

Revisiting the Levin-Roberts Patient Dropout Model¹

Vincent de Gooyert

Radboud University Nijmegen

Institute for Management Research

P.O. Box 9108, 6500 HK Nijmegen, The Netherlands

+31 24 36 15578

v.de.gooyert@fm.ru.nl

Christian Erik Kampmann

Copenhagen Business School

Department of Innovation and Organizational Economics

2000 Frederiksberg, Denmark

+45 3815 2381

cek.ino@cbs.dk

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Abstract

We review an early system dynamics model of mental health care delivery designed to investigate the premature dropout of patients from therapy (Roberts & Levin, 1976). The purpose of our paper is to a large extent pedagogical: First, using the model as a case, we wish to demonstrate the application of current standards and methods of critical model analysis as an illustration of the development of our field. Second, we propose a series of revisions to the model that illustrate techniques for promoting consistency and stringency in modeling “soft” variables related to human emotions, perceptions and attribution of cause, while remaining as true as possible to the purpose and conceptual framework of the original model. Finally, we consider the implications of the revised model for the questions raised by original authors. Many of the conclusions of the original work remain intact, but we find that the revised model provides a more consistent explanation of the dropout phenomenon using concepts that are closer to those used in psychotherapy.

1. Introduction

Like any academic field, system dynamics continues to evolve new methods, standards, and concepts that shape our style of modeling, theory building, and empirical analysis. Every other decade, the methods of system dynamics have been collected and presented in a coherent manner in a major textbook (Forrester, 1961; Richardson & Pugh, 1980;

¹ This work was initiated while we were both visitors at M.I.T. in the fall of 2011. We thank our colleagues at MIT for their hospitality and Brad Morrison, David Keith, Ozge Karanfil, and Amparo Canaveras for useful comments.

Sterman, 2000.) Although these books were primarily conceived as classroom material, they have also been instrumental in setting common accepted standards of practice and criteria for evaluating work in the field. To the latter end, we believe that it is also useful, from time to time, to revisit earlier published work in the field and assess it from current standards (e.g., Kampmann 1991). A retrospective model critique can both serve to explicate the current standards of practice, illustrate how the field has evolved over time, and provide pedagogical material for teaching.

In this paper, we perform such a retrospective critical model analysis on a model of mental health care delivery and the phenomenon of “patient dropout”. The original model was developed almost 40 years ago by Edward Roberts and Gary Levin (Levin and Roberts, 1976).

We chose this model for several reasons. First, mental and physical health care policy is a major long-standing area of interest in system dynamics. Second, the style of modeling in the Levin and Roberts study is typical of that period of time and is therefore a good representation of the state of the field in the 1970’s. Third, their study represents an early example of a “soft” model, i.e., one that includes several variables that are hard to measure in practice. The relatively “hard” modeling issues found in much of economics and business management for the most part have well developed principles of model building based upon the principles of bounded rationality and observed management practice. In contrast, we find that there are few universal guiding principles for “soft” models and hope that our study can contribute to the development of such principles.

Our analysis proceeds in three steps. First, we make a critical assessment of the original model, both at the conceptual level, where we assess the degree to which the model indeed represents the assumptions, hypotheses, and phenomena of interest in the study, and at the technical level of individual equations, where we check their consistency and performance. In the second step, we propose a series of reformulations and construct a revised model that we believe conforms to the current principles of system dynamics. The revised model includes some rather intricate modeling issues related to how patients attribute changes in their mental well-being to therapy – issues that we think are of general interest to anyone building cognitive psychological models. In the third step, we compare the conclusions of the original and the revised model to judge the significance of the changes.

Since our primary purpose is to illustrate and explicate methodology rather than settling the substantive issues in the original study, we focus on the technical aspects of model formulation and testing and try to take the premises of the study more or less as given. We have not attempted to verify the validity of the assumptions and theories used, although we did review selected parts of the theoretical literature on psychotherapy to get a basic understanding of the current state of thinking in mental healthcare provision.

Reformulating a model is of course a subjective process that depends upon the personal style and conviction of the model builder. Moreover, there is a continuum between correcting technical mistakes or weaknesses in the equations at one end, and building a completely new model based on a revised conceptualization at the other end. Our work falls somewhere in the middle: Since we find that the original study had a few conceptual ambiguities, parts of the revised model contains structure that is not represented in the original model. On the other hand, we try to adhere as closely as possible to the original model whenever we can.

We wish to emphasize that a retrospective study such as this one is not a “fair” criticism of the original work, since that would require us to assess it according to the standards of the day. Indeed, we find that the study does represent a careful and well-executed system dynamics modeling project if you judge it by those standards. In particular, the authors are very careful to relate their proposed model elements to the academic literature on psychotherapy of the time. Precisely because it represents such a careful study it is a useful case for illustrating the changes that have occurred since then.

The rest of the paper proceeds as follows: In Section 2, we present the original model and summarize the premises and intent of the study. In Section 3, we make a critical review of the model, both at the conceptual level and at a detailed equation level, similar to the process found in Kampmann’s critique of the Tsembaga Population Control Model (Kampmann, 1991). In Section 4, we develop a revised model and compare the results of this model to the original study. The final section contains our conclusions and suggestions for further initiatives to strengthen modeling practice in our field.

2. The original patient dropout model

As described by Roberts in his memoirs, he and Dr. Levin started working on the patient drop-out model for the Community Mental Health Center in the Bronx, New York (Roberts, 2007). They focused on patient dropouts because the senior staff of the Mental Health Center quickly agreed that this was their most significant clinical problem. They started by defining dropouts as patients who stopped coming to the Center for help before they were “cured” or at least helped to the extent deemed possible by the medical staff. As mentioned by Roberts, the underlying issue turned out to be as much “staff hold-on” as “patient drop-out”, i.e. many staff tried to keep patients under care longer than the patients felt to be necessary (Roberts, 2007). In the following, we provide a brief description of the original model and the results. The detailed equation listing may be found in Appendix A.²

² The original model was formulated in DYNAMO. We translated the DYNAMO equations to Vensim (version 5.10e) (Our thanks to David Keith for valuable assistance.) Vensim model files of both the original and the revised model are available in the supplementary material submitted with this paper. The

Figure 1 illustrates the core structure of the model, showing the interaction between the care provider system (green variables) and an individual client (red variables).³ At the center of the model is the notion of the patient’s *Level of functioning* (black variables), a level variable broadly representing the current state of the patient’s mental health. For treatment to occur, it is both necessary that the client *seeks* help and that the doctor *provides* help. The original research was aimed at identifying policies to prevent patients from dropping out, where dropout is defined as “leaving treatment while it is still being offered before full recovery occurs” (Levin and Roberts, 1976, p.68).

The model is characterized by two interacting balancing feedback loops. On the patient side, a decline in functioning produces efforts to secure treatment that, in proper intensity, restores functioning to its pre-episodic level. In the care provider sector, the staff perceives the drop in the patient's functioning, and allocates resources so as to produce treatment in the amount needed to effect the restoration.⁴ This interaction between the service provider and the client determines how much treatment, if any, is delivered.

