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The Application of Theory in Clinical Research: Linking Theory and Experimentation

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This paper focuses on the reciprocal connections between theory and experimentation considering the ways in which an initial theoretical position or premise that informs and constrains experimentation can lead to data and interpretations that cycle back to advance the theory. Below I will review briefly major processes in theory building and theory testing (Table 1), illustrating some of the steps involved by referring to a study currently being conducted in my lab; summarize by emphasizing the value of working

Table 1. The Process of Connecting Theory to Experiment and Interpretation

1. Meld existing data and theoretically based predictions or explanations, to generate a conceptual framework for the study.
2. Derive testable hypotheses and research questions, and associated predictions.
3. Design and implement tests of reasoning:
   a. Operationalize hypothesis and/or question, specify anticipated outcome, state null hypothesis;
   b. Identify results consistent with, and counter to, premise motivating the study;
   c. Complete the design, ensuring appropriateness of design elements given constraints and assumptions of theory and research questions
      (1) plan and conduct multiple tests
      (2) anticipate and examine alternative interpretations.
4. Test the null hypothesis.
5. Interpret data and draw links back to theory:
   a. From upheld predictions
   b. From unexpected results
   c. Reconceptualize existing theoretical accounts to accommodate new data.

within a cycle that goes from theory to experiment and back again; and conclude by noting some reminders, cautions, and general suggestions for conducting and interpreting theory-driven research.

THEORY BUILDING AND THEORY TESTING

Because we want to tie *theory* to either end of the experiment-interpretation chain, let us consider from where the theory part comes. Basically our theoretical frameworks are derived from logic that we apply in order to meld empirical observations with explanations or predictions that we draw from existing theory. For this melding process, it is perfectly legitimate to start from either data or theory, but then it is necessary to move back and forth, to connect the two. We eventually must translate the links to hypotheses, questions, and predictions, and test our reasoning, rather than be satisfied with the logical analysis as an end in itself.

If we work initially from data and established observations, we want to synthesize them to develop statements of interpreted relations, and/or tentative explanations. Then a number of routes are possible. For example, we may begin with apparent conflicts or contradictions; with robust, replicated observations and interpreted findings; or with observations from exploratory research that were not originally predicted. The next step is to generate, or invoke, theoretical contexts that could reconcile, encompass, substantiate, or connect these observations. Subsequently, we scrutinize and analyze the theoretical position(s) that we come up with, to draw and test new predictions or explanations that would logically emanate from them. It is important in this process to try to generate competing or alternative explanations to test, on an a priori basis.

There are also a number of ways to proceed when working from existing theory. We can review theories in the domain of interest to see if they identify, or if we can infer, the most crucial or central mechanisms and assumptions; particularly those that distinguish theory A from theory B. We are in a strong position to advance science if we design a test of two theories that generate competing predictions about a key phenomenon. Another possibility is to review theories to identify inadequacies or unknown elements. For example, the theory may indicate gaps; may need extension because it has been narrowly applied or tested; or may need revision because it is too global or it is in apparent conflict with some believable evidence. Finally, we can examine theories of normal functioning in the area of interest, and make deductions about how things could go awry; reasoning about what kinds of disorders these theories should be able to generate or accommodate.

To exemplify this melding process, let us consider some work currently being implemented in my laboratory to examine discourse comprehension impairments after right hemisphere brain damage (RHD). The examples are necessarily abridged because of space limitations. To keep this manageable, and to illustrate one way to proceed from accumulated data, a small and focused example of a robust, interpreted observation about RHD adults' discourse comprehension impairments is highlighted (Table 2). For convenience, the observation in Table 2 is referred to as a reflection of RHD adults' problems with competing interpretations.

