

**Evaluating Changes in Systems Thinking Capacity:  
A Methodology Based on Alpha, Beta, Gamma Analysis**

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## **Introduction**

As one of its purposes, system dynamics seek to improve the performance of a defined system. One of the benefits of using system dynamics is the ability to systematically trace the antecedents of decisions and actions back to the underlying structures of the mental models of policy makers. Systems are impacted by our decisions and actions, and in turn, we are influenced, in reciprocal fashion, by the ways a system responds to these choices and behaviors. At the root of these reiterative feedback processes are mental models, sets of beliefs and assumptions that govern our actions. It has become nearly axiomatic in system dynamics that using microworlds can facilitate explicating people's mental models. System dynamics modeling processes normally depicts a system in question through the use of computer-generated models in the hopes of making the beliefs and assumptions used in decision making more explicit. In many cases, such models become the basis of microworlds that are designed to enrich the mental models of users.

A question of seeming significance to system dynamics theory is one of knowing, whether or not people's mental models are changed after individuals play a microworld for a significant period of time. Do individuals actually think differently as a result of changes to their mental models as a direct consequence of playing a microworld? Various methods have been used to ascertain transformations in mental models (Doyle, Radzicki and Tress 1998, Dunham 2003). However, the evaluation of any effects attributed to the use of microworlds is made difficult by the fact that a tangible product is not produced in the use of the microworld itself. When feedback from actual task performance effectiveness measures are absent, then efforts to evaluate the impact of microworlds often shift to judging decision-making efficacy in producing desirable microworld performance outcomes. For example, if a microworld involves operating a business, then traditional business performance metrics, such a capacity utilization, market share, and profit can serve as surrogate measures of decision-making effectiveness. However, claims that microworld-driven performance, over time, improved solely due to changes in mental models is a difficult assertion to support. Performance is most likely impacted by a number of variables, such as learning effects, application of specialized knowledge, and comfort in using microworlds. A conundrum

often results in which participants are asked to self-report changes in their own thinking processes. Using questionnaires and self-reporting has many benefits, but also serious limitations noted by Doyle (1998) and others. However the use of alpha-beta-gamma analysis can help to limit some of the methodological deficiencies of using questionnaires. “When evaluation criteria are abstract or when individuals, work group, or organizational effort does not result in a tangible product, questionnaires are often used to detect the changes transpired. The observed changes may be the result of the intervention, or they may be caused by a number of other variables (Zmud, 1978, p.662).

As an alternative to the traditional psychometric evaluation methods for measuring changes in mental models, an approach used in the area of organizational interventions, known as alpha beta gamma analysis may prove to be beneficial. This approach relies on a process of comparative self-assessments done, over time, to capture the direction of changes in mental models as they unfold relative to previous points in time. The focus of this method is to view changes in human thought and behavior incrementally as a process composed of numerous lesser events. Measuring the effectiveness of change programs is an important and difficult task. It is imperative that managers of organizations determine if the resources utilized in an intervention may yield a desired increase in organizational effectiveness and if similar results can be realized from comparable interventions throughout an organization. (Zmud 1978 :662). The purpose of this paper is to propose a methodology for using ‘Alpha, Beta, Gamma analysis’ to evaluate the effects of microworld play on the mental models of managers and aspiring managers.

Determining the presence of gamma change that is an important finding for system modelers. Gamma change involves a redefinition or re-conceptualization of some domain, a major change in the perspective or frame of reference within which phenomena are perceived and classified, in what is taken to be relevant in some slice of reality (Torborg, Howard and Maxwell 1976: 134-135). Gamma change involves a shift in dimensions of how reality is being perceived -- the redefinition of both the relevant psychological space as well as the intervals used at time T1. In sum, gamma change refers to a shift from one state to another (Golembiewski, 1986 :553). If playing microworlds has an effect on the cognitive structures managers that are thought to be

important in decision-making processes, and an analysis indicates that gamma change exists, then, we propose, that credit for the change in mental models is due to the exposure to gamma change. The impacts of measurement error etc. are analyzed by the presence of alpha or beta type change being present. It is hypothesized that gamma change can be used to measure a change in mental models. An initial experiment in using gamma change is planned.

