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The economy of probabilistic stress: Interplay of controlling activity and threat reduction

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In this paper, we examine salient properties of control in stressing situations; the degree of control varies with the number of alternatives available to an individual within a situation. Simulated conditions of control indicate that as alternatives become more available, so does potential reduction of the probability that aversive events will occur. The simulations indicate, further, that realizing this potential rests on predictive judgements surrounding the alternatives; such judgements represent 'cognitive demands' which are regarded as stressing in their own right. After being demonstrated quantitatively, the inverse relation between aversive-event probability and requisite predictive judgements is examined empirically. Mathematical models of preference and choice are then used to identify implications of the inverse relation for the relative 'appeal' held by alternate conditions of control. Both strengths and limitations of the current formulation and its supporting evidence are noted. Finally, the present type of control regarding stressing events is compared to other types, followed by discussion of their respective roles.

1. Introduction

A salient feature of stressing situations is that they offer varying degrees of choice to the individual as to how they might be confronted (see Averill, 1973). Consider for example, an introverted person faced with the possibility of attending one of several social functions – a potentially 'stressing situation'. Each social function may comprise several types of potential interchanges involving the other invited guests. The interchanges may range from an 'innocuous exchange with a friend' to a gauche confrontation with someone who is particularly abrasive in social settings. The person may encounter such a situation under circumstances of considerable 'control' in the sense of being able to select both the social function to attend as well as the other guest with whom to carry on most of the evening's conversation. In contrast, minimal control would relegate the person to a designated function and to a specific fellow guest assigned as that evening's primary 'social contact'.

Control as depicted here affords the advantage of avoiding less desirable, more threatening alternatives (e.g. fellow guests more likely to cause embarrassment); assuming such advantage, in turn, implies judging alternatives with respect to their

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associated levels of threat. These two features of control – potential threat reduction and size of outcome set – are examined in this paper. Each is of interest in part because both 'cognitive effort' and prevailing threat have been found to instigate stress arousal (e.g. Gaines, Smith & Skolnick, 1977; Grings & Sukonek, 1971; Svebak, Storjello & Dalen, 1982; Wright, 1984).

Among other possible associations, control may somehow decrease both agents of stress; the agents may be affected in opposite directions; or one of the agents may be affected by control over and above the other.

The 'dimensions' of potential threat reduction and size of outcome set are first examined among simulated situations varying in available control. In a subsequent section, empirical correlates of these dimensions are considered; and thirdly, tentative implications of the findings are drawn out according to mathematical models of preference and choice.

2. Simulation of threatening situations varying in potential control

We begin by positing situations structured as follows. For each situation, there are p 'locations', each location containing q 'alternatives'. The p locations may correspond to p social gatherings, as described in the earlier example; the q alternatives, in turn, may be q fellow guests making up a gathering. Similarly, the p locations may represent locations of work within a job setting, the q alternatives now representing tasks that carry varying risks of injury; and so on.

Six conditions of potential control ('controllability') concerning the p locations and q alternatives are now constructed by combining two conditions of location controllability with three conditions of 'alternative controllability'. The first condition of location controllability allows choice among any one of the p locations (*C*); in the second condition, location is assigned, and no choice is available (*No*).

The first condition of alternative controllability, in turn, allows the choice of any one of the q alternatives in the selected or assigned location (*c*). In the second condition, an alternative is assigned, but the specific assignment is uncertain (*unc*) until after the *location* has been chosen or assigned (i.e. until after the selected or assigned location has been 'entered'). The third condition is the same as the preceding condition, except the alternative to be assigned within each location is apparent before one of the locations is selected or assigned. In this instance, then, there is no choice over constituent alternatives within locations, nor is there uncertainty as to which alternative is to be assigned (*no*). The six situations of potential control, then, are denoted *C c*, *C unc*, *C no*, *No c*, *No unc*, *No no*.

The controllability of a situation is now quantified as the total number of alternatives that are accessible in the situation at large, or the 'size of the response set'. It is assumed that the individual is constrained to options involving the respective locations and alternatives; excluded, for example, is the option of escaping from the situation altogether. These values for this 'dimension' range from pq (conditions *C c*) through to 1 (conditions *No unc* and *No no*).

We consider now the number of judgements necessary to ascertain the alternative carrying the least probability of an aversive event. This value is simply the size of the set of possible outcomes. The probabilities of an aversive event are assumed to be

Table 1. Values for response set size, potential outcome size and expected value of outcome for six conditions of control

Situation	Response set size	Potential outcome set size	Probability of access to the best outcome $[Pr(t_1)]$	Presence of choice	Uncertainty	Expected value of outcome
C c	pq	pq	1	y	n	t_1
C unc	p	pq	$1/q$	y	$(1/q)t_1+(1-1/q)\bar{t}_{i'}$	y
C no	p	p	$1/q$	y	n	$E(min\, p\, t_i)$
No c	q	q	$1/p$	y	n	$E(min\, q\, t_i)$
No unc	1	q	$1/pq$	n	y	$(1/pq)t_1+(1-1/pq)\bar{t}_{i'}$
No no	1	1	$1/pq$	n	n	$(1/pq)t_1+(1-1/pq)\bar{t}_{i'}$

Note. $E(min\, p\, t_i)$ is the expected value of the minimum of a random sample of $p\, t_i$ outcomes, and $E(min\, q\, t_i)$ is the expected value of the minimum of a random sample of $q\, t_i$ outcomes.

i' indicates $\underset{i>1}{i}$.

unequal over the $p\,q$ alternatives but the severity or magnitude of the event remains constant.† Hence, threat varies directly with aversive-event probability (Neufeld & Herzog, 1983). A third assumption is that there is no 'bias' in location or alternative assignment – that is, each location has an equal chance for assignment, as does each alternative within each location. Furthermore, as already implied, alternatives carrying less threat are assumed to be preferred to those carrying more threat.

Size of the set of possible outcomes under conditions *C c* is $p\,q$. That under *C unc* is again $p\,q$; selection is restricted to the p locations, but an informed choice compels attention to the q alternatives within each location, since each is an equal candidate for assignment. In contrast, under conditions *C no*, the individual need only consider the pre-assigned alternative within each location. Under conditions *No c*, all q alternatives within the assigned location must be considered. For conditions No unc, q predictive judgements, corresponding to the q alternatives of the assigned location, are again specified; this value allows that individuals will appraise existing threat according to available cues, whether or not selection/avoidance is possible (Neufeld, 1982). Where both location and alternative are assigned and are known, *No no*, only one predictive judgement is involved (see Table 1).

Quantification of potential threat reduction is somewhat more involved than that of the preceding two dimensions. In addition to the assumptions already stated, we assume that location-selections or assignments are mutually exclusive, as are those of alternatives within locations. That is, encountering a particular location-alternative combination implies not encountering the remaining $p\,q-1$ combinations. Available threat reduction, then, is quantified as the probability of access to the least threatening of the total $p\,q$ alternatives in the presenting situation $[Pr(t_1)]$. These probabilities are presented in Table 1 for the six conditions of control.

† This constancy is not essential in the current development, but facilitates continuity with the later presentation of empirical dimensional correlates.

