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A MAXIMISED-ADL INDEX OF FUNCTIONAL STATUS FOR STROKE PATIENTS

Methodological Considerations

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ABSTRACT. An index of functional status for stroke patients is presented. It is based on the observation that a patient's disposition is decided by the level of involvement of the most severely affected ADL-parameter. This allowed a suitably selected set of ADL-parameters to be scaled so that an index of functional status could be constructed which did not depend on the assumption of simple additivity of the component ADL-parameters. This index, together with two simplified versions, was contrasted with two summed-ADL indices and with an index of mobility, as predictors of outcome. The study was carried out on 57 patients.

Key words: Stroke, functional status, index rehabilitation

The treatment of the completed stroke , in a rehabilitation context, is not aimed at the eradication of the disease process or at the relief of symptoms. Instead, its primary target is the minimisation of the functional and social consequences of the disease once it has stabilized. There is therefore a need to meaningfully define and measure the functional status of stroke patients. However, the construction of the required indices is not a simple matter. Many issues arise in the selection of appropriate ADL-parameters, in their measurement, in determining group effects and in defining the optimal information content. This investigation of indices of functional status is begun by classifying them according to the nature of the group effects involved, as follows:

Type 1: Those which measure patterns of involvement of single ADL-parameters in the one individual.

Type 2: Those which measure grouped-ADL effects in different individuals.

Type 3: Those which measure grouped-person effects.

This paper is concerned with type 2 indices. At this point, some comment about "additivity" is called for. The important point to grasp is that addition is not defined on the scales of the individual ADL-parameters. For a particular scale, it is generally not true that, say, 1+2=1+1+1; or when the "1's" apply to different scales that 1+1=1+1. So that an index of functional status which is formed by the simple and arbitrary addition of its component ADL-parameters is meaningless. Likewise, the values of a type 2 index cannot be summed to give a meaningful type 3 index. Unfortunately, the assumption of additivity can easily sneak in. For example, the use of type 2 indices in parametric statistical procedures (regression analyses, etc.) implicitly assumes additivity in the arithmetic of the procedure. However, this does not condone the use of group means as indices of functional status; rather, it means that such procedures should be carried out with an awareness of the reliance being placed on the robustness of the procedure.

Two sub-types of type 2 indices are recognisable—implicit (type 2*a*) and explicit (type 2*b*). The former are indices of dependence status (1, 2, 3) in which the individual ADL-parameters, although reflected in the index, do not enter explicitly into the structure of the index, as in (4, 5). These type 2*a* indices are ordinal scales (6) which have low misclassification errors. But they do contain little information about the patient. The question must be posed: Can explicit type 2*b* indices of functional status be found which, while containing more information about the patient, still retain these desirable number and error properties?

The common method of constructing type 2*b* indices of functional status is to sum the members of some set of ADL-parameters. Because the individual ADL-parameters are not marginally equivalent in terms of the patient's overall functional status, and because addition is not defined on any ADL-parameter scale, these summed-ADL indices are not ordinal (6). The nature and importance of ordinality can be demonstrated by considering a scale where the problem is extreme (7). Here, 17 ADL-parameters are each scaled on the same 3-point scale and then summed to give a value between 17 and 51. This results in one number being assigned, on the average, to more than 4 000 000 different physical states of the patient. The question a clinician must ask of any proponent of such an index, is: If one index number is larger than another, how can he be certain that all 4 000 000 physical states attached to the larger number have a better functional status than all 4 000 000 physical status attached to the smaller number? If the answer is that he cannot, then the index must be used with great caution.

There have been attempts to construct ordinal indices of functional status not based on the assumption of simple additivity. One is based on a "natural" order of recovery of the component ADL-parameters (8). However, a natural order of recovery can only arise in restricted and artificial situations; it is doubtful if this method can give indices which are any better than type 2*a* indices. Another index (9) is based on the measured amount of work required to transfer patients in the ward environment. The individual ADL-parameters were then quantitatively fitted to the response to derive an optimal weighted combination of these ADL-parameters. Again, doubts exist in that the measurement of the response did not appear to be accurate enough for this purpose. Finally, reliance can be placed completely on some type of statistical procedure such as principal components analysis or factor analysis (10). Difficulties arise here when more than one factor is needed to adequately explain the total variance.

