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## *Data Logging and Performance Analysis Software for Teachers of Indigenous New Zealanders: Early Results*

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Technology, in the form of personal computers, is making inroads into everyday life in every part of every nation. It is frequently assumed that this is 'a good thing'. However, there is a need for the people in each cultural group in each nation to appropriate technology for themselves. Indigenous people, such as the Maori of New Zealand/Aotearoa, are in danger of losing their language because technology has a European face. Yet despite the fact that the Maori are currently experiencing a cultural renaissance, there are no commercially available software products that are specifically designed for Maori-speaking people.

The problem lies mainly in the fact that while Maori is an official New Zealand language, the language of discourse is English in the everyday and technical worlds. It is our observation that movement of a language out of both ordinary and technical use is a major cause of loss of language and associated cultural identity. Shifting the status of the Indigenous languages out of token status will require the support of appropriate technology and a commitment by educators to the promotion of the fundamental human right to express oneself in a mother-tongue. Such technology, which is essentially software designed to take into consideration culturally specific factors in language use, provides a place for First Nation people in any country to stand in the technological sense. Work is currently

underway at the level of the United Nations International Standards Organisations to ensure that provision is made for appropriate representation of character sets. This is an important first step in ensuring that provision is made for the world's peoples to express themselves in their first language.

The major aim of the recently initiated Research and Development Institute at the University of Waikato (Te Whare Wananga o Waikato), New Zealand is to address this issue by producing culturally appropriate educational software. In contrast to current commercial software, the proposed software will have the added feature of logging user interaction (Barbour, 1990). The proposed suite of software will therefore be culturally specific applications that are also designed to be research tools and teaching tools.

To illustrate these points, this paper describes the first of these projects the Ta Kupu Tamariki project. Ta Kupu Tamariki is translated as “inscribing a face with a tattooing tool”, or more literally, “writing on a face”. Ta Kupu is a Maori word processor designed for teaching literacy in the Maori language to small children. By reducing the need for keyboard input and designing the interface around the structure of the written Maori language, the program enables text to be more easily entered by children than with conventional keyboard-based word processors. The accompanying data logging and log analysis software, Tirohia (translated as “look at this”), provides a means for teachers to determine student activity and performance in learning the Ta Kupu interface and in learning to use Maori language. We are of the view that unless software eases the teacher's administrative burdens it will not be used in conventional classrooms. In addition, the Tirohia software is providing a useful framework for human factors research into mouse use, key board use, as well as proving to be a useful tool for evaluating the features of the Ta Kupu interface.

Both Ta Kupu and Tirohia are written in Modula-2, a language designed to encourage portability between machine platforms. A PC version of the software has been developed, and the software will be ported to Amiga, Macintosh, and BBC Archimedes machines for distribution to New Zealand primary schools. A generic version of Ta Kupu called Genwriter is under development and will be reported in a forthcoming paper.

### **Previous work**

There is a wealth of anthropological evidence to suggest that Indigenous peoples view the experienced world in ways which are importantly different from Anglo Saxon views. A review is provided by Davidson and Kishnor (1984). We have used the logging facility provided in the software to collect data through which to examine the claims in these and related reviews.

Current commercial programming practises make data logging difficult if not impossible (Gettys and Berglan, 1990). Recent work with input devices (Revelle and Strommen, 1990) indicates that the current means of data logging is still primarily through the analysis of video tape records. This is an intrusive, prohibitively slow and tedious process, however and not appropriate for most classroom contexts. Another common tool, concurrent verbal protocol analysis, involves having the subject report aloud on his/her activities as the subject interacts with the system. This technique is potentially a rich source of data about the processes of planning the interaction, as well as the mechanics of the interaction itself. It is frequently argued, however, that such concurrent reports intrude on the interaction process and can significantly alter the nature of the interaction (see, for example, Cooper and Holzman, 1983). Retrospective reporting (in which the subject describes his/her activities after the interaction is concluded) is less obtrusive, but is prone to memory distortions (see, for example, Thomlinson, 1984). We do not believe that these techniques are appropriate for busy classroom situations.

