Applications of the Language for Codifying Behavioral Contingencies[1]

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Abstract

This paper presents a formal symbolic language, with its own specialized vocabulary and grammar, for codifying any behavioral contingency, including the complex multiparty contingencies encountered in law, economics, business, public affairs, sociology, education, and psychotherapy. This language specifies the "if, then" and temporal relationships between acts and their consequences for the parties involved. It provides for the notation of the probabilities, magnitudes, positive or negative valences, or time delays of the consequences for the parties, and for the parties that would perceive, misperceive, not perceive, predict, mispredict, or not predict events. The language's fractal-like hierarchical and recursive grammar provides for the flexible combination and permutation of the modifiers of the language's four nouns—acts, consequences, time intervals, and agents of acts—and its four verbs—consequate, prevent, perceive, and predict— thereby giving the language the ability to describe and codify various nuances of such complex contingencies as fraud, betting, blackmail, various types of games, theft, crime and punishment, contracts, family dynamics, racing, competition, mutual deterrence, feuding, bargaining, deception, borrowing, insurance, elections, global warming, tipping for service, vigilance, sexual overtures, decision making, and mistaken identity. Applications to the management of practical situations and techniques for doing so, as well as applications in current behavior analysis research and neuroscience, are discussed.

1. Behavioral contingencies

1.1. What are they?

Behavioral contingencies[2] are the ubiquitous "if, then" situations that influence what people do and don't do. The "if" part pertains to some behavior; the "then" part to some consequence for the involved party(ies): If

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[1] An earlier and somewhat abbreviated version of this paper, titled *Behavioral Contingency Analysis*, was published in the Elsevier journal *Behavioural Processes* (Mechner, 2008)

[2] B. F. Skinner (1969) applied the term behavioral contingency to the "if, then" conditional relationship, "If a response, then a consequence," originally to describe the basic paradigm of operant conditioning. The more traditional usage—temporal contiguity regardless of conditionality—is not the sense in which the term is used here.

you drop a glass (the behavior), it may break (the consequence), and a price label on a product in a store states that if you pay that price (the behavior), you get the product (the consequence). The price label contingency might also have effects on customer behavior, sales of that product, and competitive pricing by other stores. Further contingencies may be implicit, e.g., if you wait too long, the product may no longer be available.

Behavioral contingencies exist independently of any behavior or dynamics that may occur as a result of their existence. The dropped glass would break if dropped even if it was never dropped and never broke, and the price label contingency is in effect even if no one ever sees the price label or buys anything. In general, however, a behavioral contingency is of practical interest because of its possible behavioral effects.

1.2. Behavioral contingencies in human affairs

Behavioral contingencies, often rather complex ones, are a common element of all the behavioral sciences and are at the root of the behavioral phenomena that are of concern in such diverse realms as law, business, education, economics, management, public affairs, therapy, the social sciences, child management and everyday interactions between people.

Prominent examples:
- Laws consist, in general, of "if, then" statements of the form, "If a person does or doesn't perform certain acts, certain consequences for that person shall follow." Laws are, in essence, behavioral contingency statements intended to regulate, modify, or influence behavior in a society.
- Education systems involve the behavioral contingencies that govern the interactions of students, teachers, parents, administrators, unions, textbook publishers, and members of the community.
- When business managers seek to improve operations by means of incentive compensation systems, work flow systems, and safety practices, they operate on the behavioral contingencies involved.
- The rules of games, ranging from tic-tac-toe to baseball, bridge, poker, or chess, are behavioral contingencies that determine how the games are played.
- Many everyday interactions between people involve behavioral contingency statements of the general type "If you do A, I will do B," including promises, requests, enticements, and threats, sometimes with reference to other parties, time periods, probabilities, or other qualifications.

Unlike the other major determiners of behavior—the personal histories of the involved parties and the immutable realities of physics and biology—behavioral contingencies can be modified and designed.

1.3. The roles of signals and experience

The effects of a prevailing behavioral contingency depend on the individual's history or previous experience with that contingency or with related ones. *Example*: The effect of a price tag depends on ability to read and on prior exposure to the product and to price tags. For verbal individuals, a contingency can be communicated by verbal descriptions, including "rules." For nonverbal individuals, a contingency can be communicated by other kinds of signals[3] and the information conveyed about a contingency can be accurate or inaccurate, complete or incomplete, well understood or only partially understood, again depending on history. Such history variables must therefore be considered part of the setting and therefore part of the behavioral contingency.

1.4. The value of a formal behavioral contingency language

The present paper presents a formal language, with its own specialized vocabulary, grammar, and syntax, for the systematic codification and analysis of any behavioral contingency. The practical application of this language falls into the province of behavioral technology,[4] but given the central place of behavioral contingencies in behavioral science and its applications, behavioral contingencies are also worthy of study in their own right.[5]

It is true that formal codifications of behavioral contingencies can often also be expressed, sometimes with less effort, by means of natural language, as can the codifications of other formal symbolic languages like those of mathematics or symbolic logic. But in the case of complex behavioral contingencies, formal codification, with the attendant identification of key variables and features, is often a necessary precondition for their systematic study and analysis, whether by means of experiments with living subjects, computer simulation, operations research, or other methods.

Formal symbolic languages, including the present one, also provide the advantage of cutting across all natural languages (universality), with

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[3] The technical term for "signal" is "discriminative stimulus." The term "stimulus" is avoided here because of its connotation of stimulus-response and reflex phenomena.

[4] The application of behavioral contingencies is key in such applied areas as educational technology, behavior management, clinical interventions, and business applications. Sidman (2004) pointed out that the application of behavior analysis to human affairs has still fallen far short of the potential.