The probabilities describe comprehensively the relative availability of threat reduction for conditions *C C*, *C unc*, *No unc*, and *No no*, as follows. We denote the threat (probability of aversive-event occurrence) associated with alternative i as t_i $(i = 1, 2, \ldots, pq)$; $t_i < t_j$ iff $i < j$. For condition *C c*, the probability of encountering $t_{i>1}$ is 0.

For *C unc*, it is assumed that the location ascertained to contain t_1 is selected. This assumption will be considered further, momentarily. The probability of engaging an alternative $i_{>1}$, then, entails the probability of its occurring in the location containing t_1, and that of its designation, given its occurrence alongside t_1. Given an equal chance of inclusion in the location with t_1, the first probability is $(q-1)/(pq-1)$; the second probability is $1/q$. Since these probabilities are independent, the probability of encountering $t_{i>1}$ is $[(q-1)/(pq-1)]1/q$. Consequently, the expected threat associated with alternatives other than t_1 is

$$\sum_{i=2}^{pq} [(q-1)/(pq-1)](1/q)t_i = [(q-1)/q]\ \bar{t}_{i>1},$$

since $1/(pq-1)\sum_{i=2}^{pq} t_i = \bar{t}_{i>1}$, the mean of the $pq-1$ $t_{i>1}$'s.

Note that $(q-1)/q$ is the complement of the probability of access to t_i (see Table 1).

For conditions *No unc*, the expected threat associated with the alternative $t_{i>1}$ is

$$\sum_{i=2}^{pq} (1/p)(1/q)t_i = [(pq-1)/pq]\ \bar{t}_{i>1},$$

since $\sum_{i=2}^{pq} t_i = (pq-1)\ \bar{t}_{i>1}$.

The same result applies to conditions *No no*. In each instance, $(pq-1)/pq$ is the complement of the probability of access to t_i.

Under conditions *C no*, the probability of engaging a given $t_{i'}$, where i' now indicates $i_{>1}$, involves the probability of its own assignment – l/q – as well as the probability of the assigned t_is in the remaining locations, $t_{j_{a_{i'}}}$ $(a_{i'} = 1, 2, \ldots, p-1)$, all exceeding $t_{i'}$ – $Pr\left(\bigcap_{a_{i'}}^{p-1} j_{a_{i'}} > i'\right)$. The expected threat, then, associated with the $t_{i'}$ alternatives is

$$\sum_{i'=2}^{pq} 1/q\, Pr\left(\bigcap_{a_{i'}=1}^{p-1} j_{a_{i'}} > i'\right) t_{i'}.$$

Note that $Pr\left(\bigcap_{a_{i'}=1}^{p-1} j_{a_{i'}} > i'\right) = 0$ when $(pq-i') < (p-1)$; $Pr\left(\bigcap_{a_{i'}=1}^{p-1} j_{a_{i'}} > i'\right)$ increases with decreasing i' as $(pq-i') \geqslant (p-1)$. Thus, the expected threat associated with the $t_{i'}$ alternatives will be less than $[1-1/q]\bar{t}_{i'}$.

By a similar argument, the expected threat associated with the $t_{i'}$ alternatives under conditions *No c* will be less than $[1-1/p]\bar{t}_{i'}$. Thus, the values for $Pr(t_1)$ underestimate the relative available threat reduction for conditions *C no* and *No c*.

On balance, then, $Pr(t_1)$ is a relatively straightforward index of available threat reduction; and it comprehensively quantifies this dimension for four of the current six simulated situations. As mentioned above, however, it is assumed that choice under uncertainty, conditions *C unc*, is determined by the location of t_1. That is, a *maximax* strategy is employed (see, for example, Rappaport, 1983, for a description of choice strategies under uncertainty).

Clearly, other strategies may be employed. For example, a *maximin* strategy may dominate choice. In this instance, the location whose maximum t_i is lower than the maximum t_i of any of the remaining $p-1$ locations is selected.

On the other hand, a slightly more complex strategy may dominate choice. Such a strategy involves minimizing the maximum potential regret associated with selection – known as *minimax regret*. In the present context, this strategy prescribes choice of the location whose maximum t_i differs least from the minimum t_i of any of the remaining $p-1$ locations. A third possibility is that selection is oriented toward minimizing expected threat:

$$\min\left(1/q\sum_{i=1}^{q} t_{ik}; \qquad k=1,2,\ldots,p\right).$$

Furthermore, strategies may vary across individuals. The relative influence of *maximax* and *maximin* strategies, for instance, can be expressed in the *Hurwicz function* as applied to the present context:

$$\alpha \max_i(t_{ik}) + (1-\alpha)\min_i(t_{ik}),$$

where $\max_i(t_{ik})$ = the maximum t_i in location k,
$\min_i(t_{ik})$ = the minimum t_i in location k,
and α $(0 \leqslant \alpha \leqslant 1)$ indicates the relative influence of the *maximin* as compared to the *maximax* strategy in influencing selection.

The location with the *minimum* value for this function is chosen. Relative dominance of one or the other strategy might be thought of as reflecting the pessimistic (maximin) versus optimistic (maximax) bent of the individual.

An additional potential limitation of $Pr(t_i)$ as an index of threat is its failure to reflect the presence–absence of uncertainty of outcome – conditions *C unc* and *No unc* as opposed to the remainder. Threat may be increased when several alternatives within a location can occur. This possibility will be discussed later, with reference to certain features of relevant empirical data.

On balance, then, several strategies may be involved in implementing the present version of available control to reduce threat. Deciding among these strategies requires comparison of the relative goodness of fit of their predictions to a substantial sample of choice behaviour, primarily under conditions involving uncertainty. Such comparison remains beyond the scope of this paper, but represents an important direction for future work. Instead, the current intent is to draw tentative inferences regarding the directions of relations among controllability, size of possible-outcome sets, and potential threat reduction. Indexing the latter as $Pr(t_1)$ affords ready comparison among the current conditions of control; however, doing so also carries certain limitations, as indicated above. Mathematical convenience does not speak to the validity of the selection strategy that this index implies. Note that the interdimensional relations and the empirical correlates of these relations are not necessarily exclusive to threat reduction as indicated by $Pr(t_1)$.

Associations among dimensions. The association among the above-quantified dimensions are presented in Fig. 1 for $p = 2$ and $q = 4$. The size of the outcome set is correlated with each of $Pr(t_1)$ and response-set size, $r = 0.61$, which in turn are correlated perfectly. This pattern of positive associations is representative of those obtained for simulated situations with various values of p and q (e.g. p ranging from 2 through 4, and q ranging from 2 through 8).