To avoid the problems discussed above, we prefer the approach of integrating data logging facilities with the Ta Kupu software itself. Two recent works (Gettys and Berglan 1990; Ransdell, 1990) describe data logging facilities for word processors. In Ransdell, the data log facility is used to replay the user's interactions with the word processor in real time. The program itself provided little analysis of the interactions. Gettys and Berglan's Laboratory MicroStar logs keystroke interactions with the word processor, permits playback of the work session, and provides a bridge to the SAS statistical package to support analysis of the data logs.

The Tirohia software includes data extraction facilities for mouse use as well as keyboard events. It therefore provides the facilities offered by Ransdell's software as well as the data logging facilities provided by Laboratory Microstar. Tirohia also provides a file processing package for analysing the collected data. This analysis package is based on existing material and techniques from HCI research. Established and accepted findings, such as Fitts' Law (1954) are used to generate measures for interpreting a child's interaction with the Ta Kupu program (see, for example, Gillan, et al (1990); Fischman and Mucci, (1990)). These measures permit a teacher to assess the familiarity of the child with the interface and the degree of skill with which they use the mouse.

Tirohia may also be used as a basis for further research in the areas of human factors and interface design. We present some preliminary results to show the applicability of Tirohia to assisting the teacher with administering childrens' classroom based interactions with the software. We also illustrate the utility of Tirohia in detecting flaws in the screen design and mouse manipulation methods.

This paper is organized as follows:

Section 2 describes the Ta Kupu interface, and its basis in the structure of the Maori language.

Section 3 describes the types of analysis made possible by the Tirohia data logging and evaluation software.

Section 4 presents our conclusions about the applicability of Tirohia evaluation software to teaching, and discusses further research on other domains to which the Tirohia software analysis program is appropriate.

### **The Ta Kupu Program**

Since the Ta Kupu word processor is designed for use by small children, an important concern in its design was to minimize the amount of keyboard input. Our observation is that keyboard skills are relatively difficult for children to acquire, and that pointing tasks (either with a mouse, a trackball, or other pointing devices) are easier for the children to manage (Barbour, 1990).

The Ta Kupu interface is therefore based on the Ford Grid, which contains all the possible sounds used in Maori to construct words (a set of 50 syllables, plus the vowels a, e, i, o, and u). Figure 1 depicts the editing screen, containing the Ford Grid at the bottom of the screen. A user chooses a syllable by positioning the taiaha (a spear icon which is used as a culturally appropriate mouse pointer) in the appropriate grid square and clicking the mouse button. An additional click will add the applicable macron to the vowel, and a capital letter is created by clicking the right mouse button before selecting from the grid. The text constructed is displayed in the area above the Ford Grid. While the keyboard may also be

used for text input, it is useful mainly to enter non-Maori terms such as place names, personal names, and the other characters not in the Maori character set.

Since Ta Kupu is not intended to be a full-feature text processing system, it provides only the minimal editing commands (delete, cursor movements within the text screen, etc.). By reducing the complexity of the command set, the system is made more appropriate for its target audience--young children. We note also that primary teachers are enthusiastic about the ease of use aspect of the software and see the limited features as a positive advantage. There is indeed nothing to learn other than is shown on the screen in Figure 1. Note also that all screen information is in Maori.

While most computer-based software contains English instructions to convey information to the user about the software and how it can be used, the code switching involved in the transition from one language (English) to the target language (Maori) is an additional and avoidable cognitive overhead. The Ta Kupu software avoids this problem.