Now, let us note several types of potential accounts for this observation about RHD adults' comprehension difficulties. Again, these are exemplary only, not exhaustive. Some postulated accounts (e.g., those that appeal to interpretational rigidity, or integration difficulties) stay fairly close to the data, tend to derive primarily from the disorders domain, and tend to describe more than they predict or explain. Accounts at this level are frequent in the early stages of exploratory research, when pertinent and reliable phenomena are still being defined.[1] Some more productive types of interpretations can be derived from theories that predict comprehension differences for normal individuals, by examining the relevance of various theoretical premises for understanding disorders. As one example, the theory of capacity-constrained comprehension (Just and Carpenter, 1992) suggests that some particularly demanding operations involved in processing competing interpretations may be overly taxing for RHD patients' available comprehension resources, and thus will lead to increased latencies and errors.

From this point on, focus will be on the potential accounts offered by another general psycholinguistic theory of normal comprehension, the Structure Building Framework (SBF; Gernsbacher, 1990). The SBF, like the

Table 2. An Interpreted Observation to Illustrate Theory-Experimentation Linkages

Right brain-damaged adults' comprehension difficulties tend to emerge when portions of the context point to or suggest competing interpretations.[a] For example:
when disparate sources of information must be considered and integrated
when initial assumptions and inferences must be altered
with literally false materials where alternative meanings must be reconciled with contextual cues.

[a]See Joanette, Goulet, and Hannequin (1990); Tompkins (1995).

1. Of course, whenever pertinent theoretical frameworks exist, they can be fruitful guides to the initial exploratory research in a field.

capacity-constrained theory, is appealing in its demonstrated power and generality to predict and account for observations of individual differences in comprehension, across levels of language. To develop the link between the SBF and the existing evidence about RHD adults' comprehension difficulties, and to generate predictions and associated design elements, it is necessary to describe briefly some of the SBF's key elements. In the description below, those that are underscored will be highlighted later, as hypotheses about the nature of RHD adults' problems with competing interpretations.

According to the SBF, the goal of comprehension is to build cohesive mental representations, or structures. First, a comprehender lays a foundation (mentally) from incoming information. Perceptual processes, which encode acoustic signals and generate initial propositions, create activation patterns that initiate the foundations for mental structures. Then, a comprehender elaborates the developing structure by mapping onto it related information, whether encoded from text or activated from world knowledge. Whenever activated information cannot be related easily to the initial structure, the comprehender *shifts* to begin a new substructure. And, once portions of memory are activated by any means, two modulatory mechanisms come into play. *Enhancement* heightens activation of information associated with contextually appropriate interpretations, while *suppression* dampens activation that is less appropriate or relevant to the evolving interpretation. A central finding from research conducted in this framework is that skilled comprehenders have more efficient suppression mechanisms than less skilled comprehenders, across tasks, modalities, and domains (linguistic and nonlinguistic; Gernsbacher and Faust, 1991).

Before continuing with our focus on this particular theoretical framework, it is worth noting that none of the previously mentioned accounts is incompatible. In fact, they could intersect in interesting ways, though some are clearly more specific than others. For example, a disturbance in one of the central mechanisms of the SBF, could alter the input that a comprehender works on, such that eventual resolution requires an increased allocation of processing resources; and/or could deplete resources needed to carry out other interpretive and integrative comprehension processes. In any case, we are currently pursuing work grounded in the SBF for two key reasons. First, it makes more precise, and more clearly testable predictions than capacity-constrained comprehension theory, for the discourse domain that is the center of many problems for RHD patients. Second, the SBF is broad in scope. It pertains to comprehension in nonlanguage as well as language media; and within the language domain, it applies to hierarchical levels ranging from words, phrases, and clauses to sentences and episodes. Some other desirable features of the SBF are noted in Table 3.

Table 3. Some Desirable Features of the Structure Building Framework

Broad in scope
Unites/accounts for existing psycholinguistic evidence on comprehension
Generates falsifiable predictions
Presents explicit and reasonable assumptions
Predicts some nonobvious differences between skilled and less skilled comprehenders
Relatively well documented: various central predictions have been upheld by repeated empirical tests, including some in which competing predictions were drawn from other explanatory frameworks.