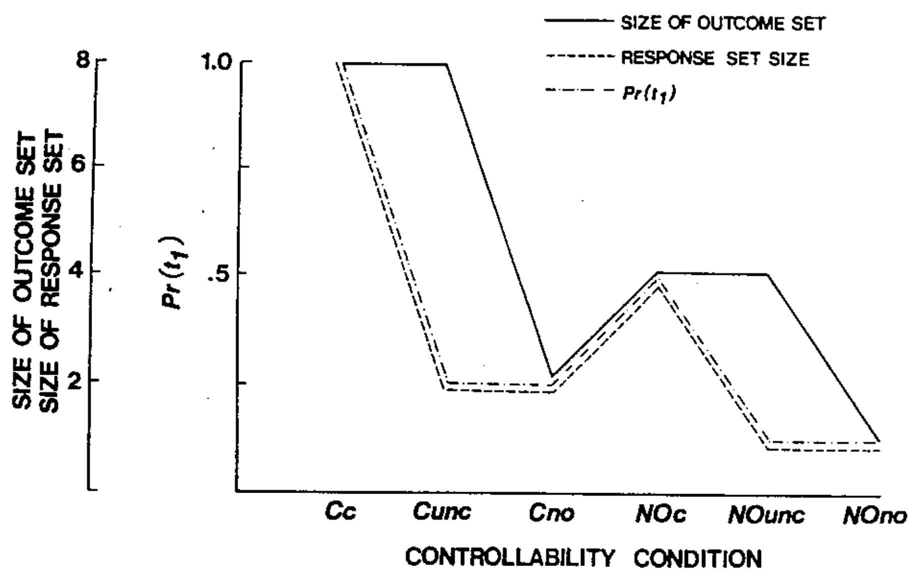

Figure 1. Covariation among controllability (response-set size), outcome-set size and potential threat reduction as indexed by $Pr(t_1)$.

The pattern leads to specific predictions concerning both interrelations among the current dimensions, as well as associations with stress. Firstly, controllability and size of outcome set should covary, as indicated. Secondly, outcome-set size should covary with stress for reasons stated earlier; and, thirdly, controllability should covary negatively with stress, because of the former's positive linkage to $Pr(t_1)$. These predictions are examined empirically, below.

Studies 1 and 2: Judgemental interrelations among controllability, size of outcome set and stress

3. Study 1

In this study 93 (43 male and 50 female) undergraduates (from the University of Western Ontario) rated 31 descriptors of 'stressing situations'. Three randomly ordered sets of ratings, addressed to controllability (response-set size), outcome set-size, and stress, were obtained.

Situation descriptors. Several considerations surrounding the current dimensions guided the construction of these descriptors. Content embodied potential 'threat to well being' (Lazarus, DeLongis, Folkman & Gruen, 1985), but did not set forth explicit loss or far-reaching change (e.g. Holmes & Rahe, 1967).

Secondly, effort was made to increase the accuracy of subjects' judgements *vis-à-vis* non-inventory behaviour and experiences. Phrases tended to minimize reliance on generalities and inferences concerning situations and potential incidents in favour of 'tangibilities' concerning situations and incidents (Semin & Greenslade, 1985). Thirdly, the situations to varying degrees incorporated the types of threat found to be salient for the current population according to several previous multivariate scaling analyses of subjective responses (e.g. Ekehammar, Magnusson & Ricklander, 1974). Included were, 'interpersonal ego threat', 'physical danger', 'novelty/ambiguity', 'threat of punishment' and 'inanimate threat'. Finally, differing levels of opportunity for affecting the probabilities of aversive incidents were implicit across the sample of situations. Items were adapted in good part from the above multivariate scaling studies (detailed in Neufeld, 1978). Examples include:

> 'Listening to a lecture and not understanding it, although others find it easy.'
> 'Going to have an injection that will hurt.'
> 'Starting a new summer job.'
> 'Discovered looking at a personal "classified" file.'
> 'Alone in the wilderness and surprised by a violent thunderstorm.'[†]

3.1. Procedure

The set of judgements directed toward controllability was preceded by the following instructions:

> On the following pages, you will find a list of situations. Please indicate by circling ONE number on each of the scales, how CONTROLLABLE or UNCONTROLLABLE each situation would be if you were in it (i.e., how much control you feel you would have).

Instructions preceding the judgements relating to the outcome-set size were:

> On the following pages, you will find a list of situations. Please indicate by circling ONE number on each of the scales, how much 'THOUGHT' would be required from you in each of these situations.That is, how much effort of thinking about what is going on would you carry out, or how much information would you have to consider when faced with these events.

And those preceding the stress ratings were:

> On the following pages, you will find a list of situations. Please indicate, by circling ONE number on each of the scales, how STRESSFUL or UNSTRESSFUL each situation would be if you were in it.

[†] The complete set of descriptors is available from the first author.

These instructions were augmented by a brief description of the term 'stress' relevant to the present context (Neufeld, 1982). The description incorporated common usages of the term, and included reference to the subtypes of stress obtained from the multivariate analyses of judgemental data, cited above.

The ratings were carried out on five-point scales anchored by 'complete control'–'no control', 'extreme effort'–'no effort', and 'very stressful'–'no stress', for the preceding respective sets of judgements. Order of the three sets of judgements was randomized for each subject, and order of situations within each set of judgements was randomized.

3.2. Methods of analysis

The judgements were analysed using 'individual-differences/points-of-view' procedures (Skinner, 1978; Tucker & Messick, 1963). Initially, the number of distinctive profiles of stress reported over the 31 situations was estimated from the sample of 93 judgement protocols. Secondly, the configuration of stress corresponding to each distinctive profile was identified. Thirdly, the specific configuration of controllability reported over the 31 situations that correspond to each of the preceding distinctive stress profiles was obtained. This was followed by computing the configuration of judgements pertaining to outcome-set sizes reported over the 31 situations that correspond to each of the distinctive stress profiles. Consequently, the covariation between controllability and stress could be estimated with respect to each distinctive stress profile; a similar estimate could be made for outcome-set size ratings and stress. (A compendium of computations involved in the preceding methods is presented in Appendix A.)

Consider, for example, the judgements of a given subject. The similarity between the subject's judgements of stress for the 31 descriptors and those of another subject was computed according to the sum of their cross-products of judgements. Such sums of cross-products were computed between the subject at hand and each of the remaining 92 subjects. The sum of squares the subject's own judgements were obtained, as well.

The sums of cross-products formed the off-diagonals of a 93×93 matrix, with the sums of squares forming the diagonals. The eigenvalues of this matrix were obtained (according to principal components analysis) and the eigenvectors corresponding to the relatively larger eigenvalues were computed.

The number of relatively larger eigenvalues indicated the number of different prominent judgement profiles within the sample; prominence would increase, for example, as the number of judgement protocols homogeneously sharing the profile increased. In turn, the degree to which a given profile was representative of the specific pattern of judgements of our example subject was indicated by the value of the subject's coordinate on the corresponding 93-tuple eigenvector. Close correspondence between the subject's judgements and the given profile was characterized by a high coordinate value relative to the subject's coordinates on the remaining eigenvectors. Put differently, the coordinate reflected the sum of cross-products between the subject's 31 judgements, and the 31 values of the profile represented by the eigenvector.

The 31 values composing a particular profile were educed as follows. Each value was obtained as the weighted sum of stress judgements from all 93 subjects, with the coordinates of the 93-tuple vector serving as weights.

The subsequent set of computations was designed to estimate how subjects characterized by a given profile of stress judgements viewed 'controllability' and 'outcomes-set size' in relation to stress. Each of the 31 controllability values was obtained as the weighted sum of controllability judgements from all 93 judges; the coordinates of the 93-tuple eigenvector corresponding to the given profile of stress judgements again served as weights. The 31 judgements for 'outcome-set size' were obtained in like fashion.

The apparent complexity of these analyses was offset by the comprehensiveness of resulting information, as follows. There was sufficient aggregation of the judgement data to throw into relief the directions of relations among the current stress-relevant dimensions. Secondly, the analyses provided for systematic individual differences in (stress) judgement configurations. Perceived variation in stressfulness over the 31 descriptors, for instance, might differ among subsamples of subjects. These differences, however, may be accompanied by corresponding changes in the configurations of judgements pertaining to the other two dimensions. The net effect may be the maintaining of similar directions of interdimensional relations throughout.