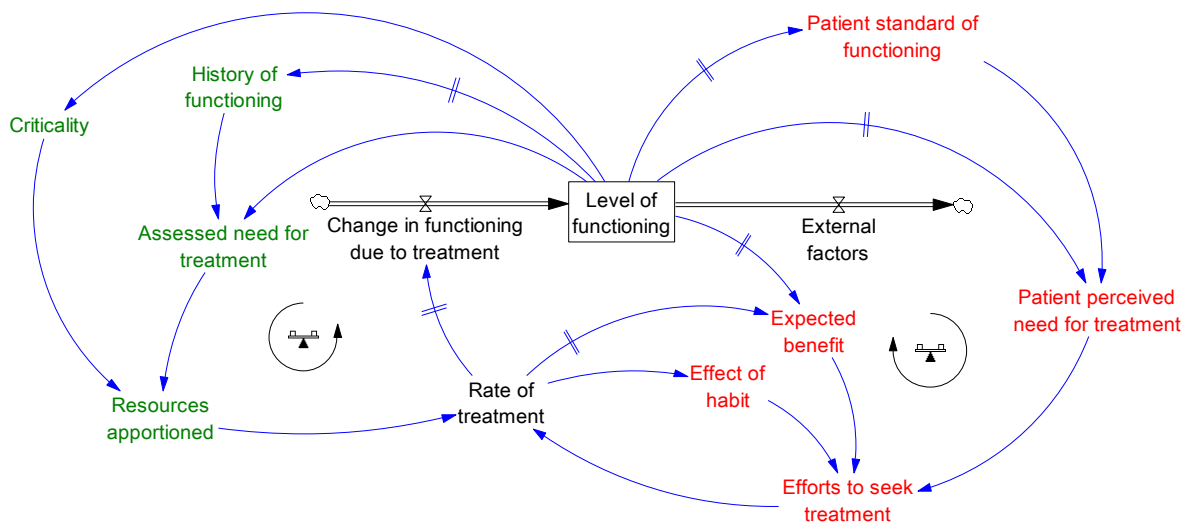


Figure 1: The core feedback loops of the original model

The level of functioning can be reduced (or possibly improved) by exogenous factors, such as environmental stress or emotionally powerful life events, and restored by sustained treatment. The assumption is that it takes time for treatment to take effect (expressed by a delay in the causal link), and that there are diminishing returns: As the

original version of the model uses abbreviated variable names (acronyms). In the Vensim version, we use the longer variable names as specified in the documentation listing of the original model.

³ Like the original authors, we use the words “patient” and “client” interchangeably, even though the former term is less used today, due to its negative connotations.

⁴ The latter mechanism implicitly takes into account that doctors have a restricted number of resources and that they try to allocate their resources to patients that need help and would benefit from help. However, the issue of scarcity and efficiency of resource allocation is not within the scope of the original study.

level of functioning approaches the normal level, the beneficial effect of further treatment effect decreases. Significantly, treatment is conceived as a direct restoration of functioning, as opposed to a process to mobilize the patient's own ability to get better – an issue to which we return later in the paper.

The patient's effort to seek treatment is derived from the perceived need for treatment, i.e., the discrepancy between the aspiration level or "standard of functioning" and the perceived current state of functioning. The aspiration level, in turn, is endogenous and based upon the long-term average of the level of functioning. A system dynamicist will immediately recognize the significance of this mechanism in producing potential goal erosion and drift to low performance – a phenomenon that was also recognized by the clinical psychological profession at the time (Roberts and Levin, 1976, p. 47-48).

The seeking of treatment is also affected by the patient's perceived benefit of treatment, where it is assumed that the patient cannot distinguish between treatment effects and other effects on functioning: Thus, if the patient is currently in treatment, the perceived benefit is a function of how much or little improvement the patient currently perceives. While this mechanism is easy to describe in words, it is far from trivial to formulate in model equations. We return to this issue later. The significance of this mechanism may be that that patient may choose to leave treatment if he or she is not improving even though the lack of improvement may be caused by other factors.

Finally, treatment-seeking behavior is also assumed to be affected by habit or inertia, expressed in the model as a function of the average rate of treatment.

On the care provider side, the staff allocates resources to treatment by assessing the treatment needed to close any discrepancy between the current level of functioning and a patient-specific standard of functioning, the latter being based upon a historical average of actual functioning, like the patient's own aspiration level but with a longer time delay.⁵ Furthermore, if the perceived level of functioning becomes so low as to pose a significant risk to the patient or to others through harmful behavior, treatment efforts are greatly increased. Finally, treatment efforts are affected by the perceived rate of decline in functioning from external sources, reflecting the idea that if the patient appears to be undergoing a period of severe stress, treatment is intensified accordingly.

The model includes an effect of patient efforts to seek treatment on the allocation of resources by the staff. This reflects two mechanisms: First, in the early stage of a treatment period, the patient must take the first initiatives in seeking treatment; if there is no such initiative, the treatment will never begin. Second, if the patient stops

⁵ In order to translate a needed improvement in function into a required treatment effort, doctors use an estimate of the efficacy of treatment, which, significantly, is assumed to be constant in this study. One would expect interesting and significant dynamics to arise under the more realistic assumption that expected treatment efficacy could vary, but we accept the boundaries of the study.

engaging in the therapy, either by not “doing the work” or by not showing up for sessions, this has a psychological effect on the staff who will easily become less willing to provide the resources needed when other worthy individuals are equally in need. In the model, both these effects are combined in an effect of patient treatment-seeking efforts on resources provided by the staff.

The intensity of treatment itself is conceived as a homogenous continuum irrespective of the form of treatment. For instance, an increase in intensity may reflect more frequent therapy sessions, or it could involve hospitalization or shifting to more potent psychopharmica.

The results of the ‘base case’ of a patient that does not dropout are shown in Figure 2 (Figure 5-1 in the original work). The model is run for 40 months. The first 10 months the patient has a level of functioning of 60 functioning points. In this stage the model is in equilibrium, the level of functioning is equal to the desired level of functioning and no treatment is given. At month 10 the patient experience a certain negative life-event, represented in the model as an immediate decrease in the level of functioning of the patient by the amount of 20 points. The balancing feedback loops immediately come into effect: the doctors assess that there is a need for treatment and the patient starts to seek treatment. The output graph shows the decrease in functioning at month 10, the rise in ‘patient efforts to seek treatment’, an increase in the ‘average rate of treatment’ and a decrease in the patient standard of functioning.

