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Evaluation of a Local Area Network in an Undergraduate Psychology Teaching Laboratory*

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The recent, rapid decrease in the microcomputer price/power ratio has led to an associated increase in the use of this technology in the Psychology teaching process. Historically, these microcomputers have been used as stand-alone machines, each with their own storage and output devices. There are a number of advantages, however, if these machines are linked together into an interconnected group or local area network. The purpose of this paper is to outline the advantages of a networked as opposed to a stand-alone system, to discuss the features required of a network utilized for undergraduate psychology teaching, and to describe a local area network which is being successfully utilized in our teaching laboratory.

The recent, rapid decrease in the microcomputer price/power ratio has led to an associated increase in the use of this technology in the Psychology teaching process. Software and interfacing systems intended for use in the undergraduate Psychology laboratory have been developed both commercially and non-commercially for a wide range of microcomputers. Historically, these microcomputers have been used as stand-alone machines, each with their own storage and output devices. In the context of undergraduate laboratory classes, however, where a large number of microcomputers is required, stand-alone systems suffer serious disadvantages related to the lack of central control and the problems associated with large scale data collation. Consequently, there is increasing interest in the interconnected groups of microcomputers known as local area networks. A local area network (LAN) is a data transmission system intended to link computers and their associated devices within a restricted geographic area. There are a number of these networks now available for purchase, however many of them offer limited facilities and therefore may not be suitable for educational use. The purpose of this paper is to review briefly the advantages of a LAN as opposed to a stand-alone system, to outline the features required of a LAN used for undergraduate psychology teaching, and to describe a LAN which is being successfully utilized in our teaching laboratory.

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Microcomputers connected into a LAN are often referred to as work-stations, and have significant advantages over a similar group of stand-alone machines. These are:

(1) Resource-sharing; whereby several computers share peripheral devices, for example, a printer or a disk drive. Apart from the immediate cost advantages associated with resource-sharing, there are other, less obvious benefits. Once a system is configured so that all students share one storage device, the control of software becomes much easier. Students no longer need to carry programs and data on large numbers of floppy disks, and new software can be made available to all students simultaneously, without the administrative problems involved in making large numbers of copies of a program. Furthermore, given adequate security, the risks of losing valuable programs, and of software piracy, are reduced.

(2) Communications; whereby the network is designed to facilitate the transfer of information from one location to another. This network feature has obvious uses in the teaching of Psychology. It can be utilized, for example, to study communication processes, group decision making and interpersonal interactions. Furthermore, the ability to transfer data from one machine to another becomes invaluable in

situations where individual data have to be collated to produce the class results for an experiment. A sophisticated communication system may also enable the synchronous control of all the micros on the network from one workstation.

(3) Distributed-processing (tied closely to 2 above); in which processing is conducted by a number of workstations, with the possibility that information can be exchanged between workstations. This contrasts with the typical minicomputer or mainframe network where a number of terminals are sequentially polled by the controlling computer. In many psychology experiments, accurate event timing is required. It may be difficult to achieve this on a mini or mainframe configuration where terminals are being polled for responses at irregular intervals without the addition of extra hardware. Micros connected to a LAN, however, are free to function independently when required, without timing or display corruptions caused by mainframe generated interrupts.

Although local area networks may initially be implemented to serve only one of the above functions, once a microcomputer is connected to a LAN, it is likely that it will become involved in other aspects of network operation. The prospective purchaser of a LAN is, therefore, urged to consider the application of a proposed network in the wider context of the applications discussed above, rather than in terms of the limited use which may be initially proposed. Thus for the purposes of the next section we will assume that any network worth considering will be able to serve any of the above functions.

A local area network for psychology teaching

Anyone considering purchasing a LAN for psychology teaching should determine whether or not the proferred networks have the following features:

Workstation Features

The computer chosen as the workstation should provide the features you would require of a stand-alone machine, that is, adequate memory and speed, good high resolution graphics, sound generation capability, adequate interfacing hardware and event timers.

