PSYCHOLINGUISTIC INVESTIGATION OF VARIABLE MESSAGE SIGNS DESIGN

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1.0 Introduction

Intelligent Transportation Systems (ITS) comprise a wide range of innovative tools for managing transport networks, as well as services for travellers. ITS tools are based on the collection, processing, integration and supply of information. Examples include:

- motorway monitoring,
- incident management,
- computerized traffic signals,
- variable message signs,
- electronic “smart cards” for tolls and fares,
- freight and public transport fleet management,
- in vehicle systems such as collision avoidance, cruise control, trip planning, emergency notification, and traffic information.

Variable Message Signs (VMS) are one of the tools Transit has deployed as part of the Ngauranga Gorge Active Traffic Management System (NATMS).

The goal of VMS’s is to influence driver behaviour by giving clear and concise messages to the motorists on traffic conditions. Comprehension of these messages is a key success factor for NATMS. To improve comprehension of its VMS messages, Transit engaged the School of Linguistics and Applied Language Studies of Victoria University to undertake a Psycholinguistic Investigation of the messages presented on these signs.

Linguistics is the scientific study of language. It has two major branches, historical linguistics, which studies how languages change over time, and descriptive linguistics, which studies language at one specified time (usually the present).

This paper presents the findings of the Victoria University study only. Transit is yet to evaluate the recommendations of the study.

The following tests were undertaken:.

(A) Speed of word recognition

¬ Response time study of recognition of general versus specific vocabulary, considering issues such as relative familiarity of words and word length (contrast INCIDENT and CRASH). See section 2.0 below.

¬ Response time study of recognition of words used in VMS displays (current and potential), contrasting different display formats (upper, lower, title case – eg. INCIDENT, Incident, incident; CRASH, Crash, crash). See section 2.0 below.

¬ Response time study where participants’ reaction times are recorded in response to different presentation orders of text lines. The study to include examples from the VMS system along with alternative orderings. See section 3.0 below.

(B) Arrangements of multi-line text

¬ Response time task related to the understanding of text (followed by paraphrase choice to confirm understanding) - responses measured in conditions varying by presentation format.

This paper presents only the findings for speed of word recognition. The arrangements of multi-line text investigations are too detailed to be summarised here.

The participants for the tests were recruited from summer course lectures or by posters displayed around Victoria University. All were native speakers of New Zealand English, and have normal or corrected-to-normal vision.

2.0 Response time study of recognition of general versus specific vocabulary and display formats

The research team decided that the first two studies from speed of word recognition could be combined into a single study in which participants' response times for key words was measured in a series of experimental sessions.

Each participant was required to attend three sessions over a three-week period. They observed half the words in UPPER CASE in the first session, and half in Title Case. The presentation was then reversed for the second session. Participants were placed into one of two groups, and the groups differed in which set of words was in UPPER CASE or Title Case in each session (see Table 1). Over the two sessions all participants saw all items in both case formats, but never saw the same item twice in one session. In the third session all participants saw all items in a presentation format chosen to simulate the VMS display.

GROUP 1		GROUP 2	
Session 1	**Session 2**	**Session 1**	**Session 2**
INCIDENT	Incident	Incident	INCIDENT
Crash	CRASH	CRASH	Crash

Table 1. Illustration of presentation formats for two participant groups over two sessions. Note the rotation of items through UPPER CASE and Title Case.

2.1 Stimuli

There were 20 VMS-related words, ie the nine items either currently in use in Transit's message systems, or used in earlier versions of some of the motorway signs. In addition to these words, further vocabulary items were selected, based on searches through Thesaurus resources. The main purposes of including these additional items were :

(i) to allow comparison of general and specific vocabulary items

(ii) to increase the size of the stimulus set used in this part of the study, thus allowing more robust statistical analysis.

	TRANSIT CURRENT	**TRANSIT FORMER**	**ADDITIONAL ITEMS**
General	incident slow delays		hazard event exit
Specific	Off-ramp queues	Accident	Crash spill brake
Other	Lane detour	Caution	Attention Care Alert Jams Backlog

Table 2. Transit stimuli: Transit and related vocabulary items used in response time study

Word frequency information was obtained from the Wellington Corpora of New Zealand English. These corpora, collected in the early 1990s in Wellington, was regarded as more appropriate to our participant population than alternative published corpora and frequency norms that are based chiefly on American and British samples. The Wellington Corpora cover spoken and written New Zealand English (NZE). In this experiment, the initial set of frequencies used were those obtained from the written corpus, since we are dealing with written presentations of the words (both in the motorway signs and in the experimental situation). http://www.vuw.ac.nz/lals/corpora.htm.