Another difficulty lies with validation. If one considers a list of possible uses, such as description, screening, assessment, monitoring and prediction (11), then it is noticeable that there is an absence of known results which can be used as benchmarks. Given that there is variation of the performance of the different indices in these situations, there is no way at present of deciding which performs best or, more worryingly, which index gives incorrect results which can certainly occur. A variation of the validation problem lies in the role of indices of functional status in the determination of a patient's disposition at the end of treatment. To use many current indices in this role would be equivalent to tossing a coin to decide disposition. The reason for this is that many indices use hospital-based criteria of dependence to grade individual ADL-parameters. As the patient outside hospital is unlikely to have unlimited, skilled support constantly available, it is not surprising that indices of functional status constructed on ADL-parameters scaled in this manner, have only a statistical relationship to the patient's disposition.

In summary, there is a need for indices of functional status which reflect as directly as possible the patient's status outside hospitals and which do not rely on assumptions of additivity of individual ADL-parameters in their formation. Such indices should explain how a patient's disposition is decided and possess the property of ordinality when used to contrast different patients. Validation of these indices should proceed with an awareness of the limitations of statistical procedures in exploratory multi-factorial studies. Such considerations define the thrust of the remainder of this paper.

Methodology

(*a*) *Index of functional status.* The procedure by which judgements about a patient's dependence status determine his disposition, is formalized in the algorithm in Fig. 1. From this, the scale of dependence status in Table I results. In this context, a set of "ADL-parameters" was selected which usually were sufficient to determine the patient's disposition (and hence his dependence status, as defined here). These were taken to be mobility, transfers, continence, self-care, domestic activities, communication and life-planning capacity. These were then scaled in terms of their individual effect on disposition (Table II). This meant that a value, say "3", no matter to which ADL-parameter it applies, implies the same disposition (assuming all other ADL-parameters were zero). This property is referred to as marginal equivalence. The patient's disposition, and hence his dependence status, was then noted to be a maximisation function of this set of ADL-parameters scaled in this manner. Symbolically:

$$\text{Dependence status} = \underset{i}{\text{Max}}(X_i),$$

where X_i = level of involvement of the ith ADL-parameter.