3.3. *Results and discussion*

A single distinctive profile of stress over the 31 descriptors was obtained: the first eigenvalue exceeded 10 000, the remainder being $\leqslant 367$. The corresponding profiles for controllability and size of outcome set served as predictors of the stress profile[†] in a multiple correlation. The value of R was 0.95; $\beta_{\text{controllability}}$ was -0.33, and $\beta_{\text{outcome-set size}}$ was 0.76.

The partial correlation between stress and controllability was -0.71; that between stress and outcome-set size was 0.92; and the partial correlation between controllability and outcome-set size was 0.514.

The associations among controllability, outcome-set size, and stress obtained here were in agreement with those following from the earlier simulations. Support, however, was limited according to the open-endedness of instructions. Those pertaining to controllability, for instance, may not have elicited responses directed exclusively to the current format of this dimension – 'decisional control', or '... the range of choice or number of options open to the individual' (Averill, 1973; p. 298). Consideration may have been given to other additional-types of control such as 'instrumental control'. Here, the probability, intensity, duration, and so on, of stress events may be modified by the individual's own actions (Gal & Lazarus, 1975). Similarly, '... effort of thinking about what is going on...', couched in the instructions pertaining to outcome-set size, may have activated reference to 'intrusive ideation' concerning the stressor situations (Horowitz, 1975; Sarason, 1984), rather than the intended dimension alone.

[†] The complete set of values corresponding to the stress, controllability and outcome-set size profiles is available from the first author.

In the following study, situation descriptors were constructed so as to focus responses on control in the form of the number of accessible alternatives. Instructions regarding outcome-set size furthermore, emphasized predictive-judgements associated with alternative selection.

4. Study 2

Apart from the above modifications, this study proceeded as did Study 1. One hundred and forty undergraduates from the University of Western Ontario (70 males and 70 females) rated 48 'stressing-situation' descriptors with respect to controllability, outcome-set size, and stress.

4.1. *Situation descriptors*

The descriptors were constructed so as to reflect directly the simulated conditions of control described earlier. Forty-eight descriptors resulted from: conditions *Cc* through *No no*; combined with two versus eight alternatives within locations ($q = 2, 8; p = 2$ throughout); combined, in turn, with four 'types of threat' ('physical danger', 'novelty/ambiguity', 'interpersonal ego-threat', and 'fear of punishment'). Examples include:

> You can accept a ride from either one of two people, each of whom tends to drive fast and takes big risks. You can choose from among 8 specific ways of dealing with the situation (of dangerous driving) in each case.
>
> *Cc*: $q = 8$; 'physical danger'
>
> You have applied to two companies for a new summer job and now you have the choice of accepting either one. Within each company, there are 2 possible positions, but you do not know which one you will be assigned in either case.
>
> *C unc*: $q = 2$; 'novelty-ambiguity'
>
> Your are given the choice between taking an in-class examination or a take-home assignment. There are 2 specific points you are not clear on concerning the material to be covered in either exam. You know that the professor will be covering only one and you are told which one that will be.
>
> *C no*: $q = 2$; 'interpersonal ego threat'
>
> Unusual circumstances have led you to pilfer something of value in one of 2 specific settings, setting A or B. Now it must be done in setting A. If you are caught, you will have 8 specific defense strategies to choose from to plead your case.
>
> *No unc*: $q = 8$; 'fear of punishment'[†]

[†] The complete set of descriptors is available from the first author.

4.2. Procedure

Each of the 48 situations was rated essentially as in Study 1. Instructions pertaining to outcome-set size were refined as follows:

> On the following pages you will find a series of situations. Please indicate, by circling one number on each of the scales, how much INFORMATION you feel there is in the described circumstances which would have to be considered in order to make any decisions about it.

4.3. Results and discussion

Analysis was essentially the same as in Study 1, except for the increased numbers of subjects and descriptors. A single distinctive profile of stress, over the 48 descriptors, was again obtained: the first eigenvalue exceeded 10 000, the remainder being $\leqslant 379$. With the corresponding profiles of controllability and of outcome-set size serving as predictors‡ of the stress profile, R was found to be 0.49; $\beta_{\text{controllability}}$ was -1.23, and $\beta_{\text{outcome-set size}}$ was 0.80.

Partial correlations were -0.68 between stress and controllability; 0.52 between stress and outcome-set size; and 0.88 between controllability and outcome-set size.

The directions of interdimensional associations agreed with the pattern following from the simulated conditions of control. In this instance, however, the results pertained more directly to the versions of these dimensions of current interest. The increased specificity allowed clearer interpretation in part by diminishing the risk of tautological measurement (e.g. the mutual tapping of 'intrusive thoughts' by the stress and outcome-set size measures, referred to earlier). Accordingly, the value of R was evidently less spuriously inflated in the present results.†

The following study augmented the preceding studies by experimentally implementing the conditions of control. Effects of variation in controllability and outcome-set size were examined with respect to direct responding.

5. Study 3: Psychophysiological and behavioural correlates of controllability and outcome-set size

Direct responding was measured according to representative behavioural and psychophysiological indexes employed in experimental stress research (e.g. Neufeld, in press). Fifty-two male and 52 female University of Western Ontario undergraduates served as subjects.

‡ The complete sets of values corresponding to the stress, controllability and outcome-set size profiles are available from the first author.

† The judgements described here were intercorrelated separately for each of 50 male and 50 female subjects from a similar population (Paterson, 1984). Mean correlations indicated directions of interdimensional relations identical to those from the present study. The magnitudes of the relations were attenuated, however, as would be expected with disaggregation.

5.1. Procedure

The study involved two sessions. The first session consisted of a series of presentations of alphabetic letters; these letters were later to represent the constituent alternatives in the various conditions of control. Presentations were designed to endow the letters with differing subjective likelihoods of 'aversive incidents'.

In the subsequent session, subjects were required to select an available alternative during each trial; availability varied over trials according to conditions *Cc* through *No No*.

During each presentation in the first session, one of 10 alphabetic letters appeared on a video monitor for 2 s. This appearance was followed immediately by either of two incidents: a 500 Hz, 108 dB (SPL at the ear) sound for 1 s, of previously documented aversiveness (Lefave & Neufeld, 1980); or, 1 s illumination of a green light. For example, one letter was followed by the loud tone on 64 per cent of its 22 presentations, and green-light illumination on the remainder. A second letter was followed by loud tone for 22 per cent of its presentations, and light illumination for the remainder; and so on. The letters thus differed in their frequencies of associated aversive and non-aversive incidents. This method of inducing differential threat association circumvented certain ethical barriers to other methods, such as enhancing noise volume to selected letters, etc. Full details of the present probability learning paradigm (Estes, 1976), as adapted to experimental stress research, are available elsewhere (Mothersill & Neufeld, 1985; Neufeld & Herzog, 1983).

Following these presentations, the respective letters were judged with regard to their associated probabilities of noise. These judgements indicated clearly that the intended probabilities had been learned (Morrison, 1985), according to previous criteria (e.g. Estes, 1976; Neufeld & Herzog, 1983).