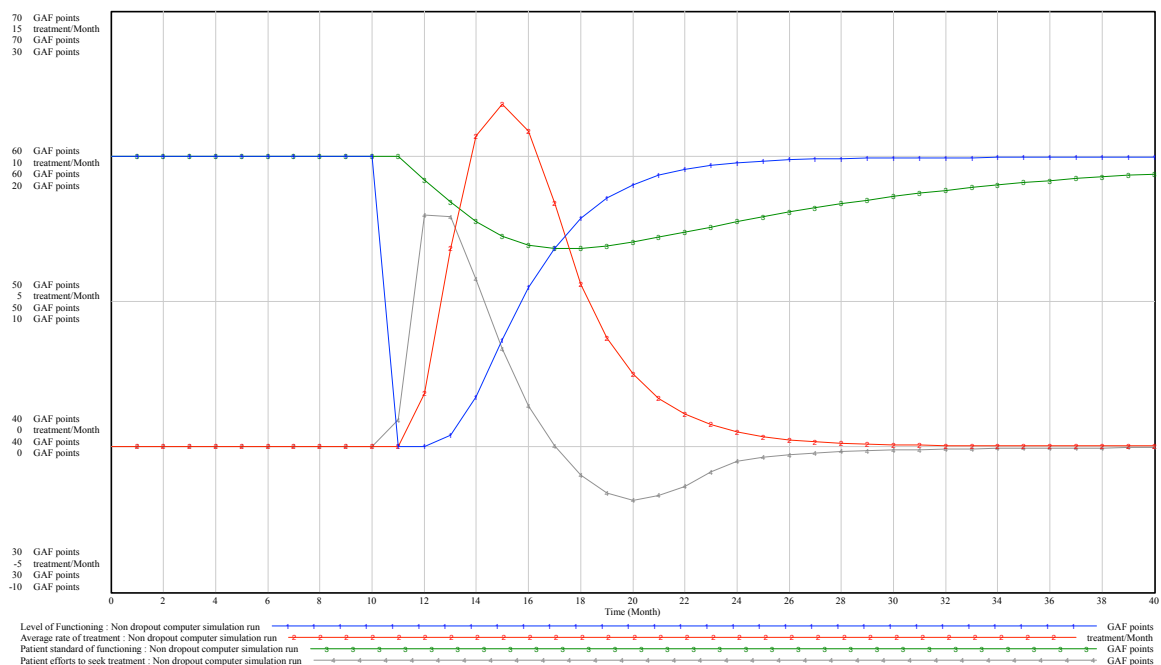


Figure 2: Output of the base case, a patient that completes the treatment

Compare this to the run in Figure 3 (Figure 5-4 in the original work) in which the patient both has less stable internal standards of functioning and has lower expectations

of the benefits of treatment. In the model this is implemented by a shorter adjustment time of the patient's internal standard of functioning and modifying the effect of expected benefits on efforts to seek treatment (see Appendix A for specification of parameter changes). Now, the patient's efforts to seek treatment are reduced long before the loss of functioning has been recovered, because the aspiration level deteriorates and removes the motivation to seek treatment. The authors characterize this situation as a dropout.

After a series of model experiments to determine the significance of various mechanisms of dropout behavior, the authors proceed to explore policies on the part of the caretaker that could remedy the problem. They find that supporting the patient's aspiration level by itself is not very effective, but that combining such support with efforts to instill positive expectations early in the treatment will lead to essentially full recovery even when the patient's inherent characteristics are as detrimental as those in Figure 3. The result is shown in Figure 4 (originally Figure 5-10), where the strategy is implemented in the model by "pouring aspirations" into the patient's standard of functioning level and initializing the expected benefit of treatment stock at a higher level.

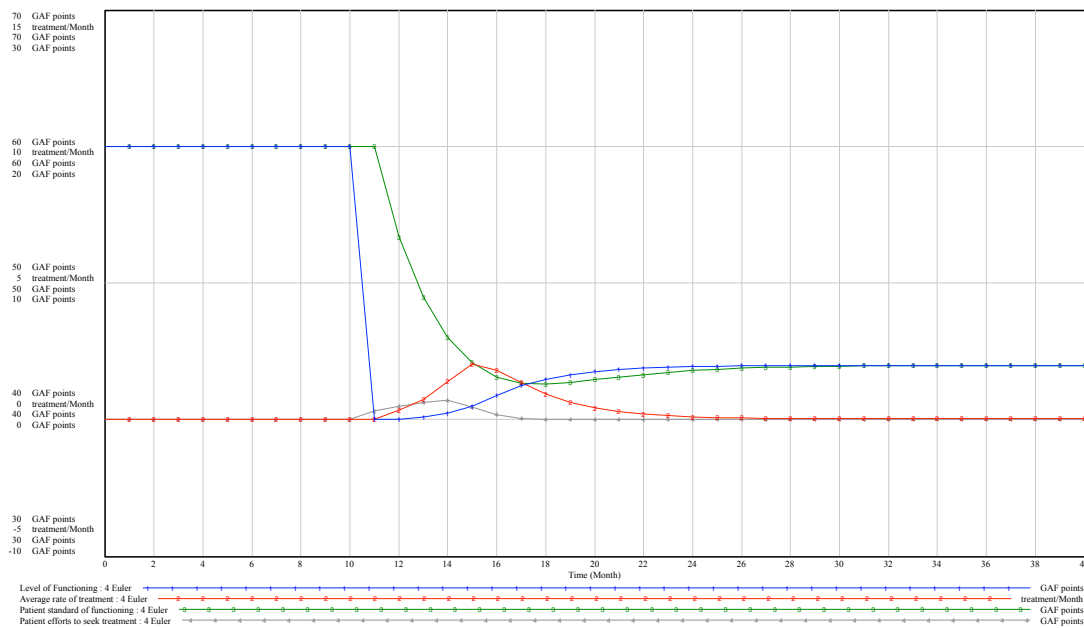


Figure 3: Drop-out case due to unstable patient standards of functioning and low expectations of treatment benefits.

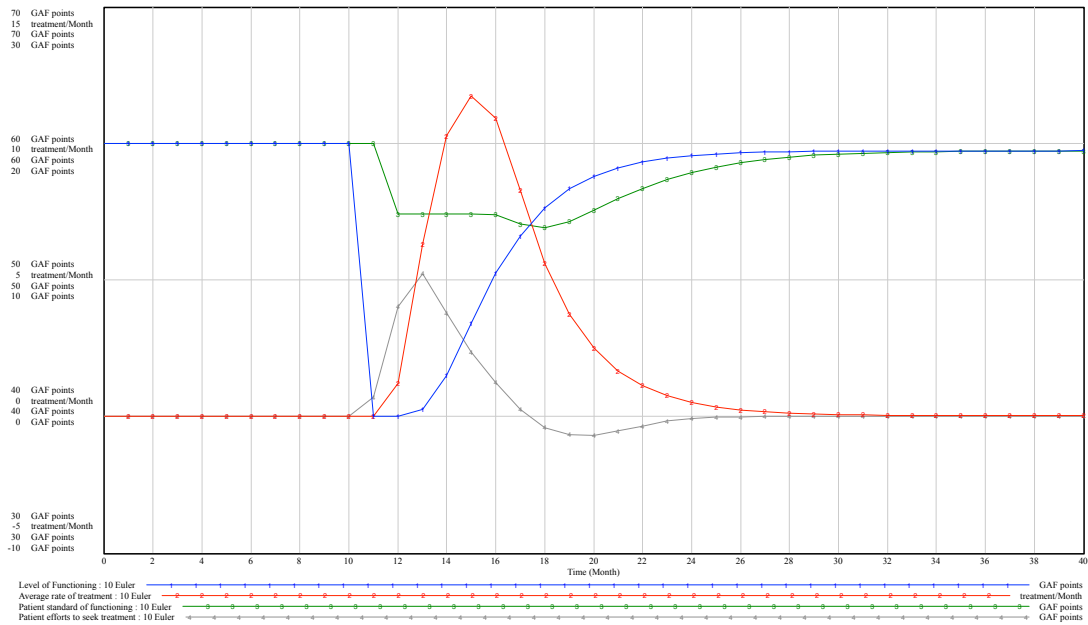


Figure 4: Successful strategy that combines support for the patient’s aspiration level and instilling higher expectations of benefits from the outset

The authors conclude from their study that the mental health care system should 1) emphasize early intervention by measures to assure that needy patients seek treatment early and receive extra intensive care in the beginning and 2) “inject hope” in the patients through staff encouragement.

