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Editorial

Introduction to special issue on contributions of mathematical psychology to clinical science and assessment

James T. Townsend [a,*], Richard W.J. Neufeld [b]

[a] *Indiana University, United States*

[b] *University of Western Ontario, Canada*

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A B S T R A C T

Evolution of clinical mathematical psychology, exemplifying integrative, translational psychological science, is considered in light of target, idealized scientific systems. It is observed that mutual benefits to psychological clinical science, and quantitative theory, potentiated through their interlacing as exemplified in this special issue, stand to parallel the historical symbiosis between older disciplines and mathematics. Enumerated are the range of psychological processes and clinical groups addressed, forms of modeling implemented, and clinical issues engaged, the latter ranging from intervention, to elucidation of deviant basic processes. A denouement comprising cogent quotations from historical figures in science concludes this Introduction.

1. Introduction

In his classic article on the slow progress of so-called soft psychology, Meehl (1978) lamented clinical science's absence of Popperian bold conjecture, and its dependence on "off-the-shelf" measures of addressed variables, which contrasted more established disciplines' theory-based measure prescription (currently writ large in the much-heralded Higgs-boson directed Large Hadron Collider). McFall and Townsend's (1998) twenty-year status check made clear that little progress had been made over the intervening period to redress Meehl's clinical-science indictment.

Subsequently, the discipline has witnessed considerable advance in clinical mathematical psychology. Mathematical psychology, and its implementation in clinical science and assessment, perforce bring into play the formal deductive properties (Braithwaite, 1968) making for theory-mandated predictions and measurement. In some cases, empirical outcrops of quantitatively expressed processes moreover have made seamless connections with measurement and statistical science, again forming the pure deductive scientific system (by Braithwaite's classic taxonomy) Meehl had extolled (e.g., "Cognitive Psychometrics"; Batchelder, 1998).

Despite their rigor, and indeed infiltration of mainstream psychological clinical-science outlets, developments in clinical mathematical psychology have been surprisingly inconspicuous on the landscape of "state of the discipline" reviews. For example, they received virtually no mention in the recent (2009) volume of the *Annual Review of Clinical Psychology* (ARCP), despite this series' declared mission to apprise readers of contemporary advances, and notwithstanding direct appeals therein for the very material embodied by the above developments (e.g., Strauss & Smith, 2009, p. 12, on the need to disentangle processes underlying cognitive disruption in disorders such as schizophrenia, as well as the need to dissect performance on the increasingly clinically popular Iowa Gambling Task [IGT]; see also Reise & Waller, 2009, p. 42; however, cf McFall's entry in the 2006 volume of that series, on quantitative modeling as a key constituent of integrative psychological science). Possibly, increased salience of these developments, availed through showcasing a critical corpus, and its advertisement on available clinical-science web sites and listservs, will foster due recognition in the field.

In any case, contextualizing the present thrust, it is anticipated that with their interlacing, benefits somewhat can be two-way between quantitative psychological science and its clinical implementation. Beneficence to clinical science seems relatively straightforward. Roughly, existing formulations of target processes are appropriated; the appropriated formulations are titrated pending accommodation of clinical-sample performance deviations; and model properties thus selectively tweaked are triaged as signifying disorder-affected functions, over and against those that are spared.

Potential benefits in the opposite direction may be less readily appreciated, but nevertheless present. For example, model generalization testing, in this context, arguably would favor existing models that readily accommodate clinical performance

* Corresponding address: Department of Psychological & Brain Sciences, Indiana University, 1101 E. 10th St., Bloomington, IN 47405-7007, United States.
E-mail address: jtownsen@indiana.edu (J.T. Townsend).

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deviations, over competitors that fail, or are strained in doing so. Encountered barriers to model application may compel productive innovation (e.g., Kline, 1980). In particular, performance patterns sui generis to clinical groups and their controls may point to otherwise unrepresented structures of processing architectures. Extant models become more comprehensive if they parsimoniously come to grips with clinically accentuated individual differences. Selected innovations in parameter estimation and empirical testing may owe their existence to the challenges of "small-sample fit-and-test" constraints endemic to the clinical arena. So may computational economizing, for example entailing performance-impelled mixtures of model structures, but novelly at the level of trial blocks, versus each and every task-performance trial. New normative models (e.g., Edwards, 1998), quantitatively conveying benchmark optimal performance, may be constructed in the service of expressing disorder-incurred absolute toll on performance, degree of disorder-related perceptual error, and so on, according to contrasting clinical-performance descriptive models. Such synergies are salient amongst the current contributions.