[5] The distinction between independent and dependent contingencies proposed in Weingarten and Mechner (1966), and hierarchical contingency structures, may be examples of types of issues that a science of contingencies might address.

codifications that are succinct and avoid ambiguity. They can reveal relationships among elements that would not be revealed as clearly by natural language descriptions, and in science they can aid in the development of classification systems and theories.

While the antecedent of the present language (Mechner, 1959) was developed as a tool for the specification of independent variables and experimental procedures (Mechner and Latranyi, 1963; Mechner et al., 1963), and has found pedagogic uses like those cited in section *1.5*, the present expanded language is designed for the codification of any behavioral contingency, including complex multiparty contingencies. The language is also well suited for the specification of the contingencies that are studied in behavioral economics (Camerer and Lowenstein, 2003; Becker, 1976, 1995, 1997), including some (described in section 5) that have become the subject of current behavior analysis research. See also section *4.13*.

Clearly, this type of contingency language cannot generate new knowledge about behavior or make empirical assertions of any kind. Behavioral contingencies do not describe or predict what behavior will actually occur—they only specify consequences for the parties involved *if* some specified behavior occurs. From the standpoint of experimental science, behavioral contingencies have the status of independent variables, and if used as such in experiments, their empirically observed behavioral effects would have the status of dependent variables (See section 5.0).

1.5. Related work

While this paper may be the first effort to develop a general language for codifying any behavioral contingency, special-purpose notation systems for behavioral contingencies have been proposed in the past.[6] The original language and notation system for codifying behavioral contingencies (Mechner, 1959) dealt with examples drawn mainly from the experimental psychology literature on schedules of reinforcement, escape and avoidance behavior, discrimination learning, and maze learning. Weingarten and Mechner (1966) took an initial step in extending the language to contingencies involving multiple parties.

B.F. Skinner proposed a notation for describing certain specific

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[6] Some behavioral notation systems or paradigms (e.g., Chisholm and Cook, 1995; Findley, 1962; Goldwater and Acker, 1995; Keller and Schoenfeld, 1950; Malott et al., 1993; Mattaini, 1995; Sidman, 2000) have been used to codify behavior analysis principles for instructional purposes and for describing behavioral phenomena that actually occur, as opposed to behavioral contingencies as defined here. These behavioral notation systems have no direct relevance to the theme of the present paper.

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schedules of reinforcement graphically (Skinner, 1958). Arthur G. Snapper adapted "state notation" (Snapper et al., 1982; Stephens and van Haaren, 1977; Tanaka and Nomura, 1993) for the computer control of certain types of behavioral experiments. In a detailed comparison of the Mechner (1959) notation system and state notation, Jack Michael reported his use of the Mechner language in the undergraduate and graduate courses he taught at Arizona State University (Michael and Shafer, 1995). Michael also used the Mechner (1959) language for his laboratory manual (Michael, 1963), and it was used in the textbook *Behavior Analysis and Learning* (Pierce and Epling, 1995). A stripped-down version of it was used in a laboratory instruction manual (Millenson and Leslie, 1979).

2. The language's vocabulary, grammar, and syntax

2.1. *The elements of the language*

This paper attempts to show how the proposed language's sparse vocabulary and simple grammar can describe a wide range of complex behavioral contingencies in diverse domains.

The units of any formal symbolic language reflect the conceptualizations of its field: the basic units of chemical notation are atoms; those of musical notation are notes; and those of the present language are acts A,[7] time intervals T, consequences C,[8] and the involved parties (designated here by arbitrarily chosen lower case letters).

These are the language's six basic elements:

1. $A \rightarrow$, read as, "If act A occurs then …" Thus every A is understood to be preceded by an implied "If."

2.   <u>Agent of the A</u>: The agent(s) of an act A are designated by arbitrarily chosen letters placed in front of the A (e.g., aA, bcA).[9]

3. $T \rightarrow$, read as "upon termination of time T …" The time period T is part of the situation, as opposed to a property of the behavior.

4.   <u>A consequence C</u> is any situation or event resulting from an $A \rightarrow$ or a

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[7] The term "act" is used here, rather than "response," which has the undesired connotation of a stimulus-response reflex, and usually of a brief response by a single individual. However, A can be replaced by R for response or B for behavior, depending on perspective and area of application, without affecting the grammar.

[8] The term "consequence" is used in favor of the traditional term "stimulus," again to avoid the "stimulus-response" connotation. But S can be used for "stimulus" or "situation," again depending on perspective and type of application, without affecting the grammar.

[9] The term "agent" or "party" refers to an individual, group, team, company, populace, or country that would perform the designated act.

$T\rightarrow$, and refers to all relevant aspects of the prevailing environment.

5.   *Prevention of a consequence*: A consequence is prevented when a horizontal arrow leading to it is cut by a vertical arrow originating from another *A* or *T*, like this: $\overset{\uparrow}{\longrightarrow}$

6.   *Simultaneity of onset*: A bracket enclosing vertically listed *A*s, *T*s, or *C*s indicates simultaneity of onset of the listed conditions. For instance, $\begin{bmatrix} A\rightarrow \\ C \end{bmatrix}$ would be read as "When *C* is present then if *A*, then …" The order in which the conditions are listed has no significance.

Only *A*s or *T*s can consequate[10] *C*s or further *A*→ or *T*→ contingencies. Thus, arrows can never emanate from a *C*, only from an *A* or a *T*.