3. Critiquing the original model

Documentation

As mentioned by for example (Kampmann, 1991), the social sciences have been plagued by studies that could not be replicated due to insufficient documentation. The field of System Dynamics however stands out because of its high standard of documentation and the model of Roberts and Levine is a very good example of this. The book includes a full description of all equations in the appendix and the most important mechanisms are described and explained in the main text. Besides some minor typos and errors in the figures, the documentation is very clearly written. Thus, we were able to reproduce the model in every detail without problems.

Units of measurement

The ‘level of functioning’ of a patient plays a central role in the model. It is “the expression of the mental health of a chronically ill psychiatric patient” (Levin and Roberts, 1976, p. 43). In the original model, this variable is measured in ‘functioning points’, but there is no attempt to explain the meaning of such a unit, nor how one may measure it. For instance, you might provide a descriptive scale that relates values of the

variable to particular psychological symptoms. This is typical of early system dynamics studies, reflecting the engineering origin of our discipline: Since there is no physical or objective basis for defining units of “soft” variables, you can “take your pick”. In social sciences, however, a great deal of emphasis is put on operationalizing soft variables or concepts so that they may be measured in empirical studies. As modelers, it behooves us, therefore, to pay close attention to how variables in our models can be operationalized.

It turns out that the field of mental healthcare uses a well-documented dimension to measure the level of functioning of psychiatric patients: the Global Assessment of Functioning score or GAF score (see for more information on GAF scores for example Aas, 2010 and Woldoff, 2004). Just like the functioning points used by Roberts and Levine, the scale runs from 0 to 100. For the GAF score however every category of 10 points (0-10, 10-20, etc.) is well described in terms of functioning of the patient. In our model we chose to replace the original functioning points by the GAF score because we think it helps in interpreting and communicating the simulation runs and outcomes. We imagine that the audience of the model consists of doctors as well as managers. We expect both groups of model consumers to have high familiarity with the GAF score and that the use of GAF score as a dimension helps the doctors and managers speak in a shared language about the problem of patient drop out.

It must be said that the development of the GAF scores took place in the last couple of decades; therefore the use of GAF score as a dimension is a luxury that Roberts in Levine did not have in 1976. Our point however still stands: whenever there is the possibility, modelers should take the effort to express concepts as done by the scientific community and the audience of the model.

Table Functions

The patient dropout model uses seven table functions. In general these table functions are not robust. The tables are defined for a limited span of values, when changing the model parameters it is easy to exceed the values that the authors accounted for. Even running the base case results in 10 situations where the values of the input for the table functions become lower than the lower limit of the table or higher than the higher limit. An example of this is the table function for the ‘patient effect on rate of treatment’. The table function has as its dimensionless output a ‘patient effect on rate of treatment’ between 0 and 1. The input consists of the variable ‘patient efforts to seek treatment’ (measured in functioning points). The table is defined for values of ‘patient efforts to seek treatment’ between 0 and 5. In many scenarios however this variable exceeds 5 by far, in the base case the value goes up to nearly 20.

Another example is the table function for the ‘treatment effect of functioning’. The input consists of ‘standard of functioning’ minus ‘level of functioning’ and the graph is defined for inputs from 0 to 25. In other words, the table function for the ‘treatment

effect of functioning’ assumes a ‘standard of functioning’ that is higher than the actual ‘level of functioning’ and assumes the two never to be more than 25 functioning points apart.

We extended the table functions by estimating the shape of the table function graphs for ‘patient effect on rate of treatment’, ‘treatment effect of functioning’ and other variables in such a way that simulation runs with all reasonable parameter values will not result in values below or above the table function graphs. We consider this good modeling practice.

First order control loops

Some of the variables used in the original model clearly have some physical boundaries. For example the ‘assessed need for treatment’ and the ‘patient effort to seek treatment’ are typically variables that should not be able to have a value lower than zero. The first order control loops to prevent those variables from crossing those physical boundaries are however lacking in the original model. Another example is the stock of the ‘patient level of functioning’. The value, measured either in functioning points or GAF points, should never be lower than 0 or higher than 100. The original model is formulated in such a way that depending on the chosen parameter values the level of functioning can cross the defined minimum and maximum.

Variable naming

Some variable names are chosen by the original authors in such a way that it leaves room for ambiguity. The variable name ‘rate of change of standard of functioning’ for example suggests that this rate is the net rate influencing the standard of functioning. The patient standard of functioning is however also influenced by the ‘rate of support of patient standard of functioning’. Because it is not the only rate, we would suggest to make the origin of the rate explicit and rename the ‘rate of change of standard of functioning’ into the ‘rate of change of standard of functioning due to anchoring’.

Another example of ambiguous naming is the ‘rate of change of functioning due to social and chemical factors’. The authors describe in their text that this rate represents factors influencing the level of functioning besides treatment. Therefore we would suggest renaming this variable to ‘rate of change of functioning due to external factors’.

Redundant variables

It seems that some concepts that the authors identified as important for the patient drop-out problem are represented by mechanisms in the model that have overlapping functions. If we follow the text by the authors we understand that the ‘treatment effect of functioning’ is included in the model to represent different effects including the effect of criticality of the patient. As described and shown in figure 2 the ‘treatment effect of functioning’ is a non-linear effect that adjusts the efficacy of treatment based

on the actual gap in the level of functioning and the standard of functioning. The effect of criticality is however also represented in the model a mechanism included in the model with just the purpose of simulating the effect of criticality. This mechanism consists of the variable ‘criticality factor’, defined as ‘level of functioning’ – ‘standard of functioning’. The variable ‘resources apportioned’ is calculated by multiplying the ‘assessed need for treatment’ already multiplied by the ‘patient effect on staff effort’. So now there are two ways in which criticality comes into play in the original model: the efficacy per treatment is higher due to the ‘treatment effect of functioning’ and the number of treatments rise because of the ‘resources apportioned’. It is not clear from the original text if the authors intended to represent the criticality in these two ways.

Argumentation for parameter values

The original text does not include a description how the parameter values were estimated. One part of the model stands out for needing an explanation for the chosen values. Both the patient and the doctors experience some delay in perceiving the actual level of functioning. The delay in the patient’s perception is modeled by the information delay ‘standard of functioning’ and the corresponding time constant ‘time to change standard of functioning’. The delay in the doctor’s perception is modeled by the information delay ‘history of functioning’ and the corresponding time constant ‘time to perceive history of functioning’. While the structure for both delays is exactly the same, the parameters differ in great extent: the ‘time to change standard of functioning’ is set to 12 months while the ‘time to perceive history of functioning’ is set to 120 months. We would argue that especially these but also other parameter values should be accompanied by an argumentation.