ITEM	WRITTEN FREQUENCY (PER MILLION WORDS)	WRITTEN+SPOKEN FREQUENCY (PER MILLION WORDS)	WORD LENGTH (N. LETTERS)
accident	69	79.5	8
alert	18	11	5
attention	163	101	9
backlog	1	2.5	8
brake	13	77.5	6
care	255	199	4
caution	13	8.5	7
crash	27	28.5	5
delays	58	41	6
detour	1	0.5	6
event	225	151.5	5
exit	18	14	4
hazard	12	10	6
incident	52	37	8
jams	13	10.5	4
lane	20	17.5	4
off-ramp	1	1	8
queues	8	9	6
slow	84	69.5	5
spill	16	11	5

Table 3. Lexical characteristics of Transit items.

2.2 Presentation context

For this test, it was envisaged that words that might otherwise be unfamiliar are less so if the context of “driving along the motorway” is established in the mind of the participant. To examine this, a third experimental session was used, in which participants -

(a) were told that we were interested in their responses to a number of words that included words they might see on motorway signs

(b) viewed the test materials in yellow on a black background, presented in a frame that was designed to be reminiscent of the VMS displays; and

(c) saw the items for lexical decision immediately after having completed a block of the other experiment, to be described below, in which they made decisions about multi-word VMS messages. To identify this condition in this text we will use the label FRAMED.

A total of 16368 responses (176 items X 3 sessions X 31 participants) were collected.

2.3 Results

The data represented in Table 4 were subject to participant and item ANOVAs, (Analyses of Variance)with Type (High frequency words, low frequency words, TRANSIT words) and Case (Title, UPPER, FRAMED) as factors.

	RESPONSE TIME (msec)	ERROR RATE %
High		
Title	492	1.61
UPPER	492	1.29
FRAME	*488*	*1.61*
Low		
Title	554	10.87
UPPER	571	12.56
FRAME	*547*	*12.39*
TRANSIT		
Title	532	6.77
UPPER	534	4.52
FRAME	*506*	*3.23*

Table 4: Mean response times (msec) and error rates (%) in lexical decision task, including VMS-style FRAMED presentation.

2.4 Recommendations

This word recognition study has confirmed widely attested effects on recognition of lexical frequency (related to familiarity of words) and of case of presentation. These findings in themselves would lead to recommendations that VMS signs should use high frequency words, presented in Title (or lower) case for ease of recognition.

The recommendations were:

(a) where possible, use high frequency (familiar) vocabulary over less frequent vocabulary, to aid fast and accurate lexical processing, which will have consequences for driver response

(b) since low frequency items are recognised more rapidly in Title case than in UPPER case, signs using less frequent items (e.g. possibly information and driver management signs rather than incident signs) should be presented in Title (or lower) case.

3.0 Response time study where participants' reaction times are recorded in response to different presentation orders of text lines

This response time study looked at the effect of the ordering of text lines on participants' responses to VMS displays. In the current three-line display format used by Transit for "incident" messages, the top line indicates an incident, the middle line informs road-users of what they will encounter, and the bottom line tells them what action they should take:

INCIDENT J'VILLE LANE CLOSED SLOW DOWN

In Transit' s two-line displays only the first and last components are included:

INCIDENT J'VILLE SLOW DOWN

The basic issue is whether drivers might respond better (i.e. faster and/or more accurately) to a different ordering of these text components. In particular, if the primary goal of the message is to get drivers to slow down, then would there be any point in putting the final line in the above messages in first position, since most reading experience is from top to bottom, so that drivers encounter the instruction to slow down first?

3.1 Materials

The materials used in this experiment include the two-line incident and safety messages currently used on Transit's VMS ("current" messages), together with messages formerly used by Transit ("former" messages) and some messages invented for this experiment ("invented" messages).

A total of 23 incident messages were used. These included 11 current messages, 6 former messages previously used by Transit, and 6 invented messages. Of the current incident messages, 8 were reversible, with the other 3 considered non-reversible since they would have made little sense if the lines were reversed (e.g. TERRACE TUNNEL | CLOSED would not make much sense as CLOSED | TERRACE TUNNEL). Of the 8 reversible messages, 5 were categorised as "direct" in that they explicitly included an instruction to slow down (see example above), and three were "indirect" in that they implied a requirement to slow down, without issuing an instruction to slow (e.g. INCIDENT | NEWLANDS RD). The non-reversible messages were all indirect.

Of the 6 former incident messages, 4 were reversible (3 direct and 1 indirect) and 2 were non-reversible. These non-reversible items were indirect.

Six further indirect reversible messages were invented, in order to further reduce the proportion of incident messages containing the text ‘SLOW DOWN”, and thereby reduce the participants’ reliance on this explicit text in their responses.