2.2 Architecture of the grammar: The four quadrants

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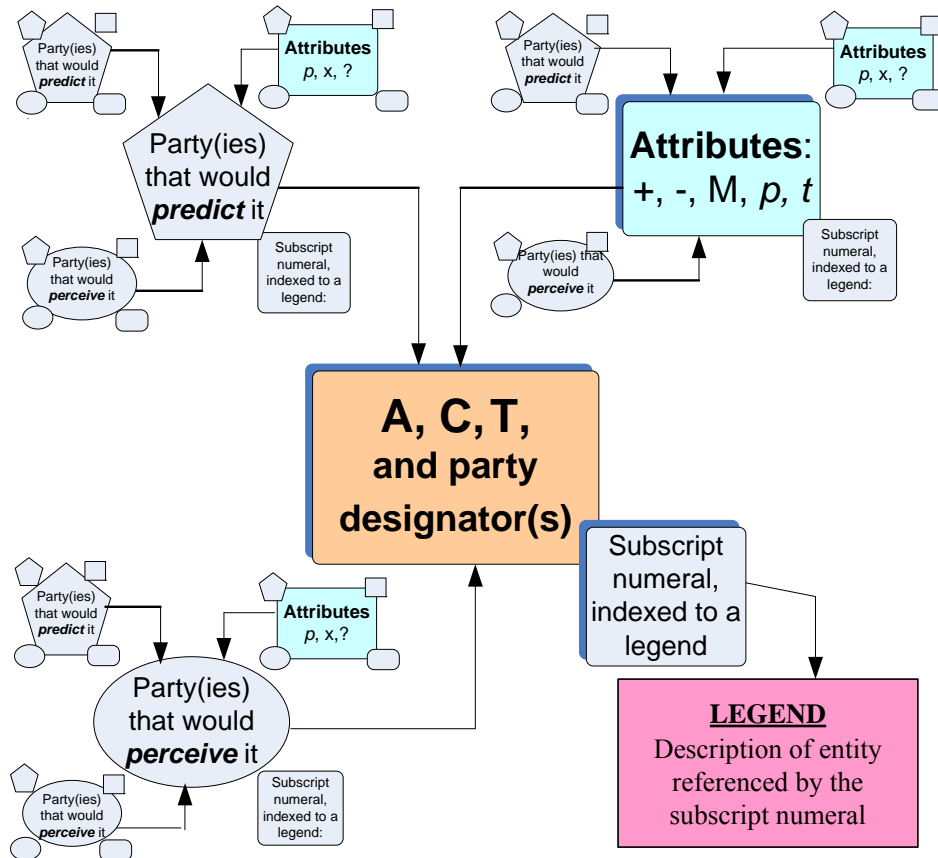
[10] The verb *consequate* has been used in behavior analysis and is useful in the present context. The alternative verbs "produce," "generate," "result in," or "cause" tend to carry undesired epistemological baggage.

Figure 1. Diagrammatic representation of the hierarchical/recursive quadrant-based grammar of the behavioral contingency language. The center box containing the language's four nouns has four quadrants, shown as shapes that represent modifier entities (e.g., perceive, predict, attributes, index numbers to the legend), each of which in turn has its own analogous quadrants.

Every element of the language can have up to four modifier categories, as shown in the four quadrants of each symbol in Figure 1 above. Each quadrant is allocated to one of the four modifier categories in a consistent way. The modifiers can, in turn, have the same modifiers in the corresponding quadrants, in a theoretically infinite hierarchical and recursive regress, fractal mode.[11]

The subscript (lower right quadrant, e.g., the numeral 5 in aA_5) is an arbitrary numeral indexed to a legend where the referenced entity is described (see section *2.3*).

The superscript (upper right quadrant) is allocated to the entity's attributes, which can be viewed as the language's adjectives and adverbs—probability, magnitude, valence,[12] duration, or variability, as explained in more detail in section *2.4* below.

The pre-subscript (lower left quadrant) of an entity indicates the party(ies) that would *perceive*[13] the entity (see sections *2.5-2.8*).

The pre-superscript (upper left quadrant) indicates the party(ies) that would *predict*[14] the entity (see section *2.9*).

One of the theses of this paper is that the verbs *perceive* and *predict* are a unique (necessary and sufficient) and parsimonious key to the generality of the language's applicability.

2.3. Subscript: Indexing to a legend

Arbitrary subscripts (usually numerals) can index the diagram's symbols to descriptions in a legend. They can also provide differentiation

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[11] These are also characteristics of such formal languages as symbolic logic and mathematics, as well as of most natural languages.

[12] A *C*'s valence indicates whether the *C* is rewarding or punishing, desirable or undesirable, beneficial or harmful, positively or negatively reinforcing.

[13] The verb "perceive" is understood to encompass all of the learned or genetically encoded discriminative responses to the stimuli or situation comprised by the perceived entity.

[14] The verb "predict," as used here, refers only to the behavioral effects of the party's prior contact and experience with the contingency involved, or with the signals (verbal or non-verbal discriminative stimuli) that were previously associated with the contingency. No other connotations are implied.

between different As, Cs, or other entities. For example, to indicate that the duration of C_1 is T, a new consequence C_2 is shown replacing C_1: $\begin{bmatrix} \mathsf{T}{\to}\mathsf{C_2} \\ \mathsf{C_1} \end{bmatrix}$

When descriptions consist of one or two words, those words can be shown in the subscript positions within the diagram, and lengthier descriptions can be provided in the legend. In a_7A_5, the legend might describe the nature of party a as a particular individual, team, population, or government under the arbitrary numeral 7, and the nature of act A under the numeral 5. Without subscripts and legends, every diagram would represent the infinite number of contingencies that have the same structure. Specificity is achieved only by the use of descriptive subscripts.

2.4. Attributes of entities

Valence: The notation C^{a+} or C^{a-} means that C has a positive or negative valence for party a. $C^{a+,\,b-}$ means that the valence is positive for a and negative for b, and C^{ab-} means that the negative valence applies to both. $C^{a(+/-)}$ means that the valence for a can be either positive or negative.