Equation formulations

There is one aspect in the model that caught our attention when considering equation formulations. The authors included a number of variables to simulate their proposed policy of supporting the patient’s standard of functioning. This part of the model includes a constant named the ‘support effectiveness factor’, influencing both the ‘needed effort to change patient standard through support’ and the ‘rate of support of patient standard of functioning’. The equations of these variables are as follows:

$$\begin{aligned}
 RSPSF.KL &= (NECPSS.K) (PERT.K) (SEF) (SW1) \\
 NECPSS.K &= ((PSF.K - FNCTN.K) / TTCSF) / SEF \\
 SEF &= 2.5 \\
 SW1 &= 0
 \end{aligned}$$

RSPSF – Rate of Support of Patient Standard of Functioning (functioning units/month)

NECPSS – Needed effort to Change Patient Standard through Support (functioning units/month)

PERT – Patient Effect on Rate of Treatment (percentile)

- SEF – Support Effectiveness Factor (percentile)
- SW1 – policy SWitch 1 (dimensionless)
- PSF – Patient Standard of Functioning (functioning units)
- FNCTN – level of FuNCTioNing (functioning units)
- TTCSF – Time To Change Standard of Functioning (months)

If we replace NECPSS in the first equation by it’s definition as mentioned in the second equation we get:

$$RSPSF.KL = (((PSF.K - FNCTN.K) / TTCSF) / SEF) (PERT.K) (SEF) (SW1)$$

In this equation we divide by SEF only to multiply afterwards by the exact same SEF. No matter what value of the ‘support effectiveness factor’ will be, it is not possible to be of any influence. Together with the fact that there is no other equation where the ‘support effectiveness factor’ is included, modeling this factor seems to be of no meaning at all.

Scenario replication

We were well able to replicate almost all the simulation runs as described in the original text. Apart from one scenario we got the exact same result, and we believe the discrepancy we saw might be caused by rounding differences. We question the operationalization for scenario 2 ‘indifference toward benefit expected’ (p. 71-75). In the base case the ‘patient efforts to seek treatment’ is strongly influenced by the ‘patient expectations of treatment benefits’. In this scenario 2 however this influence is changed. The title ‘indifference toward benefit expected’ and the description in the original text gave us the impression that the scenario was about having *no influence* of ‘patient expectations of treatment benefits’ on ‘patient efforts to seek treatment’ *at all*. The book mentions that “the influence of benefit expected upon patient’s efforts to get care (or “treatment sought”) was changed so as to make the patient’s behavior indifferent to the benefit expected” (Levin and Roberts, 1976, p. 73). We operationalized this scenario by replacing the original equation for ‘patient efforts to seek treatment’ (equation 18, A on page 194)

Patient need for treatment * Habit effect on treatment seeking * Influence of expected treatment benefits on patient efforts

by our new equation

Patient need for treatment * Habit effect on treatment seeking

and we deleted the corresponding arrow from the model. The scenario in the book mentions a restoring of the level of functioning to 55 functioning points, compared to recovering to 60 functioning points in the base case. Our simulation run with the new equation however leads to the exact same result as in the base case: a full recovery to 60 functioning points. By means of this what-if scenario, the authors test their hypothesis that the patient's expectation of benefit from treatment is a critical variable. Based on their results they partially accept their hypothesis because their observation that the patient shows only a 92 percent recovery. We would however decline the hypothesis based on our results, because we observe no differences we identify the patient expectation of benefit as not critical at all.

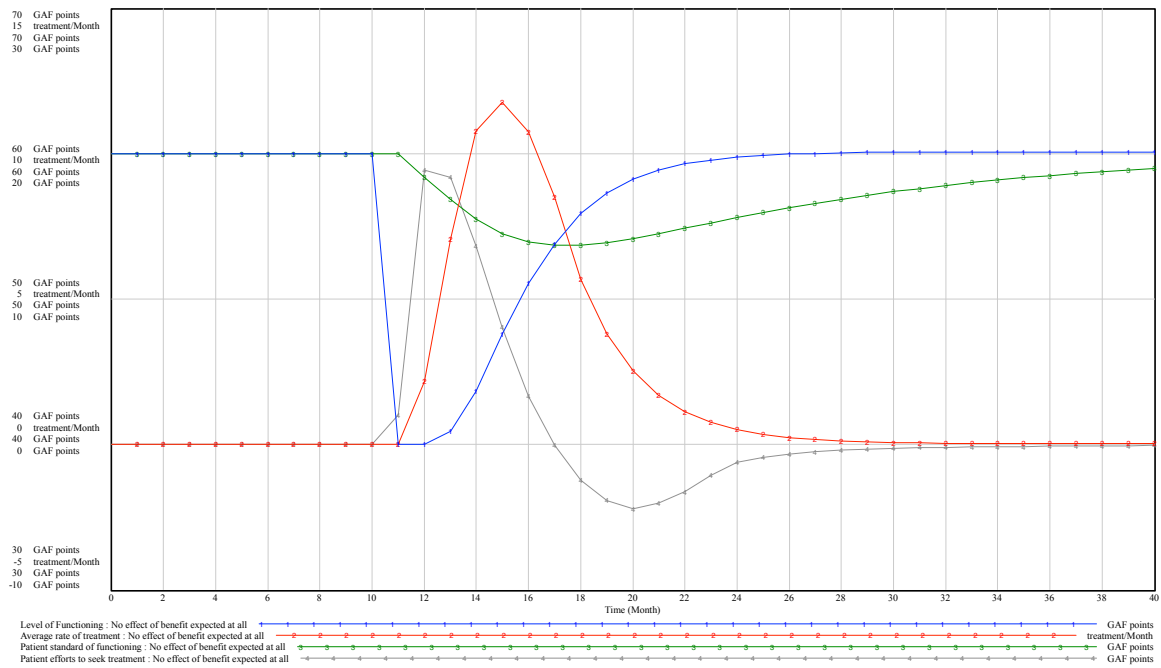


Figure 5: Output of our scenario with benefit expect having no influence at all

Only after discovering the settings used by the original authors on page 204 as part of the appendix were we able to replicate the exact same results as the authors. On this page they mention that they operationalized the patient indifference toward benefit expected by *shifting* the table function for ‘influence of expected treatment benefits on patient efforts’. Instead of using the original table function

$$([(-2, 0) - (2, 1)], (-2, 0.1), (-1, 0.3), (0, 0.7), (1, 0.9), (2, 1))$$

they used a new version namely

$$([(0, 0) - (4, 1)], (0, 0.1), (1, 0.3), (2, 0.7), (3, 0.9), (4, 1))$$

In other words, in their operationalization of the scenario the expectations of treatment benefit should have been 2 functioning points per month higher to have a similar effect as in the base case. The results are shown in Figure 6 and are exactly the same as the

results mentioned by the authors. Our critique now for scenario 2 is that the description of the scenario does not match the operationalization. This makes it very hard to follow the reasoning and the conclusions that the authors deduce from their scenario run.