A total of 26 safety messages were also included, comprising 14 currently used (3 reversible and 11 non-reversible) and 12 invented (4 reversible and 8 non-reversible).

<table>
<tr><td rowspan="6">Incident (23)</td><td rowspan="2">current (11)</td><td>reversible (8)</td><td>direct (5)
indirect (3)</td></tr>
<tr><td>non-reversible (3)</td><td>indirect (3)</td></tr>
<tr><td rowspan="2">former (6)</td><td>reversible (4)</td><td>direct (3)
indirect (1)</td></tr>
<tr><td>non-reversible (2)</td><td>indirect (2)</td></tr>
<tr><td>invented (6)</td><td>reversible (6)</td><td>indirect (6)</td></tr>
<tr><td rowspan="0" style="display:none"></td></tr>
<tr><td rowspan="4">Safety (26)</td><td rowspan="2">current (14)</td><td>reversible (3)</td><td>indirect (3)</td></tr>
<tr><td>non-reversible (11)</td><td>indirect (11)</td></tr>
<tr><td rowspan="2">invented (12)</td><td>reversible (4)</td><td>indirect (4)</td></tr>
<tr><td>non-reversible (8)</td><td>indirect (8)</td></tr>
</table>

Table 5: distribution of messages in different conditions.

3.2 Results

A total of 3038 response sets were collected (31 participants x 49 messages x 2 sessions). Each response set indicates the initial response as to whether the participant would slow down. If yes, then the response set also included the response time (speed) for this decision and the result of the second decision, i.e. "1" or "2" to indicate the degree of urgency. Below are presented at each of these measures in the following order: response proportion, urgency and response time.

- Response proportion

A first measure of the interpretation of the messages is therefore the proportion of presentations for which participants indicated that they would slow down if they saw that message Table 6 indicates the percentage of items for each message type that resulted in a button press, signalling that the participant would slow down in response to those messages.

Message type	Response proportion %	Message type	Response proportion %	Message type	Response proportion %	Message type	Response proportion %	Original %	Reversed %
Incident	85	current	80	reversible	92	direct	97	98	96
						indirect	84	85	83
				non-reversible	48	indirect	48		
		former	97	reversible	99	direct	99	99	99
						indirect	98	97	100
				non-reversible	94	indirect	94		
		invented	81	reversible	81	indirect	81	87	75
Safety	29	current	17	reversible	22	indirect	22	23	22
				non-reversible	16	indirect	16		
		invented	42	reversible	69	indirect	69	69	69
				non-reversible	28	indirect	28		

Table 6: percentages of button-press responses (indicating the participant would slow down) to messages in different conditions.

- Urgency of message

A further measure of the interpretation of the message comes from a combination of, first, whether or not the participants indicate that they would slow down, and second, if they do, what rating (low urgency vs high urgency) they give in the secondary task. Figure 1 shows the distribution of urgency values for the different incident message categories. In Figure 1 the portion of a bar marked 0 in the key is the non-response portion (which we might take to indicate absence of urgency), while 1 shows the 'low urgency" rating and 2 the 'high urgency" rating to the cases where the participants indicated they would slow down.