The second session followed approximately 5 min after the first. During each trial, a set of letters randomly selected from the earlier 10 were presented. These were divided into two subsets ($p = 2$). The size of each subset was two letters during 12 trials, randomly interspersed with four-letters for the other 12 trials ($q = 2; 4$).

Access to subsets of letters ('locations') and to constituents within subsets ('alternatives within locations') were designated by upper- and lower-case 'x's. To illustrate, condition *Cc* ($q = 4$) was introduced during practice trials as follows:

> Here are 2 letter sets of 4 letters each. (The following example was presented on the video-monitor):
>
> | | |
> |---|---|
> | X | X |
> | x x x x | x x x x |
> | C E S Q | R N O T |
> | Set 1 | Set 2 |
>
> Notice that each set of letters has a large "X" above it. This "X" indicates to you that you may choose that set of letters. In the present example, since both sets of letters have large "X"'s over them, you have the opportunity to choose either Set 1 or Set 2. Similarly, you could choose any individual letter within Sets 1 or 2, since each letter has a small "x" over it.

Each trial commenced with the presentation of letters and upper- and lower-case 'x's. Subjects were required to make the selection within the following 20 s, or a 'RESPOND NOW' sign joined the display. Where no selection was available (conditions *No unc* and *No no*), subjects simply indicated the designated subsets/letters. Delivery of loud tone or light illumination was proportional to their frequencies of occurrence to the selected/designated letter during the first session. For condition *C unc* and *No unc*, frequencies for a random letter from the selected/designated subset were employed.

Subjects were reminded of the relative frequencies of loud tones associated with each letter in the first session and were encouraged to use them in their selections. The 24 test trials comprised two presentations, of the six conditions of control, for each of two- and four-letter subsets. Presented order of these combinations was random.

5.2. *Response measures*

Psychophysiological responses of heart-rate acceleration (HR ACC), heart-rate deceleration (HR DEC), skin conductance (SC) and frontalis ('mid-forehead') muscle tension (MT) were monitored. Instrumentation and scoring employed established procedures detailed elsewhere (e.g. Neufeld, 1978). Briefly, HR ACC (DEC) for each trial was scored as the maximum (minimum) beats per minute (beats/min) between the presentation of letters and the subject's response. A 'baseline rate' consisted of the maximum (minimum) beats/min during the quiescent 5 s preceding the 24 test trials. Similarly, for MT, average microvolts of myoactivity, continuously integrated over 0.2 s epochs, was obtained during the above intervals. Skin conductance was obtained as maximum readings in micromhos during these periods.

Note that HR ACC has been associated with anticipated informational demands (Dobson & Neufeld, 1981; Endler & Magnusson, 1977) as well as covert information processing (Obrist, 1981); HR DEC has been indicative of visual intake of external stimulation (see, for example, Eves & Gruzelier, 1984; Lacey, 1972). Skin conductance has been shown in experimental stress studies to be relatively sensitive to 'attention-eliciting properties of the stimulus complex' including intensity, complexity, and novelty (e.g. Dobson & Neufeld, 1981; Geer & Klein, 1969; Lefave & Neufeld, 1980). Frontalis muscle tension, in turn, has been considered to be a promising index of threat of aversive events (e.g. Martin & Sroufe, 1970; Neufeld, 1976).

Other measures included (*a*) time from letter presentations to response registration, and (*b*) noise-probability values of selected letters, or letters designated within selected subsets. These values were based on the relative frequencies of loud tones to the letters, conveyed in the first session. Only scores on this measure for those conditions with some available control were analysed.

5.3. *Results and discussion*

Data analysis incorporated the within-subjects factors composing the 24 trials described above, and male–female as a between-subjects factor. Analysis of the psychophysiological measures employed baseline readings as covariates.

For brevity, only significant effects involving conditions of control (i.e., response-set size) are reported. Significant effects of this factor were obtained for HR ACC, HR DEC, and SC, *F*s (conservative d.f. of 1,102) = 28.13, 20.28 and 14.70, ps < 0.01. Values for HR ACC and HR DEC are presented in Fig. 2. (Note that the decelerative response corresponds to a downward deflection of heart rate; hence, lower values in Fig. 2 signify a greater response, in this sense.) The pattern of values for MT, on the other hand, was roughly opposite to that of the preceding measures ($F = 4.49$, d.f. = 1,102, $p < 0.05$). Values for SC and for MT are presented in Fig. 3.

For time to response registration, a main effect for conditions of control $F = 199.28$, d.f. = 1,102, $p < 0.01$) was qualified by an interaction with the size of letter subsets ($F = 12.35$, d.f. = 1,102, $p < 0.01$). The configuration of mean values reflected essentially the number of predictive judgements underlying selection of the least threatening letter. Noise-probability values for selected/designated letters were approximately inversely related to the degree of available control across conditions ($F = 64.19$, d.f. = 1,102, $p < 0.01$). An interaction with presentation number ($F = 10.95$, d.f. = 1,102, $p < 0.01$) indicated the inverse relation to be slightly more pronounced during the second presentation.[†]

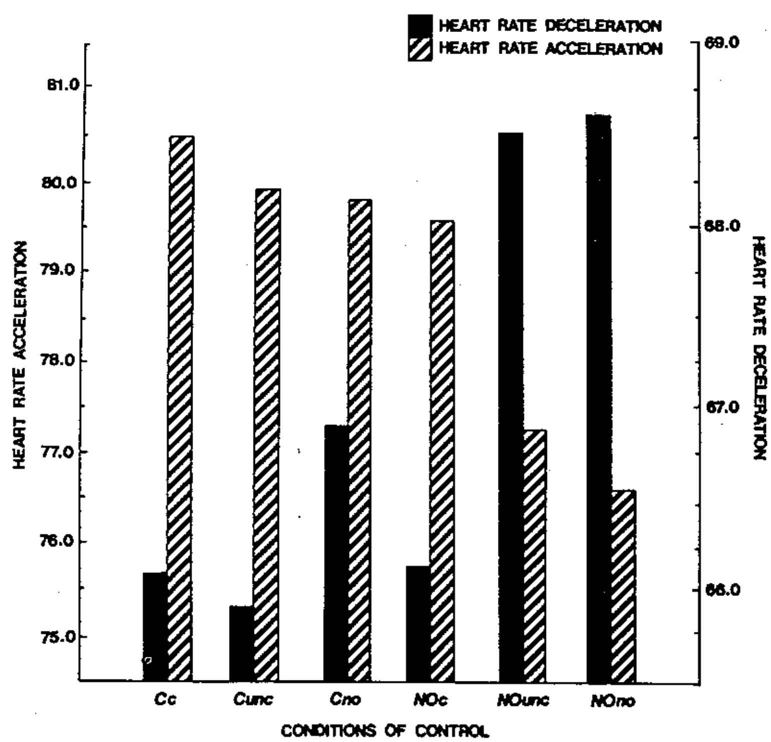

Figure 2. Heart-rate acceleration (HR ACC) and deceleration (HR DEC) over conditions of available control.

† Detailed results are available from the first author.