Software Availability

In many cases, the decision as to what microcomputer to buy will be software-driven. A key decision is, therefore, to determine whether the intellectual resources which would enable the user to write in-house software are available or whether you are reliant on software from other sources. If the latter situation applies, then it is necessary that you ascertain whether software written for the stand-alone machine will run on the network, and furthermore, whether or not you have the legal right to run this software on a LAN. Some commercial software designed for stand-alone micros will not run on LAN's due to the operation of anti-piracy protection routines. If a hard disk-based system is being used then these copy-protection routines may have to be removed from the software so that it can be transferred from floppy to hard disk. Some software publishers may baulk at the idea of making their unprotected programs available. However, if the only storage device is a hard disk, and if adequate security measures are in effect, then it can be demonstrated to reticent publishers that the opportunities for software piracy have actually been reduced as users will not be able to download programs onto floppy disk. If the publisher agrees to provide software for your network, you may be charged a licence fee, or you may be charge several times the normal price of the software for a network compatible version.

Documentation

If software is to be written 'in house', it is critical that adequate network documentation is available. Without this, the programmer will not be able to make full use of all of the features of the network operating system.

Security

Resource sharing brings with it the risk that sensitive files may be accessed or at worst corrupted or destroyed by other users. To protect against such occurrences, the network operating system must incorporate some form of security system. This should require the identification of users by name or ID code and require that some unique password be entered before access to the system is obtained. The network operating system should be able to restrict access to files belonging to the system or to other users. Provision should be made, however, so that privileged users can override these constraints.

Network speed

Generally, the faster the rate of error-free transmission, the better. It should be noted here, that the raw transmission speed which may be quoted in advertising material, may not be the only factor to consider when trying to assess the speed of a network. The time taken to access the network, the time taken to analyse information packets and the time taken to detect and recover from data collisions may reduce the real data transmission speed considerably (Gee, 1982).

Future Expansion

It should be possible to connect extra workstations or peripherals to the network at a later time. In our experience, network use will increase markedly over time as users become aware of the advantages of the LAN system. Inter-network communication should also be possible.

Error Handling

The network should fail gracefully: The failure of one workstation should minimally degrade the performance of the rest of the network, it should be possible to provide cost-effective back-ups for critical components of the network, and in the worst case scenario it should be possible for the system to be easily configured into a set of stand-alone machines, independent of the network architecture. Errors produced during data transmission should, where possible, be invisibly corrected or at least produce an intelligible error message.

Addressing

It should be possible to send information through the network both by sending it to a particular user, and by sending it to a particular workstation. It should also be possible to send information to all users simultaneously.

Cost of Networking

Ideally, the hardware required to physically connect the network together should be as cheap as possible. Obviously, the total length of the network will be a major factor in determining whether or not this is a major consideration, however, note that over a long distance, co-axial cable will be considerably more expensive than a twisted pair. It should be noted that extra software will be required to run the network, the cost of this should be included in any calculations.

Range

Because the devices used to send data through LAN's have a limited range, it is important that the required stations will be within the transmission range specified by the manufacturer. Although a LAN should have error checking facilities, if a large number of errors are created during transmission, due to operation at the limits of the specified range, the real data transmission rate will be slowed.

Extra features

The availability of other specifically teaching oriented features, may be of use. For example, the ability to copy the screen of one micro to all other screens on the network, and to control any other machine in the network from another machine, are useful features.

A description of a successful local area network: BBC Econet general outline

Introductory Psychology students at the University of Otago are required to undergo a teaching course which includes one 3 hour laboratory class per week. In previous years, in common with many other introductory laboratory classes, we encountered problems of instrumentation that imposed restrictions on the range and sophistication of experiments that were possible. In addition, there were problems with the collation and analysis of data from the large classes involved. To ease these problems, and to create avenues for further development of the laboratory classes, we implemented a LAN based around the BBC model B microcomputer.

Hardware

The BBC model B microcomputer is a 6502-based machine, produced by Acorn computers of England. It comes complete with networking firmware, excellent interfacing capabilities, a variety of high resolution display modes (up to 640 x 256 pixels), up to 8 colours available and a very fast structured BASIC. The main failing of the BBC model B is the lack of user memory available when using high resolution graphics. This problem has, however, been surmounted to a large extent with the release of the 128K Master series computers. Software written for the BBC model B is upwardly compatible with the Master series computers and since BBC micros are common in British schools and Universities, a large software pool is available. Unfortunately, the quality of this software varies widely, and little is directly applicable to Psychology teaching.