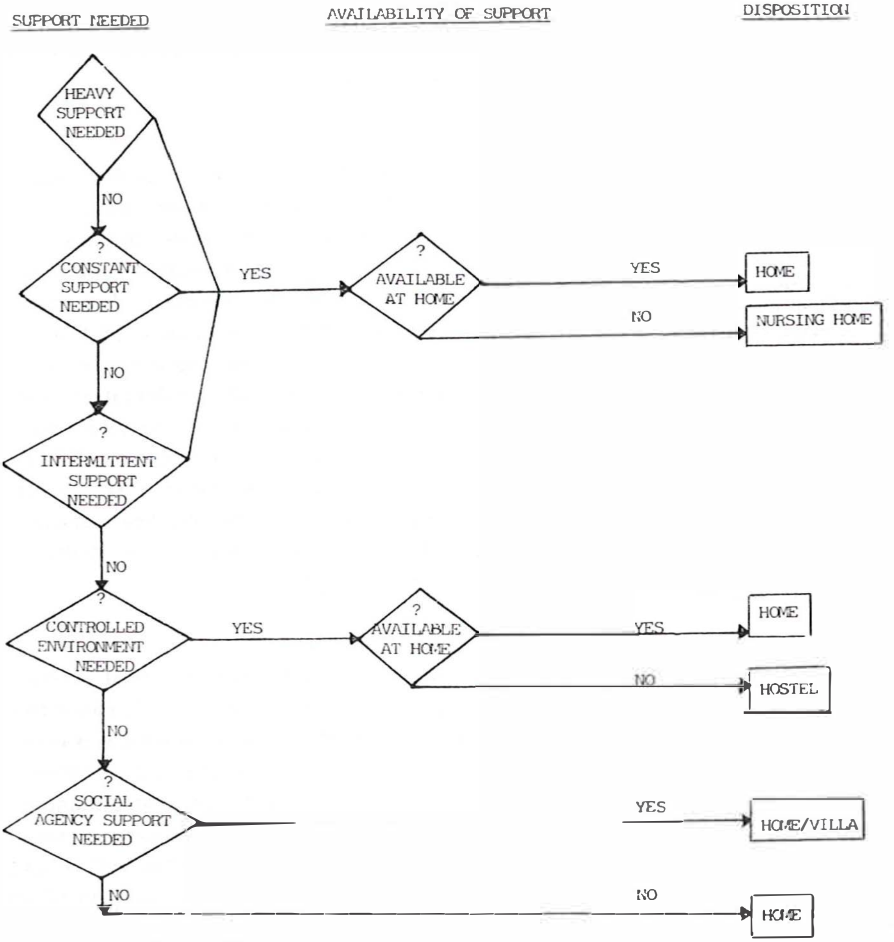

Fig. 1. Disposition-deciding algorithm

Therefore the most severely affected ADL-parameter is dominant over the remaining less severely affected ADL-parameters in that it determines the patients dependence status irrespective of what their combined effect is. There seems no reason why a similar dominance should not hold for any ADL-parameter no matter what its absolute or relative value is even though this dominance now cannot be expressed in terms of the patient's dependence status. One simple way of giving this relationship an arithmetic expression is as follows: Given a set of values, say "6", "3", "5", "1", "3", "4", "2", then the 7 digits can be permuted into a descending sequence to give the number "6543321". The larger this number, then the more the support required by the patient and the poorer is his functional status. As there are 246 such numbers, these can be transformed into a simpler integer scale without losing this property of ordinality. A typical section of this transformation table is given in Table IV. Copies of the full table are available on request.

(*b*) *Scaling and sampling.* 57 patients were followed through a rehabilitation programme in the 7-month period beginning December 1980 at the

Table I. *Dependence status scale*

Scale	Criterion
6	Requires heavy nursing care
5	Requires constant nursing care
4	Requires intermittent support—patient can be left alone for significant intervals
3	Requires hostel-like environment
2	Requires support from social agencies
1	Can live alone and unsupported at home
0	Can return to work

Table II. *Criteria for scaling individual ADL parameters*

ADL Parameter	Scale	Criterion
Mobility	6	Patient can't walk or requires weight support
	5	Patient requires balance support or supervision to walk
	3	Can walk unsupervised on smooth surfaces in a closed environment
	2	Can manage grass, uneven surfaces, single steps, recover from falls
	1	Can manage stairs, cross roads, climb hills, moderate distances. Can manage house cleaning activities
	0	Can manage public transport and/or drive a car
Transfers	6	Heavy support required
	5	Light support or supervision required
	0	Independent
Continence	5	Not continent
	0	Continent or can self-manage a catheter
Self-care	4	No assistance required for any of: bathing, toiletting, eating, dressing upper limb, dressing lower limb
	0	Independent in all of the above
Communication	3	Not sufficient to live alone
	0	Sufficient to live alone
Domestic activities	3	Not sufficient to live alone
	0	Sufficient to live alone
Life-planning capacity	3	Not sufficient to live alone
	1	Sufficient to live alone
	0	Sufficient for unstructured external activities

Royal South Sydney Rehabilitation Centre. 350 recordings of functional status were made by the therapists treating the patients, using the index described. All observations were taken at intervals of 7±1 days. Seven of these were recorded as unknown, 2 of these occurring in the first 4 weeks of treatment. Some smoothing of the raw data was necessary to allow for the fact that stroke patients do not usually make a sharp transition from one functional status category to another. This took the form of neglecting any improvement in functional status unless it was sustained in subsequent recordings. A simple step-wise regression analysis was performed using the regression package in SPSS, version 2.0 (12), implemented on a CYBER76 series computer.