Now, let us leave the example briefly, and turn to the next step in the process of connecting theory and experiment (see Table 1). That step involves deriving testable hypotheses and predictions from our theoretical context, however we have arrived at it. By *testable,* I am referring to something operationally specifiable, and falsifiable. A testable hypothesis is a declarative statement of relations that can be operationalized and negated. And a theoretically sound research question poses a clear assertion about relationships between variables, rather than a directionless "What would happen if," or "Do patients do X?" These types of questions cannot be negated and falsified.

Returning to our example, we can derive several tentative hypotheses by melding the observation about patients' problems with competing interpretations, with predictions derived from the SBF. One possibility is that RHD patients' deficits with competing interpretations may be related to difficulty in shifting and generating new substructures appropriately when they encounter material that does not obviously map onto a developing structure. This seems unlikely, for a number of reasons that cannot be developed fully in the space allotted; however, RHD adults can revise initial interpretations and represent alternative meanings when processing demands are minimized and/or when they function with higher estimated working memory resources (Tompkins, 1995; Tompkins, Bloise, Timko, and Baumgaertner, 1994). Another possibility is that their deficits with competing interpretations may be related to difficulty with suppressing irrelevant or incompatible information.

The suppression hypothesis appears to provide a good place to start, on several grounds. First, according to the SBF, ineffective suppression is a key to understanding normal individual differences in general comprehension skill (across tasks, modalities, etc.). So the theory places suppression efficiency in a position of centrality in accounting for comprehension performance. In addition, ineffective suppression could underlie a variety of other observations about communication in RHD adults, some of which

Table 4. Some Observations about RHD Patients' Communication, That Could Be Related to Ineffective Suppression

Difficulty rejecting plausible but false statements;
Intrusion errors in descriptions based on common scripts;
Tendency to pursue incorrect associations;
Connected speech sometimes embellished/excessively detailed;
Problems with linguistic tasks requiring reassignment of syntactic status of elements in a single sentence.

are listed in Table 4. Finally, the SBF can encompass other emerging descriptions of the problem with competing interpretations, such as difficulty linking disparate mental models or representations (Frederiksen and Stemmer, 1993; Stemmer, Giroux, and Joanette, 1994).

The next stage in the process of connecting theory and experimentation (see Table 1) involves implementing tests of our reasoning, which necessitates constructing a research design. The first task here is to operationalize a hypothesis and/or research question, specifying a relation; and then to develop the critical research hypothesis and the *null,* or negation of the predicted outcome. For our example, an appropriate research question would be "Does suppression efficiency predict discourse comprehension performance in RHD adults?" Our research hypothesis posits that suppression efficiency will predict discourse comprehension performance for these patients, and the null hypothesis is that there is no relationship between these two variables, beyond that expected by chance.[2]

Next in the design phase, I recommend the following step that is often overlooked, at least in written research proposals and manuscripts. After posing the tentative answer in the form of the research hypothesis, the results should be identified that would refute, and be consistent with, the premise of our study. That is, evidence should be specified that permits us to retain, or requires us to modify, our theoretical deductions. Making this step explicit helps us, and our readers, in cycling back to theory from our results. For our example, evidence in support of the research hypothesis would be that suppression efficiency predicts a meaningful proportion of variance in comprehension performance, over and above that attributable to other factors (that are less interesting in the context of the model, or that are competing theoretical alternatives).

2. This discussion emphasizes the traditional, statistical sense of the null hypothesis. However, effect size, which reflects the meaningfulness of a finding, is at least as important as statistical significance in interpreting results.

Then we complete the design of the experiment. This process involves the familiar steps of transforming constructs to variables, operationalizing populations, conditions, and so forth; ensuring that design elements are appropriate for the constraints and assumptions of the theory and the questions posed. Due to space limitations, only two additional, and related, points are developed about the design phase. The first is, we want to design more than one test if possible to replicate or strengthen the conclusions we can draw from our research. One test provides only a rough evaluation of the viability of any theoretical stance, so ideally, a researcher will select several theoretical relationships and a manageable number of hypotheses to run a broader test of a theory's premises and predictions. In aphasiology this typically forms a long-range research program rather than being accomplished in one or two studies. Second, we also want to try to rule out competing interpretations for our findings. Because there are limitations to the amount of testing we can do productively with brain-damaged adults, we need to be selective in designing our multiple tests and observations.