Each micro comes standard with network firmware, and because the only other expense involved is the installation of the dual twisted pair, plugs and network software, the cost of providing access to the network is very low. One machine will be 'lost' from the network to undertake a disk-serving role, and one machine will be set aside for every printer on the network. The minimum network would consist of a cable with a clock box (to provide a frequency standard of 100-200kHz) and terminators to prevent reflections from the ends of the cable, a file-server micro and associated storage device and several workstations. Up to 256 micros can be connected onto one network, and two networks may be linked together by a 'bridge' unit.

At present our Introductory Psychology laboratory has 20 BBC-B microcomputers linked to the Econet network, with shared access to a printer and a 10Mb hard disk. In addition, two micros that are not available for general users function as the file server and the printer server. We also have one extra micro connected to a dual floppy disk drive, to serve as a back-up file server, should the main server fail. The student accessible microcomputers are all housed in one room, with the hard disc and file server micro housed separately. Other microcomputers, used primarily for program development, are connected to the network from remote locations.

Firmware

As mentioned above, each BBC comes standard with ROM-based firmware which allows for the implementation of a very sophisticated network. The BBC Econet LAN utilizes a bus type topology whereby all components in the system are connected to, and share, a common transmission medium. The transmission medium, in this case, is a dual twisted pair, with one pair carrying data, the other carrying a clock signal. Acorn recommend that the network cover a distance of no more than 500 m. Since only one transmission path is available, there must be some scheme to allow devices to share its use. Econet does this by using a Carrier Sense Multiple Access (CSMA) system with collision detection (CSMA/CD). This simply means that before accessing the transmission medium, each device first listens to establish if the carrier signal indicating that someone else is using the network is present. If the network is free, then transmission can begin. Information is sent in packets with the address of the receiving station at the start of the packet. It is possible, with this system, that two nodes may be listening to the network at the same time, determine that it is free, and begin transmitting simultaneously. To prevent this occurrence, nodes listen to the network at the same time as they are transmitting and therefore, can detect collisions. In such an event, both stations abort transmission and wait for a random interval of time before trying again. Using this system, the Econet achieves a data transmission speed of around 240 kbaud. At this rate 64k of information can be transferred in about 2 seconds. Since most programs utilized so far have been less than 10k in length, a roomful of 20 machines can be loaded within 7 seconds. This transmission rate compares very favourably with alternative systems, such as that described by Hirtle and Kallman

(1985) where program loading times of 2 to 8 minutes were reported.

Access to the network may be controlled via the use of user-codes and passwords, and users may protect their own files from access by others. Since both file directory and user directory structures are hierarchical, with access within the file hierarchy being tightly controlled, the network manager may define the levels of access of any user by placing their user-code at a certain point in the hierarchy. A number of built in commands allow the ability to view another screen on the network, and for one machine to take control of the keyboard of any other machine on the network (there are user-controlled constraints on the use of this feature for obvious reasons).

Software

At the University of Otago, a set of 18 laboratory experiments for the introductory psychology class is organised into six sections corresponding to the topic areas covered by the lecture course (96 one-hour classes): Neuropsychology, sensory processes and perception, learning, development, social processes, and cognition. We have developed software to run all experimental procedures and data analysis and software for tutorials in some specific topics. Although we might have obtained software from other sources and adapted it for use on the network, the specific academic requirements of our lecture and laboratory course meant that it was more convenient and economical to write all our own software. Indeed our experience is that similar software from commercial businesses or other universities requires so much time to rewrite for the specific purposes of our own laboratory program that it is simpler to write our own software. At present, our laboratory experiments are designed to complement the textbook for the course (Gleitman, 1986), but they have enough generality that any general introductory text could provide the background for the laboratory course.