Demography

The average age of the patients was 66.2 years (SD=±12.77). 30 of the 57 patients were male. Eight patients came from the acute-care ward of the hospital. The remaining 49 patients were admitted from other acute-care hospitals. For these, the pre-admission interval averaged 25.4 days. Thirty-nine patients were discharged home, 10 to a nursing home, 1 to another rehabilitation unit, 5 back to the referring acute-care hospital and 2 died while having therapy in the centre. Multiple diseases were the rule. Vascular disease, as evidenced by hypertension, ischaemic heart disease, CCF, peripheral vascular disease, or diabetes, was present in 39 patients.

Structure of the index

In most patients, mobility was the most severely affected and most changeable ADL-parameter (Table III). For example, before treatment was begun, it was the most severely affected parameter, or the equally most severely affected parameter, in 53 patients. Also, of the 109 occasions in which the index of functional status was observed to have changed, a change in mobility occurred in 67 of these. Therefore for geriatric stroke patients, mobility was the dominant determinant of functional status. This dominance is not allowed for in those indices which give equal weight to all component ADL-parameters. Other parameters changed less oftan, particularly communication and life-planning capacity. On the scale of measurement used, these remained largely constant throughout treatment. However, this does not mean that they should be excluded from the index. This is for two important reasons. Firstly, they are necessary for the validity of the decisionmaking algorithm and, secondly, they serve as a counterpoise to mobility, modifying its dominance as the patient responds to therapy. This is shown in the patient's final functional status were mobility was dominant in only 44 patients. However, overall the dominance of mobility was such that it must be considered possible that mobility alone would be a satisfactory index of functional status. Also, the question is raised as to the relevance of the index when mobility is not dominant. These issues are looked at in a later section.

It is also of interest to look at the changes in the index of functional status as they related to the severity of involvement of the individual ADL-parameters. Of the 109 observed changes in the index, 58 involved a change only in the most severely affected ADL-parameter (and hence in the dependence status of the patient), 32 a change in the second most severely affected ADL-parameter (leaving the most severely affected ADL-parameter unchanged) and 12 a change in, at most, the third most severely affected ADL-parameter. This tendency for changes in this index of functional status to be due to changes in the more severely affected ADL-parameters, suggests that, in some situations, the full 7-parameter, 246-point index may be unnecessary and that an abridged index using, say, only the three most severely affected parameters, may be adequate. There is a range of possible abridged indices; however only the 3-parameter index ("M3") and the 1-parameter index ("M1") are looked at in this paper (Table IV).

Description, screening, assessment

Because of the nature of this study, the role of the index in these situations was not investigated. However, it would appear that it has many potential applications in these areas.

Control of the rehabilitation process

Control of the rehabilitation process involves a close monitoring of the patient's response to therapy and, as such, requires a type 1 index (13, 14). However, because of the ease with which a summarized recording of the patient's functional status can be achieved using this index, the weekly recording of status was found useful in two aspects of control.

One is in aiding decisions about treatment cutoff in patients showing no response at all to treatment. Once treatment has begun, a patient must be given a reasonable chance to respond. But what is a reasonable chance? While this is a matter of individual patient assessment, it should proceed against a background of accepted standards of average treatment durations. Looking at the estimated time to first change in dependence status (15), it is apparent that dependence status has largely, but not completely, plateaued by the end of the 6th week of treatment (Fig. 2). This would suggest that continuation of treatment beyond this point must have a definite clinical justification. The curve for functional status added nothing to the determination of this cutoff point.

The other aspect of treatment cutoff which was looked at was the more common problem of when to stop treatment after there had been some response. The nature of the prior responses alters the nature of the decision which the therapist must make. It is usual to stop treatment after the patient has plateaued for a sufficiently long period. The plateau verifies the clinical impression that the patient has reached a steady functional state. What constitutes an adequate plateau can be looked at by examining the distribution of the times between changes in functional status. It was found that 76% of the patients who did have a change in functional status, had had that change by the end of the 2nd week after the first change and 91% by the end of the 3rd week. This suggests that, once it is felt that there will be no further change in dependence status, the treatment be stopped 2 to 3 weeks after the last change in functional status. The index of dependence status was unsatisfactory for this purpose as treatment was often continued well past the last observed change in dependence status (11 patients had 4 or more weeks of treatment after the last change in dependence status). The use of