To exemplify these last two points, there are two additions to our illustrative research question (Table 5). The first addition refers to examining suppression efficiency in RHD adults, at several linguistic levels, and in the nonlinguistic domain. In our current research, we have incorporated tests of the *suppression hypothesis* at two linguistic levels: we are examining patients' ability to suppress incorrect meanings of lexical ambiguities, drawing from Gernsbacher's methods; and we have developed a unique test, in another problem domain for RHD adults, having to do with pragmatic inference revisions. If the results of the initial studies appear promising, we plan to extend the investigation to visual scenes.

The second addition to the research question (Table 5) alludes to potential alternative interpretations that we want to rule out in our study. For example, it is possible that RHD patients' comprehension problems can be accounted for by their premorbid capabilities, together with impairments in other aspects of cognitive processing (e.g., education; estimated premorbid IQ; vocabulary knowledge; neglect severity), so we are collecting data on each of these factors. There is a potential theoretical alternative as well, related to inefficient enhancement mechanisms. Patients who have

Table 5. Adding to Our Illustrative Research Question

Does suppression efficiency [*at several linguistic levels, and in nonlinguistic domain*] predict discourse comprehension performance in RHD adults [*after controlling for X, Y, and Z*]?
Bracket #1: extend tests to multiple domains
Bracket #2: rule out alternatives

Note: Brackets and italics [___] designate additions to original question.

difficulty resolving competing interpretations may have problems recognizing and mapping what is contextually relevant onto emerging comprehension structures. We also have built a test of that account into our study, giving it equal weight with the suppression account, since accumulated data suggest that RHD patients are slow and error-prone in appreciating context.

Returning again to the process of connecting theory and experiment (see Table 1), our next step is to test the null hypothesis, which in this example is a prediction of *no significant (or meaningful) relationship* between suppression efficiency and discourse comprehension, after controlling for other factors of interest. Then, we interpret the results, and make the remaining links back to the theory that motivated the study. The ties between interpretation and theory will be the focus of the remainder of this section.

In general, the quality of inferences that we, as investigators, can draw from our data depends on the entire chain, emanating from theory: the validities of our initial deductions; operationalizations of our hypotheses; and implementation of the design, methodology, measurement and analysis. Kerlinger (1967) notes that if there are no weak links in the research chain, then upheld predictions are "cogent evidence for the adequacy of the whole structure" (p. 620). So, assuming that these links are sound, that we are able to reject the null hypothesis with statistical tests,[3] and that we have done a good job of ruling out potential alternative explanations, we can interpret the findings in line with the reasoning we generated from our theoretical context. The results will provide corroboration or validation for the hypothesis or theoretical premise that motivated the study, and will add a piece to the theoretical prediction or explanation puzzle (particularly if they can be replicated).

For our example, if the results are as expected, the study should add to our knowledge about the nature of comprehension processes and disorders following RHD in adults. The results should also help to specify and to raise more questions for my own evolving *personal theory* (Robey and Schultz, 1993) about the nature of RHD adults' discourse comprehension difficulties. But in addition, the findings may lend themselves to corroborating, extending, and/or raising new questions for the general theory of comprehension. There is a possibility to inform the SBF theory by generating findings that it should take into account. For example, the results may suggest that the theory can be extended productively to accommodate the pragmatic inferencing domain, demonstrating the theory's applicability over and above the lexical and syntactic tests that have predominated in

3. And, from the effect size perspective, that the statistically significant relationship or difference is a meaningful one.

theory development to date. More crucially, the study and the data may raise questions about the extent to which the general mechanisms of suppression and enhancement can account for comprehension, without recourse to other mechanisms, or at least more specific or local ones, in brain-damaged and elderly patients who have less than optimal peripheral or perceptual and attentional processes. We are also examining relationships among suppression ability and notions of working memory and selective attention. The findings from our studies should help to motivate specific questions about the intersections among these theoretical domains.