In most cases, an entire experimental procedure is controlled from the network. Furthermore, when the individual students in a laboratory class have completed their data collection, the teaching assistant runs a program which reads their summary data stored on the hard disc, and performs summary and statistical analyses to feed back to the class members. It is also possible to summarize the results for all classes and thus to monitor the success of the different experiments.

Four examples of the types of experiment we have presented on the Econet LAN are described below. The first example is a demonstration of the Stroop effect, in which the color of rectangles, noncolor words, or color words must be identified. Latencies are recorded for the responses made at each workstation. The latencies are stored by each individual microcomputer, and at the end of the session, mean latencies for the three stimulus classes are transferred to the hard disc for later analysis. The Stroop effect is manifest in the uniformly longer latencies to name the color of words whose color names conflict with the color in which they are displayed. Figure 1 illustrates the Stroop effect, based on the data from 424 students. The good graphics capabilities of the BBC are utilised in the stimulus presentation for this experiment, as well as in the display of instructions and other text.

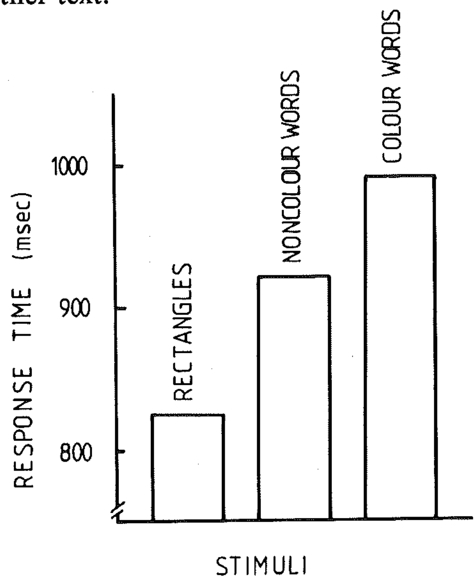

Figure 1. Mean response time for correct matches to the color of the stimulus, for rectangles, noncolor words (e.g., deer, gun) or colour words (e.g, blue, green). The greater response time for color as opposed to noncolor words is an example of the Stroop effect.

A second experiment demonstrates the phenomenon known as mental rotation. In this procedure, normal and reflected versions of three letters (G, J, R) are displayed in several orientations. The subject's task is to identify the version, normal or reflected. The mean reaction times averaged over 227 individuals (Figure 2) showed the usual mental rotation functions and were representative of individual data. The input and timing functions of the software were dealt with easily and conventionally and the rotated shapes were displayed utilizing software described in detail elsewhere (Bilkey, 1987).

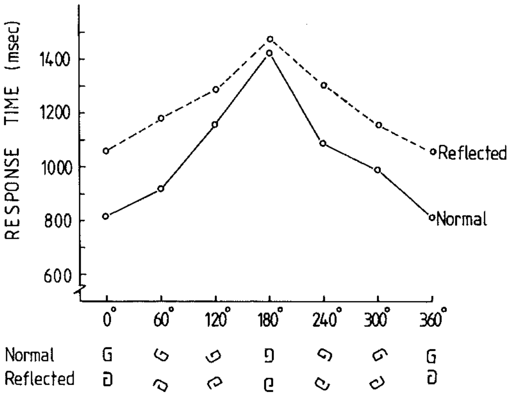

Figure 2. Mean response time for identification of normal or reflected versions of letters displayed at varying orientations. The near-linear relation between response time and orientation is the 'mental rotation' effect.

A further example of an experimental procedure mounted on the microcomputers is the study of the serial position effect as a function of list length. The data averaged over 297 individuals (Figure 3) showed text-book like functions, with the last words in the list recalled with the same degree of accuracy for the different list lengths (c.f. Wingfield and Byrnes, 1981, p.272).

The true networking capabilities of the Econet network, where information is directly broadcast between individual stations, was utilized in an experiment on the categorical perception of speech. The auditory signal from presentation of a phoneme by a tape recorder initiated all network-determined events. The phoneme was heard by all subjects working at individual stations. Functions relating category responses to the stimulus characteristics of the phonemes (onset frequencies of second and third formants) for 375 individuals showed standard categorical perception of speech functions (Figure 4).