Magnitude M: The magnitude attribute for act A, as in A^M, can refer to such intensive dimensions as effort, force, loudness, duration, or an amount of money. When M refers to the act's duration, a lower case t replaces the M. The duration t of an act is measured from its beginning to its termination. In $A_{start}{\to}A^t_{end}$, A^t is read as "end of act A's duration." The term A_{start} can be omitted, since every act that ends must also have started.

The duration attribute is particularly significant when an act is repetitive and can continue or end at any time. Examples of such acts, often called activities, are walking, running, waiting, foraging, working, or practicing a skill. In behavior research, a latency or inter-response time would be codified as an act whose terminating event is A^t.

The magnitude of a C would usually refer to the magnitude of its positive or negative valence, but can also refer to any scalable dimension like value or amount of money, or to some qualitative dimension.

For time periods, T^M refers to the duration of T.

A magnitude of a consequence or of a valence that changes as a function of some variable x can be represented by $M = f(x_i)$ shown in the attribute position of the consequence.

Probability: A lower case p, or an actual value of a probability shown in an entity's upper right quadrant, indicates the probability, in the analyst's view, that the entity would occur.

Variability: T^v or M^v indicate that the modified entity is variable.

Negation: The tilde sign $\sim$, representing the negation attribute "not," is

placed above the entity's symbol.[15]

2.4.1. Adaptability of the language

Although the attributes described above are fully sufficient for codifying the wide and diverse range of situations analyzed in this paper, additional attributes may be required to meet challenges presented by specialized applications in other fields like law, business, economics, sociology, public affairs, or psychotherapy.

In some applications, the analyst may wish to indicate not only the one-dimensional "positive/negative" valence attribute of consequences, or their probability, but also their emotional components for the parties involved. This component could be represented by a capital E in the C's attribute

quadrant, like this: $C^{a(-,\,E_1)}, C^{a(E_1),\,b(E_2)}$

The E would always have a subscript indexing it to a description in a legend. The contingency language is neutral as to how the emotion is characterized or as to the type of language used to do so, except for the grammatical constraint that it must be an adjective modifying the consequence, like "frightening," "embarrassing," "disappointing," "arousing," "alarming," "infuriating," "reassuring," "flummoxing," etc. (rather than nouns like fear, embarrassment, disappointment, anger, jealousy, etc.). Also, by defining E as an adjectival attribute of the consequence C, an E can be shown as pertaining to some parties and not to others, or different parties having different Es, as can the valence attribute or any other attribute of a C. The agent of the act that consequated the C is not necessarily the same party or the only party affected by the C.

If desired, the adjective describing E can be shown as a word in the C's attribute quadrant, instead of being defined only in the legend, provided that doing so does not interfere with the clarity of the structural relationships to be represented by the diagram.

There may also be applications in which the analyst may wish to indicate not only an act's consequence, but possibly also the act's quantitative attributes t and M, and also a qualitative attribute, like "angry," "excited," "fearful," "vigorous," "lethargic." Qualitative characterizations of acts would ordinarily be provided in the legend (indexed to subscripts of the

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[15] It is more convenient to place it above the entity than in its upper right quadrant, which is where it would be according to the placement rule for attributes. In symbolic logic it is usually placed in front of the character, but here this placement would have the drawback of the multiplicity of meanings (including "approximately") that such a placement has in various other contexts.

A) but they could, alternatively, also be indicated in the *A*'s attribute quadrant with the letter *Q* (for "qualitative"), again with a subscript of the *Q* indexed to the legend where the *Q* could be described.

The above examples illustrate how adjectives and concepts from non-behavioral realms of discourse can be seamlessly incorporated into the contingency language. These capabilities of the language are presented here not because they are important or exciting, but because they illustrate the language's adaptability to diverse areas of application.

2.4.2. Extensions of the language to other fields

It may also be possible to extend the language to non-behavioral areas, such as the description of the environmental contingencies that result in speciation and evolution—the adaptation of species to contingencies imposed by the environment (e.g., Skinner, 1966). In such a contingency analysis, the consequences would then be a species' newly evolved characteristics like camouflage or immunity, and the valences might pertain to competitive advantages or disadvantages related to reproduction and survival. The contingency analysis language may similarly be applicable to the contingencies involved in the evolution of cultural practices (Glenn and Madden, 1995; Glenn, 2003 and 2004; Donahoe, 2003), and perhaps to any system involving consequation with feedback.

2.5. The notation of perception

In $A\rightarrow_{ab}C$, the lower left quadrant of *C* indicates that both parties *a* and *b* would[16] perceive the consequence *C* of act *A*. To show that party *a* would *not* perceive *C* but that *b* would, the notation is $A\rightarrow_{\tilde{a}b}C$, with the *a* having a tilde sign above it meaning "not *a*".

$aA\rightarrow_{\tilde{a}b}T\rightarrow_{ab}C$ is read as, "If party *a* does *A*, then *C* occurs after time lag *T*. The *C* would be perceived by both *a* and *b*, and the time lag would be perceived by *b* but not by *a*." The *T* would be shown without any pre-subscripts if the analyst considers perception of the time lag not relevant to his focus.

The contingency $aA_1\rightarrow bA_2\rightarrow$ is read as "If $aA_1\rightarrow$ then if $bA_2\rightarrow$ then…" In the case where the desired meaning is "If $aA_1\rightarrow$ then bA_2 would

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[16] The term "would" or "will" is used throughout, to maintain consistency with the conditional "if, then" logic of contingency statements, e.g., "If act *A*, then party(ies) *a, b, c would* or *will* perceive or predict a designated entity." A statement of the form that *a, b,* or *c* actually *do* perceive or predict an entity, without the qualification of conditionality, would be inconsistent with the definition of a behavioral contingency statement.

occur," the bA_2 term would have the status of a consequence C.