Of course, unexpected results are also common and potentially valuable, especially if they can be corroborated in a later test, designed with appropriate predictions and methodologic controls. Unexpected findings can signal the need to reevaluate or reconceptualize a theoretical premise, or to think about the entire problem in a different light.

So, there are several ways to cycle back to theory from interpretation: upheld predictions that give us confidence in the new predictions or explanations we were pursuing, suggesting that our theoretical premise is viable; or unexpected findings that may spur us to think differently about the theory, and modify it to make it account for the new evidence. It is important at this stage of process, if there is more than one possible account of a phenomenon, to add the new data to each account and see if it can be reconceptualized to encompass the new findings. This incorporation process contributes to systematic theory advancement (Robey and Schultz, 1993).

It is worth noting here that negative or null results can be very hard to deal with, because any flaw in the process of translating from theory to experiment can cause them. If we can argue convincingly for the adequacy of our method, measurement, and analysis, then we can be somewhat more confident that our hypotheses themselves were not borne out (Kerlinger, 1967). However, the low experimental power that inherently accompanies small sample studies, characteristic of aphasiology research, makes it unlikely that we can ever conclude much from null findings.

To close this section, it is important to note that the recommendation to test competing predictions from distinct conceptual models captures an ideal in theory evaluation. However, this is not the usual state of affairs in clinical aphasiology, or indeed in many of the applied behavioral sciences. There are numerous barriers to achieving this ideal, not the least of which is the relative immaturity and ever-evolving nature of relevant theories and empirical observations. This being said, I believe that we can begin to reduce the *conceptual myopia* (Kearns and Thompson, 1991) that pervades clinical aphasiology by working to identify and refine models that are illuminating and viable; and then eventually searching for divergence, convergence, and coalescence among them. Of course, to advance prediction and explanation we need to be vigilant

about challenging our own *personal theories* or favorite models in this developmental stage, continually examining other positions that might provide better accounts for relevant data, or that have some other factors in their favor, and trying to integrate them, in order to revise our models and guide our work.

IMPLICATIONS AND APPLICATIONS OF THEORY-DRIVEN RESEARCH

At this point, one more comment is in order about the advantages of turning to normal theory for understanding disorders, highlighting the SBF theory, and the *problems with competing interpretations* that we have considered throughout this paper. With its emphasis on processes and mechanisms involved in developing coherent mental structures, the SBF specifies possible components that could lead to the observed problems, which previously have been described rather generally, using terms such as *integration deficits*. The SBF also puts descriptors like *rigidity* into a broader explanatory context—tying them to problems with shifting processes, or suppression mechanisms. But most importantly, the theory makes numerous other predictions, which should be a fruitful source of ideas for further exploration and systematic follow-up as we seek to further our knowledge about these and related issues.

Now let us return briefly to our earlier assertions about the clinical utility of this kind of theoretically guided investigation. A number of benefits were noted in the introduction and companion paper to this group of papers (Tompkins, 1996). We expect findings obtained in the framework of normal theory-guided investigation to help us develop plausible accounts of the nature of patients' strengths and weaknesses; thus, assisting us in determining what to assess, how to treat, and so forth. A normal theory like the SBF may also provide a principled foundation for the development and application of treatment techniques, whether they are newly derived or routinely used. For example, it is currently common practice to work with RHD adults on identifying relevant and irrelevant information, and discounting or ignoring that which is less appropriate. If we find suppression deficits to be an important factor in these patients' comprehension skills, and we can identify suppression deficits in individual patients, then it should be possible as well to predict, and ultimately to *test*, who might be an appropriate candidate for this kind of treatment approach, and who might not. As a result, we should be able to target the treatment approach where it is most needed, and most likely to be effective.