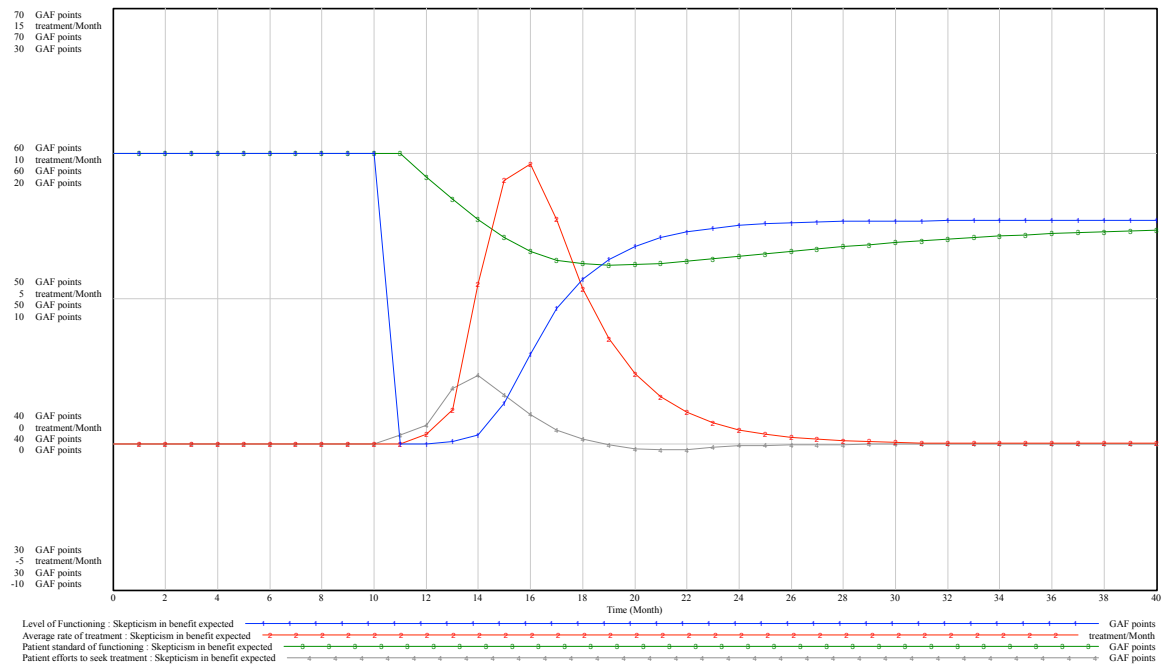


Figure 6: Output of running the model with a shifted table for effect of expected benefit

We would argue that the operationalization of a scenario into parameter values or changes in model structure should be closely coupled to the hypothesis and description of the scenario as represented in the text. For this scenario the authors failed to realize such a close coupling.

Time step

The authors do not mention what they chose to use as their time step. We could however deduce the time step they chose: we were only able to replicate the original simulation results by choosing a time step of 1 month. Together with the fact that the resolution of their graphs is 1 month (they show one value per variable per month) this gave us enough confidence to conclude that the authors chose to use a time step of 1 month.

Changing this time step to smaller numbers has a significant impact on the results of the scenario runs. Figure 6 and Figure 7 show simulation results for the same parameter values, the only difference is the timestep. When using timestep '1 month' and simulating scenario 2 we get 55 units as the 'final level of functioning'. When using the much smaller timestep of '0.0078125 months' and simulating the exact same scenario we get 53 as a 'final level of functioning'. We analyzed the differences for all scenarios when running with a timestep of 1 month or when integrating with the Runge-Kutta 4

auto algorithm with a absolute and relative tolerance of .001 which automatically adjusts the time step until it is small enough so that an even smaller time step does not result in significantly different outcomes. The results of those scenario runs are presented in Table 1 below.

#	Scenario name	Parameter values	Text 1976	Euler	RK4 Auto	Δ
	Simulations of patient drop-out					
1	Baseline Run	Base model	60 units	60 units	58 units	-3%
2	Doubling the instability of the standard of functioning	TTCSF = 3	55 units	55 units	53 units	-4%
3	Increasing indifference toward benefit expected	L = 0, U = 4	55 units	55 units	53 units	-4%
4	Combination of unstable standard of functioning and indifference toward benefit expected	L = 0, U = 4, TTCSF = 3	44 units	44 units	46 units	5%
5	Extending the treatment timetable by factor of 10	TTEFD = 60	46 units	47 units	46 units	-2%
6	Quadrupling the estimate for treatment effectiveness	SETE = 1	51 units	51 units	50 units	-2%
7	Eliminating the criticality factor	CRTTB = 1/1/1/1/1/1	58 units	58 units	57 units	-2%
	Efforts to reduce drop-out					
8	Support of standard of functioning	L = 0, U = 4, TTCSF = 3, SW 1 = 1	46 units	46 units	48 units	4%
9	Doubling initial benefit expected	L = 0, U = 4, TTCSF = 3, NPETB = 2	54 units	54 units	52 units	-4%
10	Combination of support of standard of functioning and doubling initial benefit expected	L = 0, U = 4, TTCSF = 3, SW 1 = 1, NPETB = 2	59 units	59 units	58 units	-2%

Table 1: Consequences of adjusting the time step

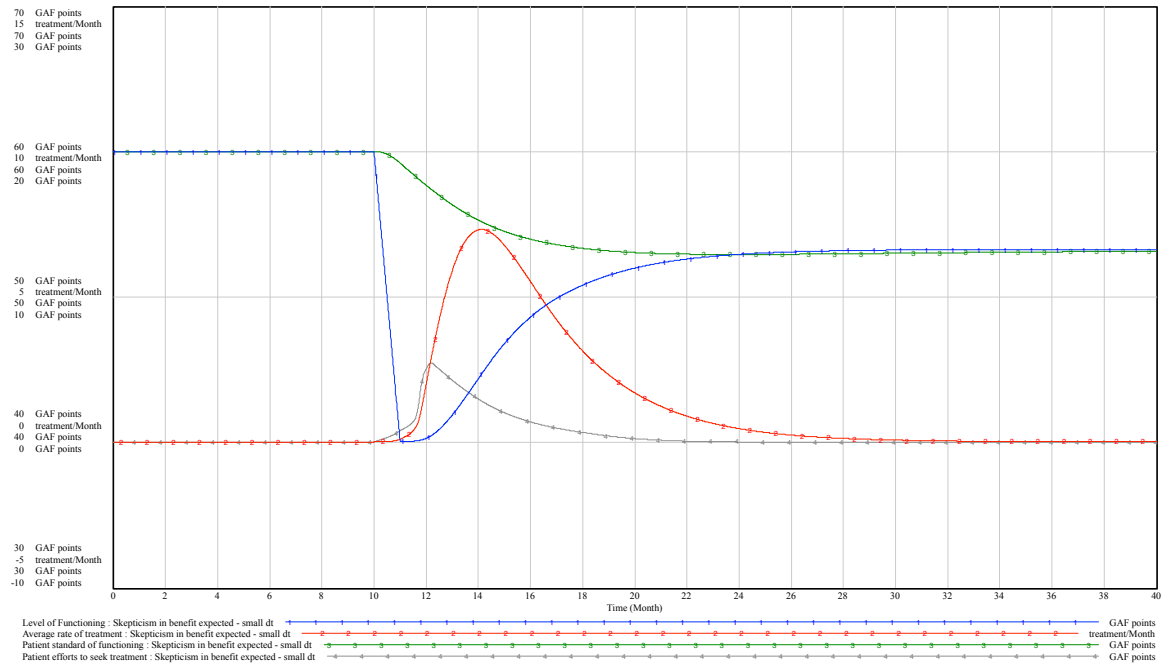


Figure 7: Output of running the model with a shifted table for effect of expected benefit with a smaller timestep

We conclude that a time step of 1 month is not appropriate. While using a smaller time step never results in differences bigger than -4% and $+5\%$ we do not see why one should accept the introduction of such an inaccuracy. Especially because nowadays in these straight forward scenario runs there is almost no trade-off between running time and accuracy because of higher computational power.