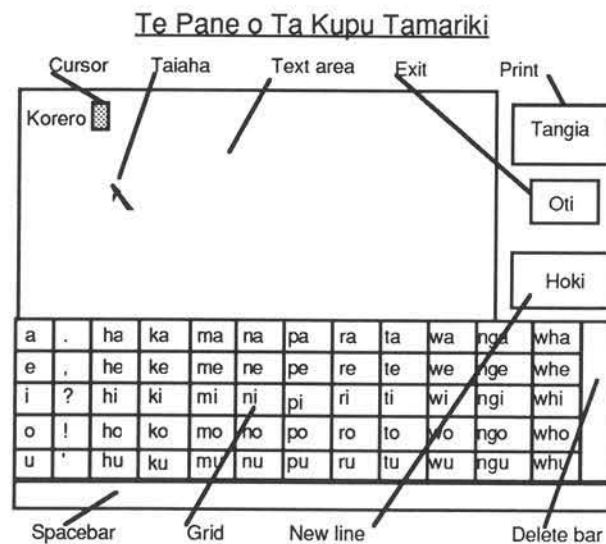


Figure 1. The Editing Screen

## **The Tirohia Data Logging and Analysis Software**

In its present incarnation, Tirohia supports for teachers by providing objective measures in the form of a report of a child's success in learning the Ford grid and in how effectively children use the mouse. In this section we discuss these data logging and analysis techniques for use by teachers. In Section 4, we discuss the more general applicability of the Tirohia techniques to other research areas.

### **Data logging and session replay**

Tirohia collects a complete log of keyboard and mouse events, serving as a complete and unobtrusive monitor of a child's interaction with the Ta Kupu software. The log is not event-driven, but instead is constructed by polling techniques. Every 60 milliseconds the logging software checks for a keypress, a mouse button click, or a mouse movement. When an event is detected, the type of the event and its clock time are recorded in the data log.

This record of events can be re-played either slower, in real time, or faster, so permitting the teacher to re-create the child's learning experience (Barbour, 1990). The replay can provide valuable insights into the child's performance, such as: where in the writing task mistakes occur; the extent of the use of deletions and insertions; and the presence of hesitations or interruptions to the task. This is derived from a composite tracking of the mouse movements that occurred during a student session. In Figure 2, a composite view of mouse movements over the grid, reveals the sections of the grid most commonly used by the student. In Section 4, we provide an example of a further application for composite records to human factors research.

### Task selection and data log analysis

While the replay facility permits the teacher to gain a fine-grained appreciation of the student's entire session with Ta Kupu, the data log analysis module gives a higher-level understanding of portions of the session. Of greater administrative value then, is the interpreted record of the interaction. The current data analysis package is designed for use by teachers, to help them evaluate the student's success in learning to efficiently and effectively navigate the grid. The student is given a composing task to complete. The teacher chooses a sub-task that will be used as an indicator of learning. The analysis portion of Tirohia then locates those sub-task instances in the log file and produces summaries of student performance on them.

As an example, consider the summary of Figure 3, where the task was to select first the "tu" grid square and then the "a" square. The summary screen displays a description of the task, table of information on specific task instances, and set of higher-level measures based on the student performance on the task instances. Specifically, the summary information includes:

a) *the table of task instance information.* This table contains a count of the number of instances of that task in the interaction, and a list showing each instance of the task that was found. The list shows the distance in pixels moved during the task and the time taken. The time is measured between (left) mouse button presses.

Straight-line distance is measured from the top left hand corner of one box to the top left hand corner of the next box. The straight-line distance is used as an indicator of the optimum path length. An average distance and standard deviation of the distance is calculated for all the task instances found.

Standard deviations for the pointing time and the distance moved are a measure of how accurate the values (time and distance) are, but they also give a measure of how consistent

the user was in performing the pointing task. A standard deviation of more than half the average pointing time indicates major differences in the performance of the task on occasion, probably due to confusion or loss of attention. It also gives an indication of whether the user had occasional problems finding items in the grid.

*b) measures of task performance:* index of difficulty, ability, and consistency

The index of difficulty is defined for Fitts' law (1954) pointing tasks as:

$$\text{Index of difficulty} = \log_2 (\text{Distance/Size} + 0.5)$$

The index of difficulty is dependent only on the geometry of the pointing task. The larger the pointing distance, the more difficult the task; the smaller the target, the more difficult the task.

Card, Moran and Newell (1983) present a formula for Fitts' law pointing tasks as:

$$\text{Time} = a + b \times \log_2 (D/S + 0.5)$$

where D= distance, S = size.