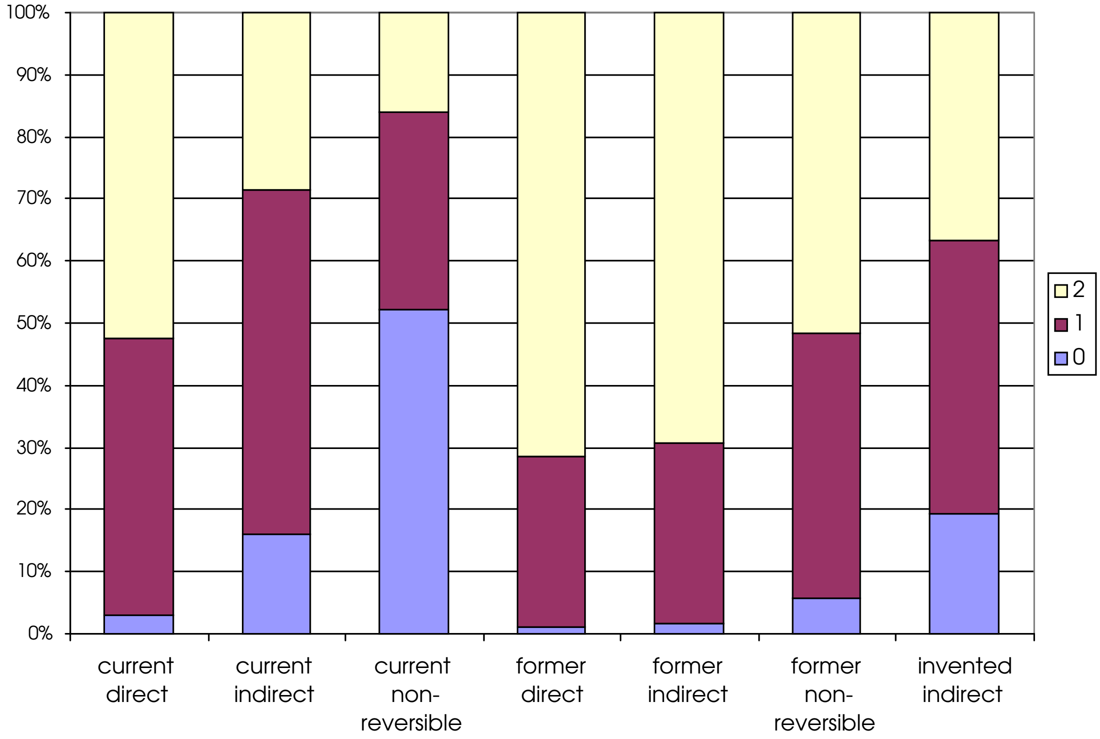

Figure 1 Urgency responses to incident items in different categories (see text for explanation).

- Response times

The assumption is that the response times in the first part of the task (pressing the button if you think you should slow down) will reflect the participants' initial sense of urgency in deciding to slow down. In other words, these response times will give an indication of how quickly drivers might respond to the messages by starting to apply pressure to the brake pedal.

Message Type	**Response time (msec)**	**Message Type**	**Response time (msec)**	**Message Type**	**Response time (msec)**	**Message Type (msec)**	**Response time (msec)**	**Original (msec)**	**Reversed (msec)**
Incident	863	current	919	reversible	919	direct	894	907	880
						indirect	967	929	1004
				non-reversible	921	indirect	921		
		former	770	reversible	752	direct	743	727	759
						indirect	777	761	792
				non-reversible	811	indirect	811		
		invented	874	reversible	874	indirect	874	859	891
Safety	1007	current	1059	reversible	1089	indirect	1089	1076	1103
				non-reversible	1047	indirect	1047		
		invented	982	reversible	950	indirect	950	932	967
				non-reversible	1021	indirect	1021		

Table 7: average response times (msec), averaged across relevant message types and sub-types.

3.3 Recommendations

This study suggests that line ordering of VMS display text may be important to the extent that the differences observed in the data reflect the relative positioning of information most obviously requiring a driver reaction.

1. *The first recommendation that text relating to the required driver reaction should be placed on the first line of the display.*

Notwithstanding recommendation 1, it was also found that the logical ordering of "statement of event"-"action to deal with that event" was effective for messages in which the statement of event was concise.

2. *The second recommendation is an exception to the first, namely that brief and non-general scene information (such as "ACCIDENT") may be placed on the first line of the display.*

The study has also revealed some marked differences between the current messages used in the VMS displays and some of the formerly used messages. The latter consistently received higher urgency ratings and faster responses. We suspect that this is related to the amount of text presented in those messages – briefer is better, and interestingly not only from the point-of-view of processing time but also in terms of how urgent the message is perceived to be.

3. *The third recommendation is that incident messages should be kept brief.*

It was also found in our examination of a small set of more closely matched messages that non-general scene information is more likely to result in faster and more urgent responses.

4. *The fourth recommendation is that specific vocabulary such as "ACCIDENT" should be preferred over more general vocabulary such as "INCIDENT".*

It would thus appear that the most effective messages are likely to be ones like the formerly used "ACCIDENT | SLOW DOWN" (recommendations 2, 3, 4), but that if it is desirable to give more detail about the reason for slowing (such as the location of some incident), then the first line should be "SLOW DOWN", as in "SLOW DOWN | INCIDENT NEWLANDS", rather than the opposite ordering (recommendation 1).

4.0 Summary

Transit recognises the importance of the studies undertaken by Victoria University for the comprehension of messages displayed to motorists through VMS. Transit is evaluating the following -

(a) using high frequency (familiar) vocabulary over less frequent vocabulary, to aid fast and accurate lexical processing

(b) using Title Case rather than UPPER CASE

(c) placing text relating to the required driver reaction on the first line of the VMS

(d) brevity of messages

(e) using specific vocabulary as "ACCIDENT" over more general vocabulary such as "INCIDENT"

and bringing consistency throughout the country for the messages used.

References

Dr Paul Warren, Senior Lecturer, School of Linguistics and Applied Language Studies, Victoria University of Wellington, New Zealand 2003. "Psycholinguistic Investigation of Variable Message Signs Design".

Acknowledgement

It is acknowledged that a large part of this paper has been reproduced from the findings of "Psycholinguistic Investigation of Variable Message Signs Design" referenced above.