Conclusion

We conclude that several suggestions could be made to improve the original patient dropout model. Some of these critiques clearly can be contributed to the fact that more than 35 years have passed since the original model formulation. Nowadays we have the luxury of more computational power and the development of the field of mental health care resulted in a clear operationalization of the level of functioning in terms of the GAF score. Other critiques however could also be made without time having passed: bad naming, inadequate argumentation for parameter values and bad equation formulations have no time or place in the field of properly applied System Dynamics.

4. A reformulated model

In the modeling process, the three most important principles can be formulated as (Martinez and Richardson, 2001):

- Start small, simulate often. We started by defining and quantifying just a couple of variables.
- Make sense. When defining parameters we made sure that they have a real world meaning.
- Partial model tests. Before putting different parts together we tested them separately.

Up to now we formulated critique on the original patient dropout model. In this paragraph however we suggest a different way of conceptualizing mental health care using the three modeling principles mentioned above as a starting point. Not because the conceptualization of the authors is ‘wrong’ but because we would argue that our conceptualization is more useful for the purpose of analyzing patients getting mental health care and identifying policies to prevent patients from dropping out.

Instead of taking the interaction between doctors and a patient as a starting point, we start by just modeling the patient. We started by modeling an individual in a normal situation, without any notion of this individual being a patient or notions of doctors or treatment. We would argue that everybody has a certain level of functioning (which we express in GAF points) and that everybody experiences some stressors in every day life (unfulfilled expectations, disappointments, etc.) resulting in the loss of a couple of GAF points per month. On the other hand, we would argue that under normal conditions everybody has a certain capacity to recover from those everyday stressors, thereby gaining roughly the same amount of GAF points per month. The capacity, or ‘resilience’, is depending on the actual level of functioning, so in our conceptualization a large ‘life event’ consisting of a drop of functioning of 20 GAF points is problematic, because the capacity to recover from such a life event is decreased by this very same life event, as shown in Figures 8 and 9.

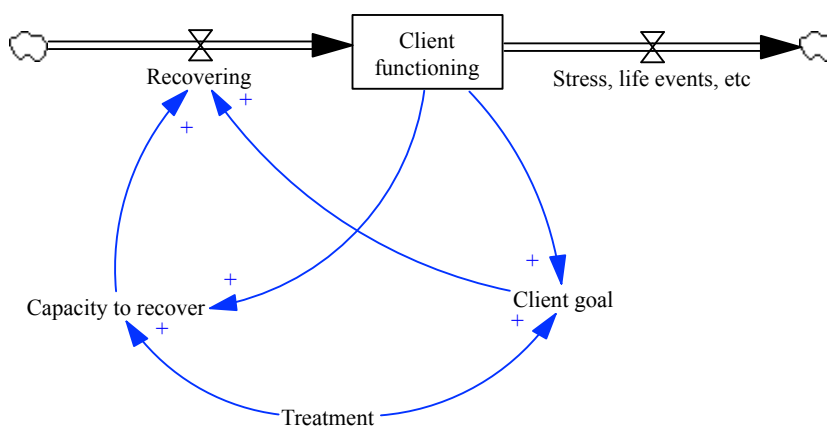


Figure 8: core feedback loops of the reformulated model

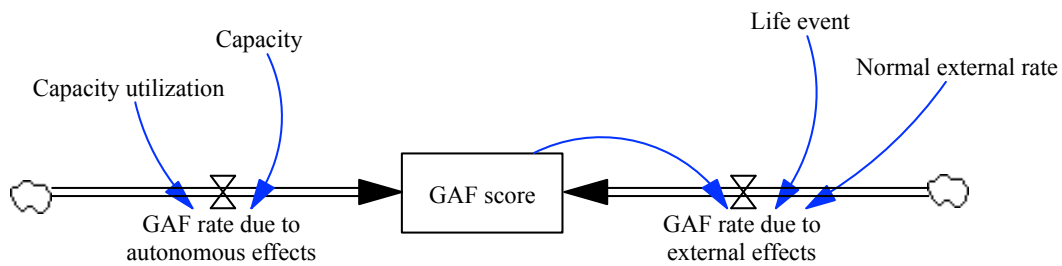


Figure 9: core stock and flow structure of the reformulated model

In the original model, treatment directly resulted in a higher level of functioning by adding a certain amount of functioning units per treatment. We conceptualize treatment as having only an indirect effect on functioning, by doctors sustaining the resilience of patients who regain their capacity to recover their functioning. Our view of mental health care is related to the concept of resilience as it is used in the literature in the field of mental health care (see for example Dyer & McGuinness, 1996; Luthar & Cicchetti, 2000; Werner, 1995; World Health Organization, 2004). Resilience is defined as “a dynamic process wherein individuals display positive adaptation despite experiences of significant adversity or trauma” (Luthar & Cicchetti, 2000). While the original model also could show a process of patients recovering from adversity, this always depended on doctors giving treatment. We include the underlying mechanism, namely that every individual has a capacity to recover on its own: “resilience, the ability to bounce back from adversity, is the challenge every human eventually faces in living” (Dyer & McGuinness, 1996). We could say that the original model describes what sometimes is named ‘the medical model’ of conceptualizing mental health care while our new model describes ‘the recovery model’ of conceptualizing mental health care.

Below we describe the major revisions in the model that come with our view of conceptualizing mental health care.

Rate of change of functioning -> rate of recovery

The original equation of the rate of change of functioning due to treatment is as follows:

$$\begin{aligned} \text{RCFTR.KL} &= (\text{ART.K}) (\text{TEF.K}) \\ \text{TEF.K} &= \text{TABHL}(\text{TEFTB.SOF} - \text{FUNCTN.K}, 0.25, 5) \\ \text{TEFTB} &= .25/.35/.4/.4/.4/.4 \\ \text{SOF} &= 50 \end{aligned}$$

RCFTR – Rate of Change of Functioning due to Treatment (functioning units/month)

ART – Average Rate of Treatment (treatments/month)

TEF – Treatment Effect of Functioning (functioning units/treatment)

TABHL – DYNAMO special notation for TABLE, High-Low

TEFTB – Treatment Effect on Functioning Table (functioning units/treatment)
 SOF – Standard Of Functioning (functioning units)

Our suggested reformulation is as follows:

$FREC = PR * AR$
 $PR = NR * EGR * ETR$
 $AR = TAR(IAR)$
 $NR = 2$
 $EGR = TEGR(FUNC/NFUNC)$
 $TEGR = [(0,0) - (1,1)], (0,0), (0.1,0.1), (0.2,0.25), (0.25,0.35), (0.3,0.5), (0.35,0.7), (0.4,0.87), (0.45,0.96), (0.5,0.98), (0.55,0.985), (0.6,0.99), (0.65,1), (1,1)$
 $FUNC = INTEG(FREC - FDEG)$
 $NFUNC = 100$
 $ETR = TETR(TI)$
 $TETR = [(0,0) - (25,2)], (0,1), (0.5,1.3), (1,1.5), (1.5,1.6), (2,1.6), (25,1.6)$
 $TAR = [(0,0) - (30,4)], (0,0), (0.5,0.6), (1,1), (2,1.7), (3,2.1), (4,2.4), (5,2.5), (30,2.5)$
 $IAR = ZIDZ(DREC, PR)$

- FREC – Functioning RECOVERY (GAF points/month)
- PR – Potential Resilience (GAF points/month)
- AR – Actual Resilience (Dimensionless)
- NR – Normal Resilience (GAF points/month)
- EGR – Effect of GAF score on Resilience (Dimensionless)
- ETR – Effect of Treatment on Resilience (Dimensionless)
- TAR – Table for Actual Resilience
- IAR – Indicated Actual Resilience (Dimensionless)
- TEGR – Table for Effect of GAF score on Resilience
- FUNC – patient level of FUNCTIONing (GAF points)
- NFUNC – Normal patient level of FUNCTIONing (GAF points)
- FDEG – Functioning DEGrADation (GAF points/month)
- TETR – Table for Effect of Treatment on Resilience
- TI – Treatment Intensity (dimensionless)
- DREC – Desired rate of RECOVERY (GAF points/month)

Patient standard of functioning -> Patient functioning ambition

The original equation of the rate of change of functioning due to treatment (without the policy of supporting the patient standard of functioning) is as follows:

$$PSF.K = PSF.J + (DT) (RCF.JK)$$

$$PSF = FNCTN$$

$$RCF.KL = (FNCTN.K - PSF.K) / TTCSF$$

$$TTCSF = 12$$

PSF – Patient Standard of Functioning (functioning units)
 RCF – Rate of Change of standard of Functioning (functioning units/month)
 FNCTN – level of FuNCTioNing (functioning units)
 TTCSF – Time To Change Standard of Functioning (months)

Our suggested reformulation is as follows:

$$PFA = ETA * PAFA + (1 - ETA) * PEFA$$

$$ETA = TETA(TI)$$

$$PAFA = 65$$

$$TETA = [(0,0) - (10,2)], (0,0), (1,0.35), (2,0.55), (3,0.6), (10,0.6)$$

$$PEFA = EFA * PAFA + (1 - EFA) * HFUNC$$

$$EFA = TEFA(FUNC/NFUNC)$$

$$HFUNC = INTEG(CHFUNC)$$

$$TEFA = [(0,0) - (1,1)], (0,0), (0.1,0), (0.2,0.08), (0.5,0.56), (0.6,0.72), (0.65,0.8), (0.7,0.88), (0.8,0.96), (0.9,0.98), (1,1)$$

$$CHFUNC = (FUNC - HFUNC) / THF$$

$$THF = 12$$

PFA – Patient Functioning Ambition (GAF points)
 ETA – Effect of Treatment on functioning Ambition (dimensionless)
 TETA – Table for Effect of Treatment on functioning Ambition
 TI – Treatment Intensity (dimensionless)
 PAFA – Patient Absolute Functioning Ambition (GAF points)
 PEFA – Patient Endogenous Functioning Ambition (GAF points)
 EFA – Effect of Functioning on firmness of ambition (dimensionless)
 HFUNC – Historical patient level of FUNCTioNing (GAF points)
 FUNC – patient level of FUNCTioNing (GAF points)
 NFUNC – Normal patient level of FUNCTioNing (GAF points)
 THF = Time to adjust Historical patient level of Functioning (months)

Our new model has a structure that differs to a great extent from the original model, but what about the behavior of the model? We were able to replicate similar behavior of a patient that does not drop out just as the base case in the original model. For certain parameter values however our model shows behavior that the original model could never result in. When the life event results in a drop in GAF points that is large enough, our model ‘tips’. For smaller life events we see a patient that recovers with an increasing speed because by obtaining a higher level of functioning the patient’s ability

to recover gets larger. If the size of the life event exceeds this ‘tipping point’ we see a patient that is in a worse state and continuous to get rapidly worse as time goes by. Under these circumstances the ability to recover is lower than the normal amount of stress experienced and the level of functioning decreases in a vicious cycle of ‘self-destruction’. The role of mental health care can now be understood as attempting to *lower the tipping point*, in other words lowering the level of functioning where the patient starts to enter the vicious cycle of self-destruction.

Our new model focuses on a person’s ability to recover from adversity. The old model includes only one source for raising the level of functioning namely by getting treatment. If one conceptualizes mental health care as is done in the original model, one becomes prone to the archetype of ‘shifting the burden’. If we imagine that in the old model there is not just one life event but a continuous strain of adversity, then we can imagine only one solution to retain a high level of functioning: *continuous* treatment. The doctors, in this case, do not solve the underlying problem but they only hide the symptoms. Conversely if one conceptualizes mental health care as is done in our model, a continuous strain of adversity is part of the base case and recovering from a continuous strain of adversity is business as usual. Only if this capacity is too severely damaged do doctors come into play in order to help the patient recover and maintaining a high standard of functioning.

We can find another major difference in model behavior in the effect of the policy of supporting the standard of functioning of the patient. Levin and Roberts were disappointed by the results that could be achieved by supporting the patient’s standard of functioning (1976, p. 84). Even if doctors spend large efforts to support the patient’s goal, the effect is very small in the original model. In contrast, our model suggests that it is very worthwhile to support the patient’s standard of functioning. Because we introduced the mechanism of patients self-recovery and doctors supporting patients in this self-recovery, the support of the patient goal has become a major leverage point for mental health care.

5. Conclusions

We reviewed the ‘patient dropout model’ in the tradition of retrospective model critiques that both serve to explicate the current standards of practice, illustrate how the field has evolved over time, and provide pedagogical material for teaching. The original model was well documented and we were able to replicate the simulation results. We did, however, identify several improvements for documentation, model formulation, and operationalization. One of the larger issues is the time step of 1 month that is not up to current standards. Decreasing the time step does have significant effects on the simulation results. We invite researchers to further continue the tradition of retrospective model critiques.

Besides critiquing the original model, we also presented a different conceptualization for mental health care delivery. Our new model formulation includes a tipping point that makes it possible for patients to get caught in a vicious cycle. Besides that, our model is much more optimistic about supporting the goal that patients set for themselves. Future directions for research could include investigating the generalizability of our new model formulation. We see the original model as closely related to the traditional ‘medical model’ of seeing patients as having an ‘error’ that should be ‘fixed’, while our model stresses the importance of the patient’s own recovery mechanisms. We can imagine that a similar distinction can be made in a traditional way of looking at education where teachers ‘put’ knowledge inside the heads of children versus seeing children as being able to follow their own curiosity and teachers acting as coaches that try to stimulate children in challenging themselves. We call for research into the application of our conceptualization in the domain of education.

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