2. The contributions

Coverage of clinical issues by the present set of contributions is presented schematically via the tree diagram in Fig. 1. Included in the caption are addressed processes, and clinical groups in whom they are studied. Targets of analysis range from intervention, including the quantitatively disciplined deployment of its elements, and monitoring of treatment response and of general regimen efficacy, to discerning deviations in symptom significant basic cognitive processes.

With respect to the latter, symptom significance ranges from that which is quite direct, as in the case of memory processes where memory deficit is a disorder's defining symptom, to that which is more subtle, as is the case with perceptual organization of deviance-significant stimuli among those at risk for sexual coercion, or selected forms of stimulus encoding deficit and schizophrenia thought-content disorder (systematic delusions and thematic hallucinations).

Certain basic process deficits moreover stand to be clinically consequential in their own right, because of their inevitable impingement on daily transactions. Normal facility with the fundamentals of processing activity, including its structure, speed, termination criteria, and response to errors, entering into the handling of environmental stimuli, arguably permeates routine self-maintenance functions. It is noteworthy that the presented analyses of such processes are not restricted to their specific disorder instantiations, but by and large are general.

The first paper (Bishara, Kruschke, Stout, Bechara, McCabe & Busemeyer) reports application of newly developed sequential learning models to conventional performance measures (e.g., perseverative errors) of the Wisconsin card sorting test (WCST), perhaps the most widely used test of so-called "executive", frontal lobe functioning. Added to content validity (also psychometric "construct representation"; Embretson, 1983) is incremental diagnostic-group discrimination, over and against that attained by conventional WCST measures.

Wetzels, Vandekerckhove, Tuerlinckx, and Wagenmakers consider dynamic stochastic modeling of IGT performance, premiering in Busemeyer and Stout (2002, see remarks on the IGT, above, apropos of the 2009 ARCP). Wetzels et al., evaluate participant-wise Maximum-Likelihood parameter estimation, and put forth a Hierarchical-Bayes (HB)–Monte-Carlo–Markov-Chain alternative. Although inferences drawn from the two methods converge when compared experimentally, the Hierarchical Bayes methodology more parsimoniously assimilates the totality of data, is more statistically comprehensive in supplying distribution properties of estimated parameters, and is deemed more refractory to data contamination entailing, for example, task non-compliance.

Accordingly, in decomposing IGT performance among chronic cannabis users, using Expectancy Valence Learning and Prospect Valence Learning models, Fridberg, Queller, Ahn, Kim, Bishara, Busemeyer, Porrino, and Stout augment their individual-participant Maximum-Likelihood fit and test procedures with HB estimation methodology. Again, substantive inferences converge, thus mediating to increasingly prominent HB estimation technology findings from more familiar classical estimation methods.

In exemplifying the clinical utility of sequential sampling models of two-choice response time and accuracy, White, Ratcliff, Vasey & McKoon analyze anxiety-prone individuals' lexical decision performance. Capitalizing on the entire performance-data matrix, decision processes are separated out from typical base processes, comprising notably item encoding and response operations. Transducing the latter into diffusion-model boundary separation, however, unveils a previously undiscovered aspect of disproportionate negative-event impact on anxiety-prone individuals, specifically comprising distinctive reaction to performance errors.

Johnson, Blaha, Houpt and Townsend address the prominent issue of local- or detail-driven-processing bias ("weak central coherence") in autism spectrum disorders. Theoretically significant deviations in the structure of processing are shown to require the depth of analysis supplied by Systems Factorial Technology. Note that the rigorously educed deviations tenably ramify to more molar transactions, to which the present structures are elemental. New processing-architecture models are developed to accommodate clinical-control group latency patterns, identified through the partitioning of distribution properties impelled by this technology.

Wenger, Negash, Petersen and Petersen examine recall processing capacity associated with mild cognitive impairment, a lead indicator of Alzheimer's Disease. Predictions involving quantitatively operationalized capacity are moored in an antedating model of disorder-implicated neuro-circuitry dynamics. The formulated capacity measure is shown to improve preliminary diagnostic-efficiency statistics, and exceeds conventional test-performance measures in its correlation with targeted structural MRI measures.