We have also developed software for laboratory experiments on memory scanning, contingency judgment (using a video-game format to present contingent and non-contingent events), spatial frequency aftereffect, signal detection analysis of recognition memory, use of the Herman grid to measure receptive field size, behavioural stereotypy, and free-operant successive dis-

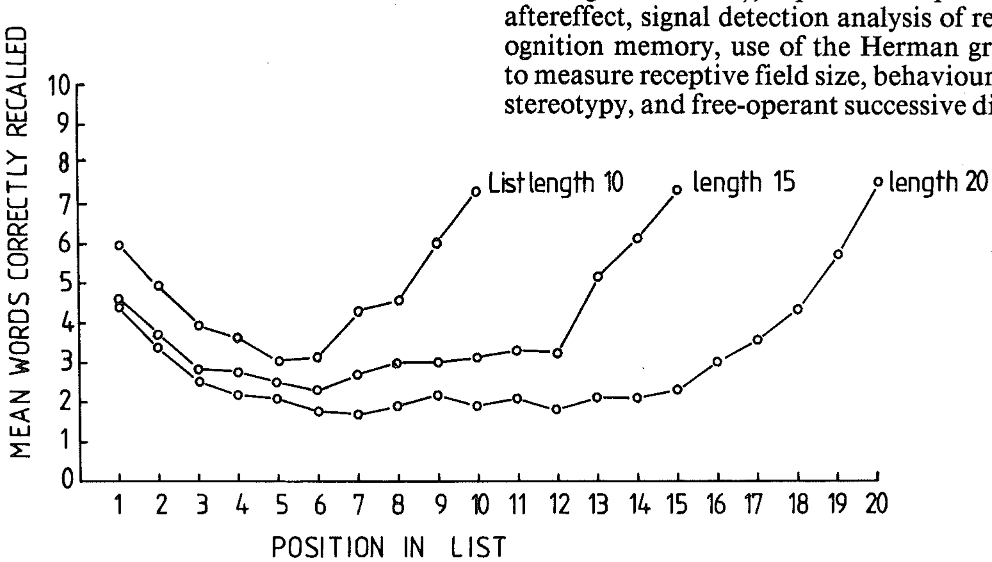

Figure 3. Mean number of words correctly recalled at various positions in a list of length 10, 15 or 20 items. The data demonstrate the serial position effect.

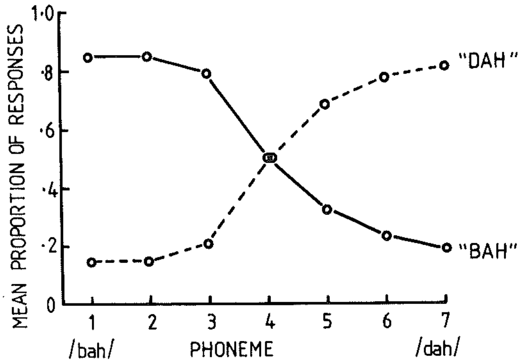

Figure 4. Mean proportion of classification of phonemes as 'bah' or 'dah' for phonemes varying in onset frequencies of second and third formats.

crimination. The increased experimental control that is possible with microcomputer-based procedures has minimized the error variance in the class data and has allowed the lucid demonstration of some robust effects in experimental psychology.

We have also developed and adapted software to maintain administrative records for the large introductory class, including grades for examination and assessment. We have found that the network can be put to many other uses such as word processing and access to the University's mainframe VAX. For reasons of economy, it is possible for all stations in the laboratory to be served by one printer, but the lengthy queueing time involved when one or two pages of results are to be printed from each station justifies additional printers.

Further Developments

Most of our current laboratory software fits into the category of experiment generators (Eamon and Butler, 1985), due to the relative ease with which this type of software can be written. We are however, in the process of developing software which requires a different approach to the teaching process, for example, a simulation of a simple visual field, (Bilkey, 1988) and we are also exploring the use of software that makes greater use of the network features, for example decision making and resource allocation simulations.

We consider that this system still has potential for further development, particularly in the area of software, as described above. Although more complex simulations may prove to be beyond the power and memory of these machines, it is clear that much can be achieved with relatively inexpensive equipment.

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