2.6. The notation of misperception

$_aC$ implies that party a's perception of C would be "correct" in the sense that it corresponds to the analyst's belief, that being the sense in which the terms "correct" or "actual" will be used throughout. If the analyst wishes to show that the perception would be a "misperception" or idiosyncratic,[17] the misperceiving party's designator, still shown in the lower left quadrant, would have the letter x in its own upper right (attribute) quadrant. For example, $_{a^xb}C$ means that a would misperceive C and that b would perceive it correctly. To elaborate on the misperception, the analyst could explain under, say, the legend's numeral 5, $_{a^x_5b}C$ that a would, for example, misperceive a neutral comment as hostile. The term "misperceives" is used broadly here for any perception that is idiosyncratic or "subjective," in the sense that it deviates from the analyst's belief.

When time is an attribute of an act (i.e., its duration) rather than a feature of the situation, the party's perception, misperception, or non-perception of the act's duration would be shown as the pre-subscript of the t, like this: aA^{a^xt} or $aA^{\tilde{a}t}$. The latter diagram could mean "a not keeping track of how long its act A was taking."

2.7. Perception, misperception, and non-perception of valences

If a party would perceive (or misperceive or not perceive) a consequence C, would that party then also perceive (or misperceive or not perceive) that same C's valence? The answer is that it would, based on the distributivity rule which states that any perception, non-perception, or misperception of the C applies also to that C's valence and any of its other attributes. *Example*: $aA \rightarrow_{ab}C^{b-,a+}$ could mean that a would harm b and benefit himself, with both a and b perceiving this consequence *and* its valences. If either a or b would *not* perceive either or both of these valences, that party's designator would be shown with a tilde over it, in the lower left quadrant of the non-perceived valence term, to override the distributivity rule. For example, to show that a would *not* perceive the C's valence $b-$ in spite of perceiving the C itself, the $b-$ valence symbol would need the pre-

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[17] In behavior analysis terminology, misperception or idiosyncratic perception means responding to a stimulus (here termed consequence) as if it were a different stimulus.

subscript $\tilde{a}$: $_{ab}C^{\tilde{a}b\text{-},a+}$. $_{\tilde{a}b}C^{b\text{-}}$ would mean that a would perceive *neither* C nor its valence, but b would.

To show that a party would misperceive a C's valence but not the C itself, that party's designator, with the letter x in its upper right quadrant, is shown in the valence's lower left quadrant. Familiar examples are Adam and Eve, or Snow White, who might have perceived the apple correctly but misperceived its valence.

The valence shown is the one the analyst considers the real one. The precise nature of the misperception he has in mind can be described in a legend.

Here are some combinations (remember that the C's pre-subscript applies not only to the C but also to its attributes):

$_aC^{a\text{-}}$ a perceives both the C and its negative valence for itself.

$_aC^{a^x a\text{-}}$ a perceives the C and misperceives its negative valence.

$_{a^x}C^{a\text{-}}$ a misperceives both the C and its negative valence.

$_aC^{\tilde{a}a\text{-}}$ a perceives the C but not its negative valence.

$_{\tilde{a}}C^{a\text{-}}$ a does not perceive either the C or its negative valence.

2.8. Misperception of a party: Who done it?

$_b a A$ means that b perceives that a is the agent. $_{b^x} a A$ means that b misperceives the fact that a is the agent. This distinction could come up in false accusations or in criminal law where there can be divergent assertions regarding the agent of an act. Again, the nature of the misperception could be described in a legend. Analogously, the notation $_{a^x}T$ means that a would misperceive T, and the notation $_{\tilde{a}}T$ means that a would not perceive T at all.

2.9. Prediction

The term "predict," as used here, encompasses all of the behavioral effects of the party's prior experience with similar contingencies, or with signals (called verbal or non-verbal discriminative stimuli by behavior analysts) that were previously associated with similar contingencies. Signals consisting of verbal statements of contingencies are sometimes called rules. A signal that might occasion a party's prediction of a consequence has the status of a C.

When indicating that a party would predict a consequence, the analyst therefore reflects his beliefs regarding the effects of the party's relevant history. The specifics of such a history may or may not be known to the analyst. The history is necessarily a part of the contingency, whether or not that history is described, and whether it is known or unknown.

It should be noted that the use of the term predict has no connotation of "predicting the future" or of a teleological meaning. Nor does is it a stand-in for such terms as "anticipation" or "expectation." It refers only to the party's behavior "predict," at the time the contingency is in effect—behavior based only on the party's relevant history.

2.10. The notation of "predict"

The party(ies) that would predict a C are designated in the C's upper left quadrant, like this: ^aC. $aA \rightarrow {}^a_aC$ means that a would perceive C when it occurs and would also predict it. $aA \rightarrow {}^a_{\tilde{a}}C$ means that a would predict C but would *not perceive* it (note the $\tilde{a}$ in C's lower left quadrant). *Examples*: committing suicide, *predicting* the consequence of sending a letter without *perceiving* that consequence when the letter reaches its destination, *predicting* the consequences of issuing an order without *perceiving* the order being carried out, dropping a bomb on a target. The reverse, $aA \rightarrow {}^{\tilde{a}}_aC$, means that a would perceive C when it occurs but would not predict it. Here one might say that C would surprise a.

Depending on the desired emphasis and focus, the analyst may or may not indicate the party(ies) that do or don't perceive or predict a particular consequence.

2.11. Perceiving or predicting another party's perception or prediction

$aA \rightarrow {}^bC^{a-}$ means that party b would predict that a would hurt himself. The notation $^{a^x}C^{a-}$ means that a would mispredict it. To show that b would also *perceive* that a was mispredicting C^{a-}, the b would be shown in the lower left quadrant of the a^x, like this $^{b}a^xC^{a-}$. The diagram $^{ba^x, b}C^{a-}$ would show that b would, in addition, predict correctly that a's act would be hurtful to a.