As reported in the paper by Neufeld, Boksman, Vollick, George and Carter, certain cognitive operations customarily relegated to the status of cognitive-performance base, over and against target processes, again nevertheless assume target status in terms of clinical salience. Such is the case for collateral-function-facilitative stimulus encoding in schizophrenia. Fixed-parameter modeling of this process is expanded to mixture model status, accommodating evident randomly distributed encoding model parameters. The expansion ushers in computational options harboring several types of clinically significant information, an approach to clinically-imposed small-trial-sample model fit-and-test constraints, and strategies for navigating temporal probes of fMRI isolating symptom-significant cognitive processes.

Maddox, Filoteo and Zeithamova introduce a classification-performance-model variant that incorporates a mixture of strategy structures, but economically fixes the admixture within trial blocks, versus allowing it to vary on a per-trial basis. This quasi-restricted model identifies the loci of classificatory deficits in alternate striatal-damage groups, but also renders predictive validity surrounding future patient status, incremental to conventional categorization-performance measures, and superior to WCST-based measures.

The clinically vital topic of medication effects on cognitive functioning is taken up by Speekenbrink, Lagnado, Wilkinson and Jahanshahi, with respect to categorization learning in Parkinson's Disease patients. Their adopted probabilistic-learning measurement model discerns similarities and differences to controls