Table III. *Status of individual ADL-parameters before and after treatment*

ADL parameter	Number of patients	
	Improved	Not improved
Mobility	39	18
Transfers	28	29
Continence	6	51
Self-care	24	33
Communication	6	51
Domestic activities	10	47
Life-planning capacity	6	51

Table IV. *Section of the table: Transformation sequenced numbers to integer numbers*

Sequenced number	Integer number
6600000	218
6554333	217
6554331	216
6554330	215
6554310	214
6554300	213
6554100	212

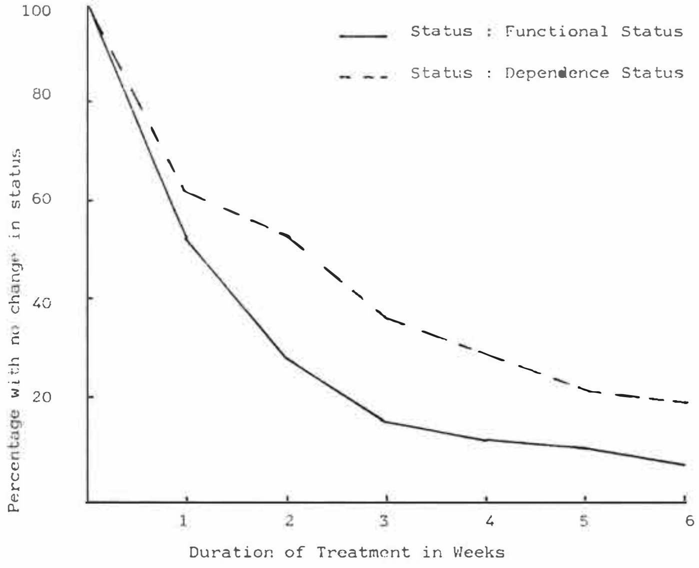

Fig. 2. Distribution of survival times to first change in status.

the index of dependence status here would result in longer plateaus (i.e. periods of verification) which would be unsatisfactory.

Such intervals are not absolute; there will be occasions when clinical considerations justify longer periods of treatment. This was so with 4 patients in this study. On the other hand, it was interesting to note that 17 patients were discharged from the unit before they had plateaued. These mainly were patients who were independent enough to manage at home and for whom treatment at an outpatient level was sufficient and available. This demonstrates the fallacy of using the length of stay in a rehabilitation unit as an outcome parameter as it can be either longer or shorter than the true duration of treatment. For the purpose of later analysis, the duration of treatment was defined as the time taken for the patient's functional status to plateau, plus 2 weeks. This was measurable in 33 patients.

Analysis of predictors of response

The comparison has been extended in this section to 6 indices consisting of the full 1-parameter maximised-ADL index of functional status ("M7"), the 3-parameter maximised-ADL index of functional status ("M3"), the 1 parameter index of functional status (equivalently, the index of dependence status ("M1"), and the index of mobility status used in the study ("B"). In addition, 2 summed-ADL indices were formed from the same component ADL-parameters used for M7, one having the same values for each ADL-parameter ("SQ") and the other having the values compacted so that there were no gaps in each scale ("SP"). A preliminary inspection showed that the maximised-ADL indices and the summed-ADL indices were distinctly different number sequences.

Using the initial functional status, measured on each of these 6 scales, as a predictor, supplemented by age, sex, pre-admission interval and the laterality of the motor deficit, a step-wise regression analysis was carried out to derive the set of joint predictors of the duration of treatment (as defined earlier). Because the response variate was the same in all 6 regression equations, the total variability was also the same. However, the variability explained by the predictors differed considerably as indicated by the R^2 values, being greatest for M7 and least for SQ. Looking at the F-statistic in the final regression equation, most of the difference in R^2 with the 6 scales was due to changes in the significance of the initial functional status as a predictor (Table V). This indicated that, for the prediction of the duration of treatment, M7 recorded the initial functional status in the most discriminatory manner. This was an encouraging finding and suggested that the finer measurement of functional status in M7 was meaningful.

Next, the predictors of the final functional status, as measured on these 6 scales, was investigated. Here, the predictor "number of preceding changes in status" was added to the list of possible predictors. The analysis was carried out at the beginning of each of the first 4 weeks of treatment.