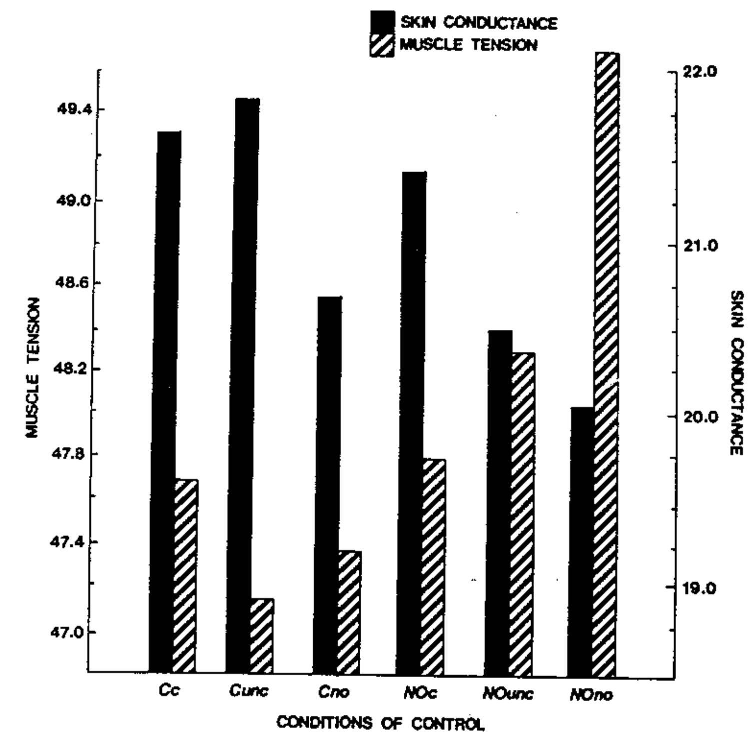

Figure 3. Skin conductance (SC) and frontalis muscle tension (MT) over conditions of control.

Thus, behavioural and psychophysiological correlates of the current formats of outcome-set size and controllability, in the form of response-set size, were obtained. For example, heart rate increased with increasing outcome-set size, from *No no* through *Cc*; similarly, MT increased with decreasing controllability and $Pr(t_1)$. Previous evidence, then, of stress arousal to 'cognitive demands' and threatened aversiveness (e.g. Svebak *et al.*, 1982; Wright, 1984) extended to the present versions of these dimensions.

The results obtained here have been found to be robust across studies addressing other issues but using the same paradigm. Furthermore, they have been buttressed by self-report measures of stress arousal (Kukde, 1985).

Response modalities 'paralleling' outcome-set size (HR ACC, HR DEC and SC), however, did so in an approximate fashion. That is, there was a relatively pronounced net decline over the six conditions of control; similar observations attend the net increase in MT, the measure paralleling $Pr(t_1)$. Meanwhile, the specific changes in these measures over the presented conditions were not identical. Values of MT and HR ACC, for example, were respectively lower and higher under conditions *C* than under conditions *No*. Such a pattern was not obtained for HR DEC nor SC. Furthermore, none of the response modalities bore a one-to-one correspondence to the properties presented in Fig. 1.

Note that the current measures are considered to be imperfect indicators of stress arousal. Psychophysiological measures such as those of the present battery may be expected to be differentially activated by alternate properties of a stimulus situation; an exact tracking of the respective properties, however, is seldom, if ever, obtained (Averill & Opton, 1968; Martin & Venables, 1980; Obrist, 1981). All in all, level of inferences from these measures must be constrained by the specificity of support they provide.

6. Associations among controllability, outcome-set size, and $Pr(t_1)$, and simulated preference for control

In this section, it is shown that configurations of preference for situations varying in available control can be determined by associations among the dimensions that have been examined quantitatively, and empirically, above. The pattern of associations educed here is compared to that where either high or low sizes of outcome sets attend increased $Pr(t_1)$.

Patterns of preference are simulated by implementing the respective dimensions/values into the Election-by-Aspect (EBA) model of preference and choice (Tversky, 1972*a*, *b*). This model makes provision for difficulties posed by earlier models when, as in the present case, items (situations) share like dimensions (e.g. probabilities of t_1 exceeding 0). Detailed accounts are available elsewhere (e.g. Tversky, 1972*a*; Tversky & Sattath, 1979).

Preference for a given item, x, is given by the EBA model as:

$$P_T(x) = K^{-1}[U(x) + U(\tilde{x,y})p(x,y) + U(\tilde{x,z})p(x,z)],$$

The terms of this formula are defined as follows:

$U(x)$ = the (subjective) utility associated with attributes that are unique to x;
$U(x,y)$ = the utility attached to attributes that are shared between x and y;
$U(x,z)$ = the utility of attributes that are shared between x and z;
$p(x,y)$ = the probability of choosing item x over item y;
$p(x,z)$ = the probability of choosing item x over item z;
and K = the sum of utilities of both unique and shared attributes over the triad of items.

The 'attributes' of x, y and z comprise (*a*) differences between the maximum possible size of the outcome set, given p and q, and the actual size for x, y, or z; and (*b*) differences between the minimum possible value of $Pr(t_1)$, given p and q, and the value of $Pr(t_1)$ in effect. These attributes are indexed as follows:

$$\text{Reduction in outcome-set size} \equiv 1/pq(pq - v),$$

where v = the outcome-set size in effect for the current item;

$$\text{Increase in } Pr(t_1) \equiv w - 1/pq,$$

where $w = Pr(t_1)$ for the current item.

If the reduction in outcome-set size or the increase in $Pr(t_1)$ for one item, x, is a portion of that for another, y, the overlapping amounts contribute to $U(\tilde{x,y})$; the remaining amount of attribute for the item with larger reduction or increase, in turn, contributes to $U(x)$ or $U(y)$.

Consider first structures of x, y and z, where size of outcome set is relatively independent of $Pr(t_1)$. With outcome-set size as the first element and $Pr(t_1)$ as the second, $x = (1, 1), y = (8, 1)$, and $z = (1, 0.125)$. Let $p = 2$ and $q = 4$; the utility per unit of reduction in outcome-set size $= \alpha$, and that per unit of increase in $Pr(t_1) = \beta$. Then,

$$U(x, \tilde{y}) = (1 - 0.125)\beta,$$

$$U(x, \tilde{z}) = 1/8(8-1)\alpha,$$

and

$$U(x) = U(y) = U(z) = 0.$$

Thus,

$$P_T(x) = (0.875\beta + 0.875\alpha)/(0.875\beta + 0.875\alpha) = 1,$$

since, according to the EBA model, $p(x,y) = [1/8(8-1)\alpha]/[1/8(8-1)\alpha]$, and $p(x, z) = [0.875\beta]/[0.875\beta]$.

Since $P_T(x) = 1$, $P_T(y) = P_T(z) = 0$. In other words, x 'absolutes dominates' y and z in preference/choice.