This relationship has been shown to hold for a wide range of pointing tasks, including mouse pointing. Card, Moran and Newell (1983) suggest values

$$a = \sim 1.03, b = \sim 0.1$$

for the constants "a" and "b" based on the results of their experimental results for mouse pointing tasks. Few studies have used Distance/Size ratios of less than one, but such tasks are common in our records of students selecting from the grid in our exploratory research.

The size of a rectangular target is dependent on the angle of approach. If the target is approached at an angle  $q$ , then the size of the target can be approximated by:

$$S = \text{height} \times \cos(q) + \text{width} \times \sin(q)$$

Pointing time for a task is given by Fitts' law. So to obtain a measure of the user's pointing ability, the actual pointing time is compared to the time predicted by Card, Newell and Moran (1983) for mouse pointing tasks. This gives a rating that is reasonably independent of the difficulty of the pointing task. The value for ability is calculated as:

$$\text{Ability} = 1 + 5 \times \frac{(T_{\text{predicted}} / (T_{\text{predicted}} + T_{\text{average}}))}{1}$$

where  $T_{\text{predicted}}$  is the value predicted by Fitts' Law, and  $T_{\text{average}}$  is the average time for all the tasks found. This gives a relationship where the ability rating decreases with increase in pointing time, and where the ability value is normalized to the range [1, 5]. This relationship is only approximate, as the correct constants for the task of selecting from the grid are not the same as the constants given by Card, Newell and Moran.

A measure of consistency is obtained by taking the inverse of the percentage error in the pointing time, where percentage error is the standard deviation divided by the average pointing time:

$$\text{consistency} = 5 - 5 \times (\% \text{error in time} / 100)$$

$$\text{where } \% \text{error in time} = 100 \times \text{s.d.} / \text{average\_time}$$

The consistency values are normalized to a [1, 5] range by eliminating task instances with a % error of greater than 100 (which indicates an interruption of the task). This measure gives a numeric scale for the consistency of pointing performance, which, although somewhat arbitrary, is easily understood. Teachers using the report created by this process of analysis will have a clear indicator as to whether the task of using the mouse is facilitating the writing process. Our early findings are that students make fewer mistakes with the mouse. We attribute this to the on-screen focus required from mouse driven software. This feature is in marked contrast to traditional software in which on-screen focus is only possible for touch typists.

### **Conclusions and further work**

We have described a word processor, Ta Kupu, designed for use in teaching written Maori language skills to children. The interface is constructed so as to use mouse selection for text input, thereby making the program easier to use than conventional keyboard-input programs. We have also described a data logging and analysis tool, Tirohia, which provides an unobtrusive monitor for Ta Kupu sessions. A session can be replayed in real time, permitting the teacher to re-create and analyze the student's learning experience. In addition, analysis of the data log can produce measures of user performance which indicate a child's level of ability in navigating the grid and in manipulating the mouse.

The data logging, analysis, and evaluation capabilities of the Ta Kupu program are already providing a valuable aid in several fields of research, in addition to serving as an aid to teachers. In particular, we are currently examining the following applications in the areas of human factors and interface design/evaluation:

- 1) Human factors: The interaction replay, task identification, and task tracing modules of Ta Kupu provide powerful tools to examine in detail the ways in which users manipulate screen objects with a mouse. One interesting preliminary result is that there appears to be

two types of paths used to move from one grid square to another: a user tends either to prefer a straight-line path (Figure 4a), or to prefer a “dog-leg” path following the angles of the grid layout (Figure 4b).

Another related observation is that some users differ in their methods for locating the target object on the screen. Some prefer to move the mouse as they search for the target object, sweeping the mouse about as they visually scan and apparently using the mouse movements to guide the search. Others prefer to hold the mouse still and to scan by eye movement alone.

Interestingly, if the speed of task completion is examined, then the “dog-leg” path strategy correlates with the use of the mouse as a search guide, and these strategies result in faster task completion than the straight-line and visual scan strategies. This is a preliminary indication of differences in cognitive strategy that can be detected by Tirohia. According to Kirby [9], such “microplans” for learning and task accomplishment are amenable to change in a teaching environment.