When the verb *predicts* is applied to a probability, the meaning is similar to that of the verb "estimates." The expression $^ap_1$, for instance, would be read as "party a's prediction/estimation of p_1."

2.12. Nuances of meaning involving probabilities and predictions

This diagram could mean that if a asks (aA_1) b for a favor, then if b complies (bA_2) with the request $_bC_4$, the consequence would be C_3. The analyst can express the following nuances regarding bA_2:

$$aA_1 \rightarrow \begin{bmatrix} bA_2 \rightarrow C_3 \\ _bC_4 \end{bmatrix}$$

$(bA_2)^p$ - The probability of bA_2 occurring (complying) is less than one.
b^pA_2 - p is the probability that b (rather than another party) would do A_2.
$^a(bA_2)$ - a would predict bA_2. Replacing the a with a^p would mean that the analyst considers the probability to be p that a would predict bA_2.

2.13. Why the terms "aware," "intend," and "expect" are not used

The term "aware," when applied to a contingency, is imprecise in that it could apply equally to the act only, to the consequence only, or to the party's prediction of the consequence only, and when applied to the act or to the consequence it does not distinguish between its perception and prediction. The terms *perceive* and *predict*, on the other hand, are precise in that they can be applied with pinpoint precision to acts, consequences, and attributes, and unlike the term "aware," they can be modified by a probability or as a *misperception* or *misprediction.*

The terms "intend" or "expect"[18] are also imprecise in that they do not tell us if an intent or expectation is still present if the consequence is modified by a probability or delayed by a time interval. The contingency language avoids such ambiguity. It is able to express these concepts fully, along with their many possible nuances of meaning, by specifying that the act's agent *predicts*, *mispredicts*, or *does not predict* the act's consequence, with further nuances provided by recursively assigned modifiers.

2.14. Vertical arrows that terminate and change contingencies

A vertical arrow (initiated by an A or a T) cutting a horizontal arrow,

$$\begin{bmatrix} aA \xrightarrow{\quad\uparrow\quad} C \\ T \end{bmatrix}$$
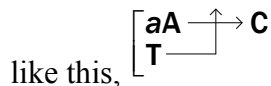
like this, terminates the contingency represented by that horizontal arrow. This diagram could describe the contingency involved in catching a plane or train or in meeting a deadline.

To show that a vertical arrow not only prevents a consequence but also

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[18] For other discussions of related terminological issues, see Chisholm (1957), Baum and Heath (1992), Hineline (2003) and Foxall (2007).

creates a new one, the vertical arrow is shown pointing to the new consequence C_2, as in the diagram on the right. Note that at the intersection of the arrows, only the contingency represented by the horizontal arrow is terminated or changed. The horizontal arrow does not cut or affect the contingency represented by the vertical arrow.

$$\begin{bmatrix} C_1 & {}_{\tilde{a}b}^{b}C_2^{b+,\,a-} \\ aA_3 \longrightarrow {}_{ab}C_5^{a+} \\ bA_4 \end{bmatrix}$$
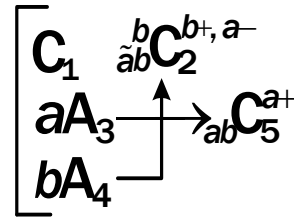
2.15. Recycling contingencies

To show that a contingency remains in effect and can repeat, a recycling arrow is used. For example, when a CD has been played, it can be played again. To indicate that an act can recycle n times, the n is written above the recycling arrow: $\overset{n}{\underset{\rightarrow}{\boxed{}}}\mathbf{A} \rightarrow \mathbf{C}$

3. Other features of the contingency language

3.1. Distributivity relations among the quadrants

The default rule is that an entity's subscript (the numeral that indexes a legend item) is distributive across all of the entity's modifiers, but the analyst may sometimes want to use separate subscripts for individual modifiers.

The verbs *perceive* and *predict* also extend to the modified entity's attributes (shown in the upper right quadrant)—i.e., any entity that is perceived or predicted includes all of that entity's attributes, these being similarly perceived or predicted. For example, ${}_{b}a^{p}\mathbf{C}^{a+}$ means that b would perceive that p is the probability that a would perceive C and C's valence.

All other relations are non-distributive. For example, in ${}_{a}^{b}\mathbf{C}$ a would *not* also perceive the fact that b would predict C, that is, the perception by a would not be distributive to the upper left quadrant, and vice-versa. To show that a would also perceive that b would predict C, the a would have to be shown again in the b's lower left quadrant.

3.2. The grammar of consequences

A general default feature is that only one consequence C is present at one time, because every C is presumed to include all of the relevant features

of the prevailing situation. Thus, any change of C is a new, again all-inclusive, C produced by a further A or T.

Suppose, for instance, that A_1 consequates C_{tone}, and C_2 is a light coming on subsequently. C_2 then replaces C_{tone} (tone alone), and may then consist either of both the light and the tone together or of the light alone. The

$$A_1 \rightarrow \begin{bmatrix} T \rightarrow C_2 \\ C_{tone} \end{bmatrix}$$

legend would state which, if the analyst considers the distinction relevant. In either case, C_{tone} (tone alone), having been replaced by C_2, is no longer present.

3.3. When all consequences are represented by one C

The analyst would always narrow his analysis to those consequences that are relevant to his focus and would represent these with a single C, notwithstanding the fact that all real-life acts have multiple and innumerable consequences, in the sense of the proverbial wing flap of the butterfly in China ultimately affecting the weather on the other side of the earth. A party performing an act would never perceive or predict all of the act's consequences. *A mundane example*: If I open the refrigerator and pour myself some juice, I might predict that I would be drinking juice in a few seconds and then perceive it. I would probably not perceive or predict all of the physical, chemical, and thermal consequences of opening the refrigerator or of the juice on my stomach chemistry. *A weightier example*: If a company's directors close down a factory, they would predict and/or perceive certain of the consequences and their time lags, but not some others.