The utility values entering into these values of P_T reflect an equal preference for the attributes involving outcome-set size and $Pr(t_1)$. Some individuals may prefer increased control, which in the present context, implies preferences for elevated $Pr(t_1)$ over reduced outcome-set size, while others may prefer the opposite combination (see, e.g. Burger & Cooper, 1979). For the first 'type of individual', let $\beta = c\,\alpha$, where c is a scalar > 1. Again, $P_T(x) = 1$, $P_T(y) = P_T(z) = 0$. The same pattern occurs when, instead, $\alpha = c\,\beta$, corresponding to the second type of individual. In this case of independent variation, then, there is no competing preference for y and z; furthermore, there are no effects of differential values placed on one attribute versus the other.†

We turn our attention now toward the structure of x, y, and z representing a negative association between these attributes. Items x, y, and z are structured according to conditions-of-control *Cc*, *No c*, and *No no*; $x = (8, 1), y = (4, 0.5)$, and $z = (1, 0.125)$. Setting $\alpha = \beta$, $P_T(x) = 0.39$, $P_T(y) = 0.25$ and $P_T(z) = 0.36$. For $\beta = c\,\alpha$, where for illustrative purposes, $c = 2$, $P_T(x) = 0.48$, $P_T(y) = 0.32$, and $P_T(z) = 0.20$; where $\alpha = 2\beta$, $P_T(x) = 0.24$, $P_T(y) = 0.22$, and $P_T(z) = 0.54$.‡

Such results extend to positive associations between outcome-set size and $Pr(t_1)$ as implemented in triads of two highly similar items and one dissimilar item (Rappaport, 1983). In this instance, to facilitate computations, a minor unique attribute is added to each item. Item structures, differential utilities, and values for P_T are presented in Table 2.

† Like results are obtained for a positive association between the two attributes: $x = (1, 1)$, $y = (4, 0.5)$, and $z = (8, 0.125)$.

‡ All computations are available from the second author.

Table 2. Values of P_T for x, y, and z, where x closely resembles y

Item structure	Conditions of control	Attribute values	$P_T(x)$	$P_T(y)$	$P_T(z)$
x (8, 1, 0.01, 0, 0)	*Cc*	$\beta = 2\alpha$	0.33	0.33	0.33
y (8, 1, 0, 0.01, 0)	*C no c*	$\alpha = 2\beta$	0.17	0.17	0.66
z (1, 0.125, 0, 0, 0.01)	*C no*				
x (1, 0.125, 0.01, 0, 0)	*No c*	$\beta = 2\alpha$	0.17	0.17	0.66
y (1, 0.125, 0, 0.01, 0)	*No unc*	$\alpha = 2\beta$	0.33	0.33	0.33
z (8, 1, 0, 0, 0.01)	*No no*				

Note. The last three elements of item structures refer to minor unique attributes of x, y, and z.

A factor shown to substantially affect the appeal of situations affording control, is the associated cost of controlling activity, or as in the above development, the utility of the activity's relative absence (Solomon, Holmes & McCaul, 1980; Wright, 1984). In the preceding simulations, this factor had no effect on patterns of preference when the amount of activity, corresponding to size of the outcome set, required to obtain the benefits of control [elevated $Pr(t_1)$] was essentially unpredictable from these benefits.

These preference/choice simulations clearly indicate that conditions affording increased $P(t_1)$ are inevitably to be preferred when size of outcome-set varies independently of $P(t_1)$. Competing preference for conditions of lesser $Pr(t_1)$ is introduced, when $P(t_1)$ and outcome-set size covary positively. Results indicate that other things being equal, if conditions of increased control are not to absolutely dominate preference/choice behaviour, a positive association is required between controlling activity – predictive judgements surrounding the outcome set – and $Pr(t_1)$.

In this sense, the positive association between these dimensions, as presented earlier, takes on considerable potential importance. Moreover, individual differences in relative preference for reduction in one dimension or the other are inconsequential for (simulated) preference/choice behaviours without the association.

Observe that the above simulations have not included conditions of uncertainty, *C unc*, nor *No unc*. These conditions raise issues of choice strategies under uncertainty, as well as the possibility of increased stress when several situational outcomes remain possible (as described earlier in this paper); corresponding limitations of the foregoing development are underscored.

7. General discussion

The structure of control in the form of 'alternative availability' or 'decisional control' (Averill, 1973), has been examined with respect to corresponding levels of outcome-set size and $Pr(t_1)$. Results indicate that the 'benefits' of this type of control, at least as expressed in $Pr(t_1)$, are aligned with outcome-set size and corresponding predictive judgements (e.g. Estes, 1976; Kahneman, Slovic & Tversky, 1982). This association appears to have empirical correlates and may implicate patterns of preference and choice concerning alternate conditions of control.

Other types of control may embody similar relations between expenditure of controlling activity and threat reduction. In the case of 'instrumental' or 'behavioural control' (Averill, 1973; Thompson, 1981), some action may be performed on the stressor itself so as to diminish threat. For instance, an introverted individual may circumspectly avoid any provocation of whichever fellow guest is contacted during a social gathering; a worker may be extremely cautious to avoid danger, regardless of the task being performed. Greater threat reduction may be associated with more complex or effortful behaviours. The observation that considerable control may not be 'universally appealing' (e.g. Gal & Lazarus, 1975; Thompson, 1981) suggests such an association.

Similar observations attend, for example, 'cognitive control' (Averill, 1973). The individual may direct controlling efforts toward his/her level of stress arousal as opposed to the external events giving rise to stress (Leventhal, 1970). Cognitive control includes the 'comforting redefinition' of stressing situations into more favourable terms (Thompson, 1981), taking cognizance of one's own abilities for dealing with impending events (Neufeld, 1976), etc. Once again, benefits in the form of stress reduction may approximate levels of cognitive activity undertaken. Understanding of the workings of other types of control such as these may benefit from a similar analysis of their structure regarding threat reduction and expenditure of controlling activity.

Relations among these types of control, and their associated 'benefits and costs', warrant consideration as well. To illustrate, decisional control may be employed to engage the least-threatening aspect of a stressing situation. Behavioural and/or cognitive control may then be employed to deal with the 'residue threat' carried by the engaged option.

Furthermore, one type of control may play a greater role in threat reduction than another type, depending on the availability of each. Where decisional control is unavailable, for example, threat reduction may rest largely on the effective implementation of behavioural control.

The roles of each type of control may vary over individuals, as well as conditions of relative availability. Specifically, some individuals may prefer behavioural control if it requires less processing of information than does decisional control, which entails predictive judgements. Such individuals, for example, may prefer less involvement in cognitive activity because of impaired cognitive efficiency, including that underlying such judgements (Neufeld, 1982). With reference to the analysis of preference/choice behaviour, increased subjective cost of dealing with elevation in number of potential outcomes (increased utility of its reduction) may be paralleled by reduced subjective cost of activity associated with behavioural or other types of control.

As stated earlier, the formulations on decisional control presented here do not implement outcome uncertainty *per se*, as a separate source of stress arousal. Unpredictability may be disturbing in its own right if it generates, for example, 'conflicting covert responses' to coexisting inequalities in threat, as couched in multiple potential outcomes (see, for example, Maher, 1970). The empirical effects of uncertainty on stress arousal have been unclear. They have varied with the manner in which uncertainty has been induced (Gaines *et al.*, 1977; Monat, Averill & Lazarus, 1972), the specific measures of stress arousal obtained (Epstein & Roupenian, 1970), and personality characteristics of subjects (Gaines *et al.*, 1977; for a review of this literature, see Paterson & Neufeld, 1987).

A recurring difficulty in examining uncertainty as a source of stress arousal is that of isolating its effects. For example, increasing the probability of the more threatening of two outcomes from 0 to 100 per cent, increases unpredictability up to 50 per cent, and then reduces it. Concomitantly, likelihood of the less desirable outcome increases throughout.