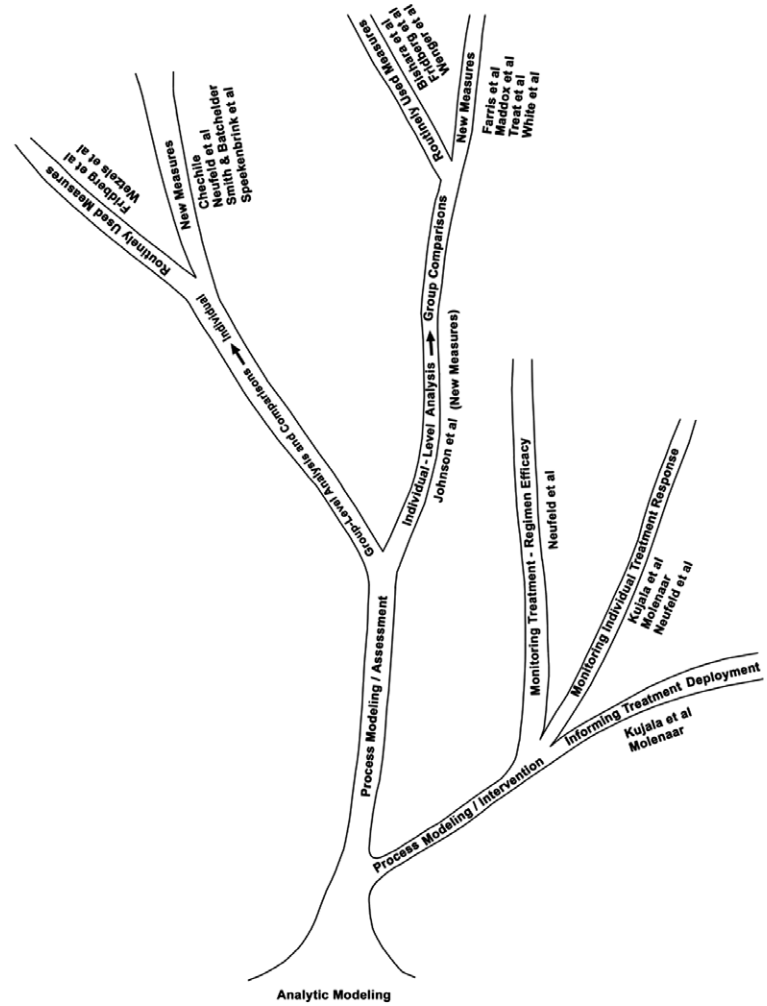

Fig. 1. Organizational schema of contributions. *Addressed processes and clinical groups*: Memory processes among alcohol substance abusers (Smith & Batchelder); Memory processes in alcohol-induced amnesia and Korsakoff Syndrome (Chechile); Working-memory facilitative stimulus encoding in schizophrenia (Neufeld et al.); Category learning in medicated and medication-free Parkinson's Disease patients (Speekenbrink et al.); Dynamical-decision-model parameter estimation for clinical science/assessment application generally (Wetzels et al.); Dynamical decision processes among chronic cannabis users (Fridberg et al.); Global–local item processing (central coherence) in autism spectrum disorders (Johnson et al.); Dynamical decision processes among stimulant- and alcohol-dependent individuals (Bishara et al.); Perceptual processes among sexual-coercion-risk individuals (Farris et al.); Dynamical category learning among striatal-damage (Parkinson's and Huntington's Disease) patients (Maddox et al.); Attention, memory and perceptual-organization properties among individuals with clinically-significant eating-disorder symptomatology (Treat et al.); Recall processing among Alzheimer's disease-risk individuals (Wenger et al.); Dynamical decision processes among anxiety-prone individuals (White et al.); Grapheme-morpheme learning in dyslexia-risk triaged individuals (Kujala et al.); Psychotherapeutic interactions applicable to treated populations generally (Molenaar).
Individual-Level Analysis → Group signifies modeling of individual data, followed by testing for statistical significance of group differences.
Group-Level Analysis and Comparisons → Individual signifies accommodation of individual differences in model expressions of group performance, with possible importation of corporate group results to refine and stabilize estimation of individuals' model properties.

in categorization strategies, but the configuration systematically changes in model-identifiable ways according to medication status.

Farris, Viken and Treat use statistical benchmarks of perceptual independence, as defined in General Recognition Theory, to identify etiologically suspect perceptual anomalies in perceived stimulus-feature associations, amongst individuals posing risk for sexual coercion.

Multinomial Processing Tree Modeling (MPTM) of memory storage and retrieval operations may well be the mathematical process model most widely used in clinical science. Chechile's most recent MPTM innovations extend MPTM's clinical applicability, by developing and testing simulatively, and with memory-impaired participant data, a novel and highly tractable method of importing group-performance modeling to stabilize individual parameter estimation.

Remaining with MPTM, Smith and Batchelder present a further advance in exploiting natural linkages with traditional data theory and statistical science. Individual parameter values are deemed to emanate from a randomly distributed population of values, not unlike those of any random independent variable of the General Linear Model. These pivotal ideas were introduced by Batchelder into the clinical science literature as early as a decade ago (Batchelder, 1998). In the present article, they are synthesized into a unifying model architecture, comprehensively providing for individual expressions of a common MPTM structure. Application in clinical science and elsewhere of this Hierarchical Bayesian approach here again is facilitated through Markov Chain Monte Carlo algorithms.

Formally modeled attention, memory and bi-dimensional perceptual-organization tasks are brought to bear on symptom-significant eating disorder symptomatology, by Treat, Viken, Kruschke and McFall. This measurement-model package amounts to a multi-method quantitative-modeling battery, and virtually serves as a prototype for cognitive-modeling applications generally.

In the report presented by Kujala, Richardson, and Lyytinen, Luce's choice axiom forms the "computational kernel" for a method of monitoring grapheme-morpheme connectedness derived from responses to a multiple-choice game, designed to preempt dyslexia among high-risk children. Statistical properties of the confusability estimation, from this computationally feasible innovation, fare well as against more costly full Bayesian methodology, and classical unbiased and efficient estimators.

Molenaar brings to bear on psychotherapy process analysis stochastic optimization control theory, not unlike that of quality-control monitoring inhabiting engineering science and supporting disciplines. Doing so endows the therapist with a dynamical guidance system for adjusting therapeutic interchange. Mathematical foundations and derivations are general, de facto implicating interactions in this setting as a case in point. Such elegant developments are ignored to the peril of progress in the field – including its subdomain of demonstrably efficacious Cognitive Behavior Therapy – no less than ignoring, say contemporary medical robotics, would imperil progress in the field of clinical surgery.

3. Concluding comments

As stated by Roger Bacon, "Physicians must know their science is impotent if they do not apply to it the power of mathematics". Kurt Lewin noted that, "There is nothing so practical as a good theory". The current offerings make clear that "good theory" includes such features as closed-form solutions and theorem-proof continuities. Indeed, such good theory seems quite indispensable to "Best Practice".

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