CONCLUSIONS AND CAVEATS

In this paper, I have tried to illustrate how a clearly articulated position like the SBF raises a richness of questions and predictions that have the potential to unify and specify previous observations, and to direct a search for new ones. A comprehensive theoretical orientation will suggest a *program* of research that can contribute to advancing our knowledge, and that should generate testable clinical implications and applications. The appendix to this paper lists some reminders, cautions, and general suggestions for linking theory with experimentation and interpretation. Most of these points will already be familiar to the reader. In addition, many have been discussed in the text of this paper, and others have been elaborated on in another paper in this section (Davis, 1996). Consequently, they will not be explained further here. Suffice it to say, in conclusion, that we are convinced that we can advance the scholarly nature of our work in clinical aphasiology, by focusing more care and attention on any of these common weak links in the chain that encompasses theory, experimentation, and interpretation.

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APPENDIX: SOME COMMON "WEAK LINKS" IN THEORY-EXPERIMENT-INTERPRETATION CHAIN

FRONT END PROCESSES: THEORETICAL PREDICTION AND EXPLANATION:

- theoretical issues are raised for the first time in the discussion section.
- theoretical position and associated predictions are not clear and explicit, so research appears to lack a sound theoretical base, even if there is one.
- little attention is paid to theoretical perspectives or issues in the introduction, literature review, or rationale, so it is not clear what motivated the selection of specific design elements, or guided the ultimate interpretations.
- proposed theory is not testable, has difficulty accounting for some reliable observations, makes unreasonable assumptions, does not capture the dimensionality of a construct, etc.
- hypotheses are too broad or vague to delimit critical tests, or potentially falsifying statements.
- research questions are vague (e.g., "What effect does X have on Y; What if . . .); do not specify a proposed relation that can be negated and tested.
- author presents *N*th generation translation or interpretation of theory, without evaluating primary sources and original data.
- potential interest of predicted findings is not obvious.

EXPERIMENTAL IMPLEMENTATION:

- rationales for theory-experiment correspondences (operationalizations) are lacking, questionable, or unclear [refers to usual concerns of validities, appropriate analyses, etc.].
- conditions are not designed to allow contrasts between various hypotheses that would be generated by one or more candidate theories.

- design elements are not appropriate to the constraints and assumptions of the theory (e.g., using off-line, metalinguistic tasks to gather data about lexical organization, or automatic access procedures).
- tasks, measurement approaches, or other operationalizations are adopted from existing literature, without carefully considering their validity in the present application.
- measurement net is cast broadly, rather than constrained by a theory suggesting what data will be most useful for falsifying a model or position. Useful information can be obscured, and spurious relationships generated, in this kind of "fishing expedition."

INTERPRETATION:

- findings reported as a "test" of a theory when that theory's premises were not linked explicitly to questions of interest, or to study design. Theory should be used to motivate hypotheses, questions, performance expectations, designs, etc. from the outset.
- theoretical position is "accepted" after passing only one critical test (when data falsify a null prediction that is central to that position).
- findings are interpreted as "consistent" with Theory A, without indication that they could also be consistent with other positions.
- researcher generates or reasons about evidence in favor of a hypothesis, without attempting to falsify it.
- problem of negative results in terms of implications for theory: any weak link in theory-experiment-interpretation chain can account for them (e.g., experimental power, etc.). Failure to reject the null hypothesis/prediction is not proof of the null.
- description is not prediction or explanation; correlation is not causation.

GENERAL SUGGESTIONS:

1. Justify choices at each point in the chain (conceptual, methodological, interpretational).
2. Beware of making readers work too hard to infer framework, predictions, rationales for design elements, etc. Their inferences might not reflect what was intended, or they may quit trying. Explicitness will enhance comprehensibility as well as replicability.

3. These general suggestions are particularly important when writing grant applications: reviewers will not assume that we know the things that we do not specify explicitly. The grant review process tends to be much less forgiving than that for manuscript review.