In the present instance, as uncertainty increases, so does the set of potential outcomes and presumably predictive judgements. (Compare *C unc* to *C no*, and *No unc* to *No no* in Table 1.) As a result, it is difficult to ascribe any evidence of increased stress arousal categorically to multiplicity of potential outcomes. On balance, however, bear in mind that such a factor may in its own right increase stress, and that the current formulations make no separate provision for this factor.

In closing, consideration is given to the quantitative format of certain observations on stress-relevant control adopted in this paper. More formal developments are relatively rare in this research domain. A notable exception is Osuna's (1985) account carried by a series of theorems with closed proofs of the 'stress of waiting for a desired event'. The comparative merits of more versus less formal approaches to topics such as the present one is beyond the scope of this paper, but have been debated elsewhere (e.g. Bandura, 1984; Staddon, 1984). Advocates of what Staddon has termed 'unaided verbal reasoning' might contend that the current type of quantification skirts important processes such as interaction between the 'controlling individual' and the agents of stress, the individual's 'appraisal of the progression of events', including the apparent success of control, the subjective transition of events from 'challenging' to 'stressful', and so on (see, e.g. Lazarus & Folkman, 1984). The greater comprehensiveness with respect to such issues claimed for informal approaches, however, may be more apparent than real. In responding to Bandura's (1984) complaints that computational models of human functioning have failed to incorporate constructs such as 'reflective self-awareness', Staddon has stated:

> Maybe so; my argument shows that this neglect stems not from the inability of formal models to handle these subtle concepts but from the requirements to be precise in specifying relations between inferred and measured variables that they impose. Bandura's models incorporate internal factors with ease, not because they go beyond information-processing theories, but because they are not (formal) theories at all (p. 504).

The constraints imposed by increased formality are exemplified in the current presentation as follows. Ferretting out the association among dimensions of decisional control has first required us to spell out the composition of these dimensions. We have been compelled to specify what is meant by 'threat reduction' in terms sufficiently rigorous to allow quantification. In turn, certain limitations of the adopted quantities have become comparatively clear. The nature of controlling activity has been identified in such a way as to implicate the considerable research on prediction and judgement, including common errors, for possible future consideration (Pitz & Sachs, 1984). Further, without operationalizing the current dimensions of control and their associations quantitatively, it would not be possible even tentatively to mesh findings with mathematical models of relevant behaviours, such as those involving preference and choice. Overall, the contributions of more formal approaches to the research domain of stress and coping may ultimately be at least as substantial as those of informal approaches.

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Appendix A

Matrix operations applied to judgement data

Let the number of subjects serving as judges be n, and the number of situations judged be s. For each unique pair of subjects, cross products between the ratings of stress over the s situations are obtained and summed. These sums vary according to the correspondence between the two sets of rating values ('scalar products indexes of inter-individual profile proximity').

The preceding scalar products are then used as elements to form a matrix Z. Element ij, located in the ith row and jth column of Z, is the scalar product between the ratings of subjects i and j $(i, j = 1, 2, \ldots, n)$. Accordingly, the order of Z is $n \times n$. The number of relatively larger eigenvalues, r, of matrix Z is obtained (based on a principal components analysis of Z); r, in turn, corresponds to the number of distinctive profiles among the sample of n judges. The larger a given eigenvalue, the more prominent among the n protocols of ratings is its related distinctive profile.

The n coordinates of each associated eigenvector represent the similarities between the corresponding distinct profile, and the respective rating protocols of the n judges. In the case of the first eigenvalue, the coordinates are proportional to the n protocol means, thus reflecting differences in 'elevation' only.

The configurations of reported stress representing the r distinctive profiles are obtained according to the following matrix product:

$$\mathbf{VW} = \mathbf{S},$$

where the matrix, $\mathbf{V}$, of order $r \times n$, has as its rows the r eigenvectors of $\mathbf{Z}$; $\mathbf{W}$ is of the order $n \times s$, and comprises the original ratings of stress; and $\mathbf{S}$ is an $r \times s$ matrix whose r rows represent the r distinctive profiles of stress.

The specific configurations of values pertaining to response-set size associated with the r distinctive profiles of stress are obtained as the $r \times s$ matrix product, $\mathbf{C}$:

$$\mathbf{VX} = \mathbf{C},$$

where $\mathbf{X}$ is the $n \times s$ matrix of original judgements relating to response-set size.

Finally, the specific configurations of values pertaining to outcome-set size associated with the r respective distinctive stress profiles are obtained as the $r \times s$ matrix product, $\mathbf{D}$:

$$\mathbf{VY} = \mathbf{D},$$

where $\mathbf{Y}$ is the $n \times s$ matrix of original ratings relevant to outcome-set size.

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Erratum

Morrison, M. S., Neufeld, R. W. J., & Lefebvre, L. A. (1988). The economy of probabilistic stress: Interplay of controlling activity and threat reduction. *British Journal of Mathematical and Statistical Psychology*, **41**, 155–177.

Table 1, p. 57, columns 6 and 7. The entries in these two columns simply should be interchanged.

P. 157, second paragraph, 6 lines down. In the sentence beginning, 'For conditions *B*, '*Bb*' should read '*No unc*'.

Table 2, p. 172, in the second column headed 'Conditions of control', the entry in the second row of notation should read *Cc*, rather than *C no*; the third-row entry should read *No no*, rather than *C no*; the fourth row, *No no*, rather than *No c*; the fifth row *No No*, rather than *No unc*, and the sixth row, *Cc*, rather than *No no*.

The Editor apologizes for any confusion these errors may have caused.

Addendum

Marley, A. A. J. (1989). A random utility family that includes many of the 'classical' models and has closed form choice probabilities and choice reaction times. *British Journal of Mathematical and Statistical Psychology*, **42**, 13–36.

I did not reference Robertson & Strauss (1981) in my paper, although I was aware of their work and its relevance to my own results. In retrospect, this was an error, and the following summarizes the relation between these two papers. (The terminology in the following agrees with those papers.)

Theorem 1 of Marley (1989) can be interpreted as stating that any horse race random utility model (for choice probabilities and reaction times) that is generated by a generalized stable survival function has the property that the element chosen is independent of the time of choice. This result generalizes part of Theorem 1 of Robertson & Strauss (1981) where it is additionally required that the horse race random utility model be of (multivariate) Thurstone type. (In fact, it is necessary to redevelop Robertson & Strauss' results in terms of nonnegative random variables and multiplicative utilities, as opposed to their use of real random variables and additive utilities, to obtain this interpretation.) It is easily seen that Marley's Theorem 1 is a generalization of Robertson and Strauss' Theorem 1 since there are many generalized stable survival functions that are not of multivariate Thurstone type—e.g. Marley (1989, Example 4, p. 28).

Turning to the converse of Marley's Theorem 1, we ask: if a horse race random utility model has the property that the element chosen is independent of the time of choice, then is the model generated by a generalized stable survival function? Part of Robertson and Strauss' Theorem 1 can be reinterpreted as proving that such is the case provided, once again, that the horse race random utility model is of multivariate Thurstone type. It is not kown whether the converse holds without the Thurstonian condition—regrettably, it is not immediately obvious how to extend Robertson & Strauss' proof technique as it depends heavily on structure yielded by the Thurstonian assumption.

Reference

Robertson, C. A. & Strauss, D. J. (1981). A characterization theorem for random utility variables. *Journal of Mathematical Psychology*, **23**, 184–189.