3.4. Diverse consequences: When more than one consequence is shown

On the other hand, when the modifiers of the consequences are heterogeneous and yet relevant to the analyst's focus, a single C cannot always represent all of them. The analyst would then represent them with more than one C. *Examples*: (1) Party a introduces parties b and c to each other. The result would be two consequences—$_bC_2$ (b's perception of the situation that includes party c), and $_cC_3$ (c's perception of the situation that includes party b): $aA_1 \rightarrow \begin{bmatrix} _bC_2 \\ _cC_3 \end{bmatrix}$ Also, C_2 and C_3 may have different valences for the three parties a, b, and c, which may also have different predictions or perceptions of those valences; (2) A business executive a assigns a task to b and c. When b and c divide the work and each takes a different part of the job, the consequence for each of them would necessarily be different.

In some cases, the analyst may want to distinguish between diverse consequences of a single act. *Example*: shooting at a target and hitting it. In this case, A_1 is pulling the trigger, C_1 is the gun firing, and C_2 is the bullet's point of impact. A party could perceive and/or predict either of these consequences and not the other.

There are also cases where the analyst may want to assign different *probabilities* to the performance of the act and to its consequence occurring (e.g., to the act of shooting at a target and to the *probability* of hitting it).

$$aA_1^{p_3} \rightarrow {}_bC_2^{p_4}$$
$$bA_3 \rightarrow C_4$$

In the real world, the flow of acts and their consequences is continuous and seamless. In codifying a situation, exactly where in that flow the analyst chooses to draw the demarcation line between an act and its consequence depends on the desired focus. When the consequence of aA_1 serves as the cue for party b's act, this cue can be just the sight or some other consequence of a performing the act.

3.5. Consequation by external agencies

A situation C may be consequated by an external agency e as well as by one of the parties involved in the contingency proper. *Examples of externally consequated C*s: the hand that a bridge player is dealt, a test item presented to a test taker, or any situation presented by the physical environment. In these cases, the external agency would be the card dealer, the presenter of the test item, or the physical environment. Acts by such external agencies eA would be shown only if the analyst considers this aspect of the contingency relevant to his intended focus.

The diagram at the right shows that a would perceive that he has an e-mail, $_aC_3$, sent by an unknown external agency eA_1. If a opens the e-mail (aA_2), a will predict and perceive that it will be displayed on the screen (C_4), including an attachment. The a

$$eA_1 \rightarrow \begin{bmatrix} aA_2 \rightarrow {}_a^aC_4 \\ {}_aC_3 \quad aA_5 \rightarrow {}^{\tilde{a}}C_6^{a-} \end{bmatrix}$$

shown in C_4's upper left quadrant means that a would predict that opening the e-mail would consequate the screen image $_aC_4$. This a pertains only to C_4 and has no bearing on the $aA_5 \rightarrow C_6^{a-}$ contingency, namely on whether a would also perceive or predict that if aA_5, (clicking on the attachment), the computer would be infected with a virus C_6^{a-}. The $\tilde{a}$ designator in the upper left quadrant of $^{\tilde{a}}C_6^{a-}$ indicates that a would not predict that opening the attachment would incur a virus. To show that a *would* predict it, the a would need to be shown in the upper left quadrant without the tilde, like this, $^aC_6^{a-}$.

3.6. The notation of uncertainty

Uncertainty is indicated by a question mark after the entity to which the uncertainty applies. The specific nature of the uncertainty, or the reason for it, can be elaborated in the legend. The numeral indexing the legend can be shown in the question mark's lower right quadrant: $b?_5$.

$^{a?}C$ means that the analyst is uncertain that a would predict C. $_{(a?)b}C$ means that the analyst is uncertain as to whether a would perceive the C. When a party, rather than the analyst, is uncertain, the party's designator is shown in the question mark's attribute quadrant: $_{(a?^a)b}C$. (The logic underlying this rule is that the uncertain party is like an attribute of the uncertainty.) To show that the analyst is uncertain regarding the *correctness* of a perception or prediction, the question mark is shown in the party's attribute quadrant: $^{a?}C$. To show that it is a who is uncertain about the correctness of a's own prediction, an additional a is shown in the question marks's attribute quadrant: $^{a?^a}C$. To indicate that the analyst is uncertain as to the valence for b but not for a, the notation is $C^{a+,\, b\,(+/-)\,?}$

3.7. Uncertainty and probability

When to use the question mark and when to use the probability notation: A question mark indicates the lack of some existing information where the uncertainty would be eliminated if that information were available. An indication of a probability, on the other hand, suggests that the event depends on an external process like the tumbling of dice, the order of the cards in the deck, or the results of decision processes of others. In such cases, a second branch of the consequating arrow can show the consequence for the *1-p* complement of the probability (see section 4.12), if doing so is relevant to the focus. A probability can have as a modifier a party's prediction/estimation (shown as the p's pre-superscript), but an uncertainty cannot.

Notations of uncertainty or probability are used only when they are relevant to the analyst's focus. Although all consequences would necessarily be probabilistic to some degree, relatively small uncertainties are usually unimportant in relation to the focus, and the analyst may therefore not indicate them.

3.8. *Simplifying assumptions and abbreviations*

Formal symbolic statements are inherently stripped down to presumed essentials through the use of simplifying assumptions intended to eliminate features that might mask the intended focus. With that intent, the analyst simplifies the contingencies being represented by selecting some features and omitting others. The result bears the same type of relationship to real-life contingencies that a drawing of an object bears to the real object.

A common simplifying assumption is the omission of the *T*s representing the time lags between all acts and their consequences. When the time lag is relevant, the contingency might be shown as $A \rightarrow T \rightarrow C$.