2) Interface design and evaluation: Data logging and analysis facilities such as those intrinsic to Ta Kupu provide valuable tools for evaluating the program’s interface. As an example of possible applications, analysis of user logs from Ta Kupu interactions have prompted two alterations to the interface. Firstly, it was noted that young users frequently clicked the wrong mouse button when attempting to select a grid element; the system was subsequently redesigned to accept a click from either mouse button for the selection task. Secondly, examination of data logs revealed a relatively large number of students mistakenly selected the “ha” grid square rather than the appropriate “na” grid square required by the given task. It was then determined that the font provided did not differentiate enough between the “h” and the “n” characters. When these characters were corrected, the problem in differentiating between these two grid squares was eliminated.

- 3) Vocabulary assessment: first nation peoples are becoming increasingly concerned that their languages are falling into disuse. Tirohia reads conventional ASCII text files. Many first nation languages use variants of the Latin alphabet. The Maori language uses the Latin characters shown in Figure 1. These characters have close ASCII equivalents. We are in the process of conducting an historical survey of samples of documents written by Maori language users over a period of 100 years with a view to establishing the substances of such claims about reductions in vocabulary use that could indicate gradual disuse. This research applies Ta Kupu and Tirohia to tasks equivalent to that outlined in Efron and Thisted (1976).
4. We are in the process of exploring whether Efron and Thisted's (1976) technique can be used to accurately estimate the growth, and then predict growth, in vocabulary use during a longitudinal study of classroom use of Ta Kupu as analysed by Tirohia.

In conclusion, the algorithms in Tirohia are applicable across a wide range of human factors work involving cognitive strategy research (Kirby, 1984) and in evaluation of primarily mouse-driven interfaces, as well as its current role in providing support for classroom teaching.

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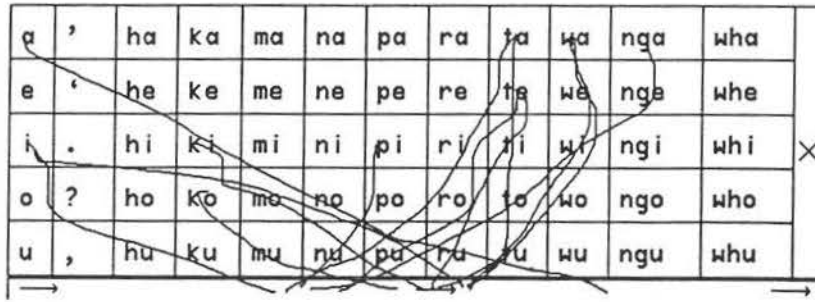


Figure 2. A composite view of mouse movements over the grid

Whakarapopotanga

Task: mouse pointing from "tu " to "a ".

Number of task instances found : 4

-----Mouse movement-----		
Instance	Distance travelled	time (seconds)
1	427	2.325
2	393	2.023
3	416	2.247
4	427	1.908
Average	415	2.125
Std dev	13	0.167

Straight line distance: 410  
(all distances in pixels)

Index of Difficulty : 3.0  
Ability (1-5) : 2  
Consistency (1-5) : 5

Figure 3. A sample summary screen

a	'	ha	ka	ma	na	pa	ra	ta	wa	nga	wha
e		he	ke	me	ne	pe	re	te	we	nge	whe
i	.	hi	ki	mi	ni	pi	ri	ti	wi	ngi	whi
o	?	ho	ko	mo	no	po	ro	to	wo	ngo	who
u	,	hu	ku	mu	nu	pu	ru	tu	wu	ngu	whu

Figure 4a. A straight-line path movement from “tu” to “a”

a	'	ha	ka	ma	na	pa	ra	ta	wa	nga	wha
e		he	ke	me	ne	pe	re	te	we	nge	whe
i	.	hi	ki	mi	ni	pi	ri	ti	wi	ngi	whi
o	?	ho	ko	mo	no	po	ro	to	wo	ngo	who
u	,	hu	ku	mu	nu	pu	ru	tu	wu	ngu	whu

Figure 4b. A “dog-leg” path from “tu” to “a”