1st week. The explained variability (i.e. the R^2 values) was unacceptably small, probably indicating an incomplete model specification resulting from the omission of relevant predictors. The only predictor at this stage is the initial functional status with the relative effectiveness of prediction, using the 6 scales, indicated by the R^2 values in Table VI. These differ from those in the previous analysis. The increase in total variability for M7, as indicated by the sums-of-squares in Table VI, is not accompained by a parallel increase in the explained variability. This is so because this situation requires an index which is sensitive to change in functional status as the main predictor is simply the response measured at an earlier point of time. But M7, despite being a more sensitive measure of static status, can only record the same number of changes in status as does SQ and hence is not significantly superior to SQ as a measure of change in status. As M7 has a greater error component, this, overall, means that the unexplained variability is greater for M7 than it is for SQ, as indicated in Table VI. A similar reason holds for SQ being a better predictor of final functional status than is SP.

2nd week. As expected, all R^2 values have increased. With time, the "initial" status will come closer, in a predictive sense, to the final status. However, the R^2 values are still unacceptably small. The relative effectiveness of SP, SQ, and M7 as predictors remains unchanged, as would be expected from the previous reasoning.

3rd week. M1 and B fail to increase at this time. This appears to be due to the parameter "number of preceding changes in status" having an effect

Table V. *Predictors of the duration of treatment*

Scale	F-Statistic of predictors in final regression equation: Initial status	Age	R^2
M7	29	10	55.0
M3	23	9	49.5
M1	11	7	34.9
B	18	11	44.0
SQ	7	5	28.3
SP	10	6	33.2

Table VI. *Predictors of final status: R^2 values*

Scale	Time of observation: Beginning of 1st week	2nd week	3rd week	4th week	Sums of squares
M7	28.5	38.6	54.5	64.7	156832
M3	31.0	42.1	59.8	68.8	11 684
SQ	35.2	47.5	64.8	65.3	1 702
SP	46.8	56.9	75.0	76.2	255
M1	26.7	42.1	41.5	69.7[a]	75
B	28.9	44.5	39.0	78.1[a]	99

[a] Here, the number of preceding changes in status was also a predictor. In all others, the only predictor was the initial status.

though not large enough to appear as an explicit predictor.

4th week. All predictors now have an acceptable R^2 (of the order of 70%) indicating that the model is now adequately specified. For M1 and B, the parameter "number of preceding changes in status" is now an explicit parameter. Looking back at the original data, this appears to be due to those patients who have improved their mobility by the end of the 2nd week, having a greater chance of further improving their mobility than do patients who have had no improvement in mobility to this point.

Overall, M7 does not perform well as a predictor of final functional status. Because the patient "jumps" through the scale, its sensitivity to changes in status is not as great as its sensitivity to static status.

Correlation of indices

Some studies (16) have used a correlation analysis to validate indices of functional status. However, this study has shown (Table VII) that correlations can be as high as 0.88 and yet the indices perform, statistically, quite differently. A high correlation coefficient is therefore a necessary, but not a sufficient, condition for equivalence of such indices. However, a high correlation with other parameters may be set as a desirable property. For example, in comparing maximised-ADL indices with summed-ADL indices, the higher correlation of the former with B may be taken as a point in their favour. Some aspects of the correlation matrix confirm earlier findings. The higher correlation of M1 with M3 than with M7 is consistent with the mode of construction of M3. Again, the smaller correlation of B with M1 after treatment, contrasted with that before treatment, is consistent with the smaller

Table VII. *Correlation matrix of the 6 indices: Before and after treatment*

	M7	M3	M1	B	SQ
M3	.98 (.85)				
M1	.88 (.79)	.95 (.93)			
B	.87 (.78)	.93 (.86)	.96 (.90)		
SQ	.77 (.85)	.76 (.89)	.65 (.81)	.64 (.69)	
SP	.81 (.84)	.79 (.90)	.67 (.87)	.68 (.78)	.98 (.98)

Bracketted coefficients are correlation coefficients for indices after treatment.

role mobility plays in the determination of dependence at the end of treatment.

