative measure. There was a significant difference between the mean scores of the pre and post test (one-tailed; $t = 2.22$; d.f. = 17; $p < 0.05$).

Equivalent questions on the tests were devised to identify students' misconceptions in correlation. For example, the tests included questions that were designed to test a student's understanding of the strength of correlations. Participants' answers to equivalent questions on the pre and post tests were examined to see if there was any indication that the program had affected particular misconceptions in correlation. To illustrate this, answers to one of the questions is considered.

One question on the tests asked participants to choose from sets of correlation coefficients the set that showed the weakest to strongest relationship and to explain their answer. In one of these sets a very weak correlation is viewed as weaker than a negative correlation, but a positive correlation is viewed as stronger than both: 0.83, 0.65, -0.91, 0.03. In another set, the negative correlation is viewed as weaker than both a very weak

correlation and a positive correlation: 0.83, 0.65, 0.03, -0.91. Participant responses to either one of these sets were categorised as the conception that a positive correlation is stronger than a negative one ('strength' misconception).

One of the learner activities was designed to address this misconception: students were asked to arrange the correlations on the screen in order from that which represents no relationship between variables to that which indicates the strongest relationship between variables (figure 2). Sixteen out of the eighteen participants invoked the feedback to this activity which provided the appropriate arrangement of correlations on the screen.

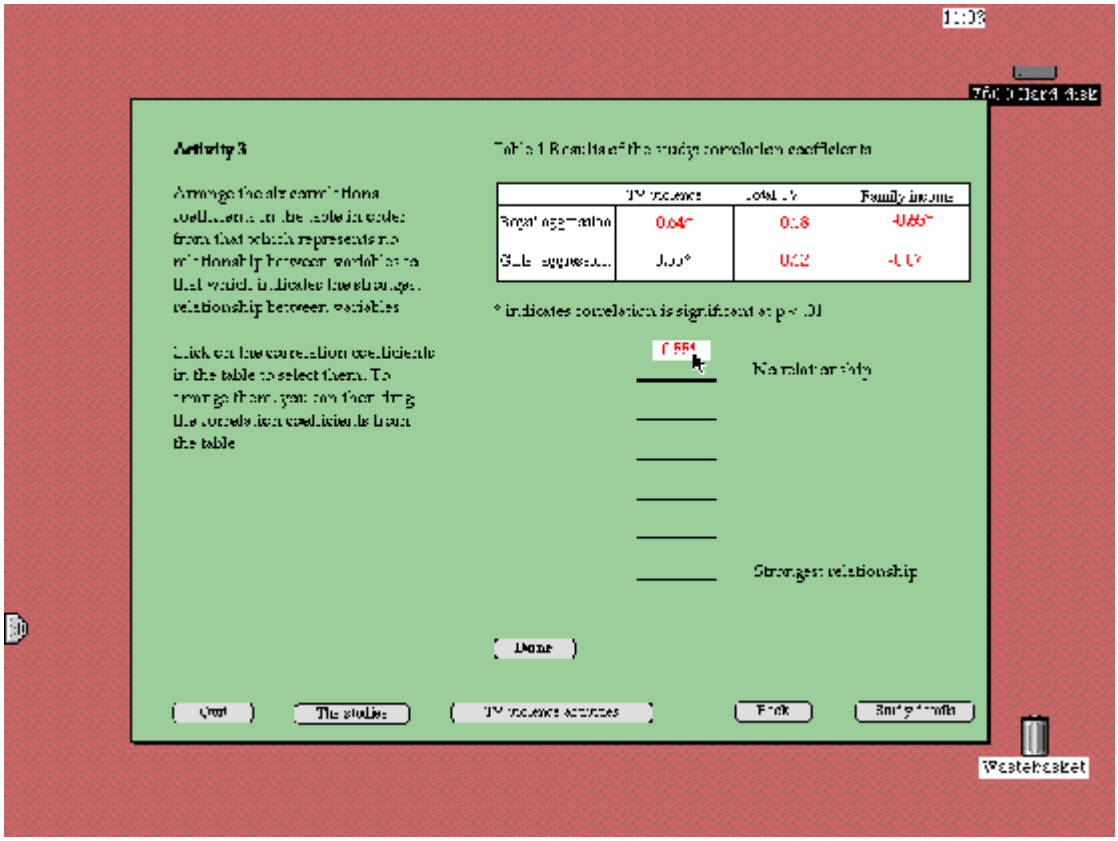

Figure 2. Activity 3 in *Link*

Three of the participants' responses were categorised as 'strength' misconception on both the pre and post test. However, four of the participants responses were categorised as 'strength misconception' on the pre test, but as correct on the post test. For example, on the pre test one participant indicated on the question the set of correlations in which the (strong) negative correlation was weaker than no correlation and a positive correlation, and in explaining this wrote "going from a fairly strong -ve [negative] correlation to zero(ish) then upwards to a +ve [positive] correlation: It's the only one that steadily moves in 1 direction". In contrast, on the equivalent question on the post test this

participant correctly indicated that '-0.91, 0.83, 0.65, 0.03' shows the strongest to weakest relationship and answered "although in opposite directions the *strengths* are going from left to right". (His emphasis).

For the above question, a one-tailed McNemar test was carried out to see if there was any significant pre and post changes in the observed frequencies of responses that were categorised as the 'strength' misconception, but the findings were not significant ([Binomial test]; $p = 0.62$).

IMPLICATIONS OF THE FORMATIVE STUDY

The formative evaluation study provided valuable data concerning students' interactions with the program. The observation and think-aloud records concerning students' interactions as they used the program provided qualitative data that has been used to inform the further development of *Link*. For example, it was evident that feedback provided to the participants when they completed activity 2 was not always clear to them and this aspect of the program has been revised. An expert evaluation of the program was also conducted which indicated that the completed version of *Link* should provide feedback to a learner activity that is contingent on the user's actions at the interface.

The findings of the formative evaluation suggest that *Link* contributed to students' general understanding of correlation. Qualitative data concerning students' misconceptions in correlation indicated that for some students the learner activities in the program addressed particular misconceptions that were identified on the pre test.

CONCLUSIONS AND FURTHER WORK

A revised version of *Link* has been developed and a summative evaluation of this program will be conducted. Although the formative study indicated that *Link* contributed to students' understanding of correlation, it is possible that this could have been due to a practice effect from completing the tests. This summative evaluation study could therefore use a control group and will investigate whether learner activities in the program address and remedy students' misconceptions in correlation.

In conclusion, a formative evaluation where a variety of data is collected is necessary in the development of computer assisted learning programs for statistics because it provides data that can be used to improve the program's design and data that concerns aspects of the learning process.

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