### **Research Design**

A preliminary study using twenty-five undergraduate business majors is being done. In this study students played a series of microworlds and were asked to respond to a questionnaire in which critical variables that influenced their decisions, before and after they participated in playing the microworld, were identified. The method described by Torborg (1980) was applied to the collection of and analysis of data. He suggests the use of profile analysis as a means to determine if gamma change has occurred. Profile analysis is a method for examining differences between patterns of scores on the same set of items or scales (Torborg, Howard and Maxwell 1980: 114). The profile set consists of pre, post, and what has been termed “then” answers to a self-assessment questionnaire. The profiles set is analyzed for the mean, shape, and dispersion of the collected profile set (Nunnally 1978). Several statistical approaches are then applied to the data. Among these are:

- An inferential test for non-independent statistics, suggested by Kirk (1978)
- Group level test (2 groups) Mann-Whitney U test
- (Greater than 2 groups) Kruskal-Wallis H Test

Depending on the differences between the mean, shape, and dispersion an assessment of whether gamma change has occurred can be made. If gamma change is present, it can be shown that a change in state has occurred. It is hoped that preliminary findings will be helpful in assessing the impacts of microworlds on the user’s decision making. Further, the results may be compared to other methods under development for evaluation of the impacts of microworlds as a possible test of validation of methods.

## Measuring Cognitive Change

With regard to self-report data, *alpha change* represents a relatively unbiased measure of variation between time 1 (T<sub>1</sub>) and time 2 (T<sub>2</sub>), where the report is taken using a data collection instrument. *Beta change* refers to a variation in a measured state where those apparent changes are due to recalibration of an instrument by participants in between assessments. (Torborg et. al .1980). With the presence of beta change, a biased metric of change exists. The difference between true change and that expressed by the measure cannot be determined. It has been suggested that differences can be determined from the collection of information of **Pre** and **Post** intervention surveys. One can compare the differences between ideal criterion levels and actual levels. For example, in a system dynamics framework, it could mean measuring the differences of how the variables, and or loops are perceived as driving the dynamic behaviors of the system versus the variable and or loops that are actual drivers of the system.

It has been suggested (Howard cited in Torborg et. al), that a third measure be added to the Pre and Post testing normally preformed for evaluating the presence of alpha change. This third measure is a second response to the post inquiry process. First, respondents report how they perceive themselves at present. Immediately after answering each item, they answer the same item again, only this time in reference to how they now perceive themselves to have been just before the microworld was played. (Note1). This third item is labeled the **Then** measure. (p.112). Research (Howard and Daily 1979, Howard, Daily and Gualanick, 1979) suggests that Then/Post measurements were more similar to objective ratings of change in behavior and performance than Pre/Post self reports.

When referencing the mental models of participants playing microworlds, we are, in the Pre, asking after evaluating the problems and system at hand – “What do you believe to be the key variables that drive this system?” In the Post we are asking-after evaluating the problems and system at hand – “What do you *now* believe to be the key variables that drive this system? In the Then we are asking –after evaluating the problems and system at hand, what do you now think about your Pre analysis of the variables that was done earlier? Through Alpha Beta, Gamma analysis, participants are able to evaluate what they now know as compared to what they thought they knew. The

differences that are reported, using a Pre/Then are apparently a better measure of the shifts in pre and post assessments of a change than the use of a pre/post comparison alone.

## **Method**

The use of profile analysis has been suggested as a means to assess the presence of alpha, beta, or gamma types of change. The method allows the measurement of change at the individual and group level. Profile analysis allows the examination of the patterns of scores that are collected. One can examine the closeness of the patterns under question. Nunally, (1978) suggests that profiles can be compared based on their statistical level, distribution shape, and dispersion.

1. Level -- The mean of scores on all items in the profile. Profiles are similar if the means are not significantly different.
2. Shape -- Two profiles are similar in shape if the correlation between the two profiles is positive and statistically significant from zero.
3. Dispersion -- Two profiles are similar in dispersion, if the standard deviation of item scores in one profile is not significantly different from the standard deviation of item scores in the other profile.

The type of change that occurs in people's thinking is measured in two distinctly different ways.

1. Beta change is reflected by a difference between an individual's mean scores across all items on the Pre and Then measure.
2. Gamma change is reflected by a lack of congruence between factor structures of ratings taken before and after the intervention.

Factor structures are based on the pattern of correlations or patterns of covariances among variables. Gamma change can be identified through examination of profile shapes (correlations) and profile dispersions (standard deviations). If gamma change has occurred then the correlations between Pre and Post measures are less than the correlations between Post and Then measures. If the standard deviations of Post and

Then profiles are not different from each other but each is different from the standard deviation of the Pre profile, this is more evidence that gamma change has occurred. This process can be applied to both the individual and group and may be another means of evaluating a change in thinking. Millsap and Hartog( 1988) have suggested an alternative method that aids in the determination of whether the intervention or some other variable was responsible for the gamma change. They define two types of gamma change, differential, which is an indication of change due to an intervention effect, whereas parallel change is not (p. 582).



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