Measures of Geriatric Disability

The evaluation of disability in geriatric patients requires a measure of functional status which is applicable to a number of different diseases. It is by no means clear that many current indices can be extended in this manner when allowance is made for the varying importance of the component ADL-parameters. As this index has involved the choosing of a set of ADL-parameters which would allow the decision-making algorithm to be applied to most geriatric situations, there is reason to believe that, if the method of construction of the index is accepted, the index can be applied as a measure of general geriatric disability. At the same time, it should be recognised that it would have little application as a measure of disability for young paraplegic patients.

DISCUSSION

A sequence of maximised-ADL indices of functional status has been illustrated. They are highly structured indices based on certain assumptions about the patient's dependence status outside hospitals. Their construction does not depend on the assumption of additivity of the component ADL-parameters. Indeed, through their lack of correspondence with 2 summed-ADL indices of functional status, both as number sequences and as predictors of outcome, they reinforce doubts expressed in this paper about summed-ADL indices. Given the assumptions made, these indices are ordinal when contrasting different patients. However, this does not mean that they can themselves be summed to give measures of grouped-person effects. For this, a different (type 3) index is required. The structure of the index played an essential part in evaluating their performance. For example, the way individual ADL-parameters changed as the patient responded to therapy was revealing, demonstrating how the central role of mobility was modified. Further, the structure of the index explained certain limitations of M7 as a measure of change of functional status. There are therefore advantages in developing well structured indices of functional status.

Validation of the index was difficult. Correlation analysis was of little use because of the absence of a proven index which could be used as a reference standard. In any case, a high correlation coefficient is only a necessary condition for the equivalence of indices. At a practical level, it was found that a correlation coefficient has only to depart slightly from unity for the indices being compared to be regarded as dissimilar. Validation by comparing performances of the indices in particular situations was hampered by the absence of quantitative relationships which could be used as benchmarks. However, the use of these indices for monitoring treatment cutoff gave results in accord with clinical practice. In this situation, it was found that the index of dependence status performed better than the index of functional status. As the investigator has some choice as to how detailed the index can be, this result shows such a person must not always assume that the most detailed index is always to be preferred.

In predicting outcome, two distinct situations exist. The first is that where a measure of functional status, at some point in time, is required. This is referred to as static functional status; for this, M7 seemed to record the functional status in the most discriminating way, in turn indicating that the additional detail recorded for M7 was meaningful. The other situation was where a measure of change in functional status was the requirement, in which situation M7 performed poorly. The study brought out the difficulty in predicting final functional status when the initial functional status was the main predictor. Ideally, an interval scale of functional status would be required; however, the likelihood of finding such a scale is small.

Misclassification errors, although important, were not investigated in this study as the sequential recording of status allowed a retrospective correction to be made where necessary. But there are some "error-producing" aspects of the index about which any user should be aware. Some parameters, such as "communication" and "life-planning capacity" may be regarded as somewhat vaguely defined, although it would appear that a consensus would be readily reached in any unit using the index. The choice of the individual ADL-parameters and their measurement allows scope for variation to meet particular needs. Another feature of the index is what may be called "error amplification". An error in the most severely affected ADL-parameter will change the value of the index more than will an error in the least severely affected ADL-parameter. Again attenuation of some of the scales of the ADL-parameters can amplify error. For example, if the patient's continence status was incorrectly recorded as "5", the error is "5", not "1". The possibility of increasing error disproportionately should always be kept in mind.

The study has been presented as an exploratory study to compare indices about whose properties little is known. Exact prediction of responses was not attempted as the state of knowledge was not considered sufficient to justify the effort which would have been required to mount a properly designed longitudinal study (17). Doubtless, such will be required once valid indices of functional status have been developed.

Lastly, the ease with which a maximised-ADL index can be used should be emphasized. On any one recording, it requires that the therapist treating the patient answer only 7 questions, as indicated in Table III, and that the investigator recode these answers using a conversion table such as that in Table IV. Overall, maximised-ADL indices, when used for static recordings of functional status, are a useful addition to a rather limited armamentarium.

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