Abbreviations provide another way to simplify diagrams. For example, the symbol C^{a+} is an abbreviation. If the analyst considers the specific reasons for the valence being positive for *a* important, he can elaborate them in the diagram proper or in a separate diagram indexed to the point of insertion. *Examples of reasons*: Upon the occurrence of *C*, *a* might be able to avert an impending negative consequence or procure a positive consequence by certain further acts.

3.9. *"And" relationships: Cooperation, contracts, agreements*

When a consequence depends on the occurrence of all of two or more events, the symbolic logic symbol $\cap$ for the intersection of sets (the "and" relationship) is used.[19] *Example*: Mother says to child, "I will read you a story (C^+) in five minutes (T_3) if you have brushed your teeth (A_1) and gotten into bed (A_2) in those five minutes:" $(A_1 \cap A_2 \cap T_3) \rightarrow C^+$. The $\cap$s mean that all three conditions must be met.

The $\cap$ symbol is also used in codifying cooperation, as when *a* and *b* perform separate acts aA_1 and bA_2 when they cooperate. *Example*: If *a* and *b* make an agreement ($aA_1 \cap bA_2$) by exchanging promises, undertakings, signatures, or money, and agree to perform further acts ($aA_3 \cap bA_4$), namely the undertakings stated in the agreement, presumably for the parties' mutual benefit C^{ab+}, this would be represented as $(aA_1 \cap bA_2) \rightarrow (aA_3 \cap bA_4) \rightarrow C^{ab+}$. The specific terms of the agreement can be elaborated in the legend. If aA_1 and bA_2 are thought of as a single act rather than as separate acts, the notation abA would be used instead of the expression with the $\cap$ symbol.

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[19] As explained in Mechner (1959), the "and" symbol is an abbreviation for a diagram that would show the possible occurrence of any of the permutations of the sequence of the events in question, with reciprocal vertical arrows showing that the occurrence of each sequence prevents the subsequent occurrence of the others.

3.10. Durations of acts

In many contingencies the consequence is a function of the amount of time that has elapsed, or that is consumed by an act. A Chinese proverb relates the contingency of being afraid to dismount the tiger that keeps getting hungrier.

Here t is the duration of $aA_{dismounts}$ (time since mounting), and M and/or p are direct functions of t, where M is the magnitude of the negative consequence

$$aA_{mounts} \rightarrow \left[\begin{matrix} aA^{t}_{dismounts} \Rightarrow C^{a(-)M,\,p}_{pain} \\ C_{riding} \end{matrix} \right.$$

and p is its probability. *Examples*: procrastinating having a dental or medical problem taken care of, fear of reporting a worsening business situation to one's shareholders, fear of confessing a crime, delaying paying a tax penalty, or not fixing a leaky roof.

In the analogous contingency where the valence is positive, patience is rewarded, or the magnitude or probability of the reward increases the longer one

$$aA_{request} \rightarrow \left[\begin{matrix} aA^{t}_{waiting} \Rightarrow C^{a(+)M,\,p}_{reward} \\ C_{promise} \end{matrix} \right.$$

waits. Foraging, too, can be described by this general contingency, where finding food may depend on the time t spent foraging.

3.11. Repetitive recycling of an act: Learning and practicing

Familiar examples of possible behavioral effects of recycling contingencies are the progressive decrease in t (i.e., an increase in the speed of the act) seen in learning and practicing, or an increase in t seen in fatigue or drug effects. Such observed effects can then be described by the function $t = f(n_i)$.

$$\underset{\hookrightarrow A^{t} \longrightarrow C}{\overset{n}{\hspace{1.5em}\rfloor}}$$

3.12. Behavioral history factors

Some aspects of a behavioral contingency description are independent of the histories of the involved parties, and some are not. The specification of the acts, the time periods, the consequences, the parties, and certain of the entities' attributes like probabilities and magnitudes, reflect the analyst's beliefs about the situation's objective or physical features, without consideration of the parties' histories. But such modifiers as *perceive, predict*, and the valences of consequences do depend on the parties' histories and reflect the analyst's beliefs about the effects of those histories, as discussed previously in section *2.9*. For example, the glass will break if dropped regardless of any party's history, but a party's prediction of that

consequence and its valence for that party *would* depend on the party's history. Thus, parties' histories can be specified as part of the contingency if doing so is relevant. The representation of any given situation would therefore depend not only on the analyst's focus and analytic intent but also on his beliefs regarding the parties' histories and motivations, and would, accordingly, be different for different parties, and for the same party(ies) at different times.

4. Examples of applications

4.1. Wrong predictions: Getting swindled, wrong number, "friendly fire"

A party might mispredict the consequence of its act *A*. *Examples*: dialing an incorrect phone number in error, paying a swindler for nonexistent real estate, a soldier shooting one of his own men. These situations would all be represented as $a\mathbf{A} \rightarrow {}^{a^x}\mathbf{C}^{a-}$. The a^x in the *C*'s upper left quadrant shows that *a* would mispredict C^{a-}. These examples make the point that only consequences that would actually occur (i.e., in the analyst's view)—calling the wrong party, obtaining an invalid deed, and shooting a comrade—can be codified, in this case represented by the *a-*. Consequences that would *not* occur, (e.g., "expectations"), cannot. Only the legend would state what the parties may have intended or expected—calling the desired party, obtaining a valid deed, and shooting an enemy. The diagram can show only that the party would have predicted a consequence that differs from the actual one.[20]

To show that *a* would also *perceive* the actual consequence if and when it occurred in each of the above examples, the *a* would also be shown in the lower left quadrant of the *C*, as in $a\mathbf{A} \rightarrow {}^{a^x}_{a}\mathbf{C}^{a-}$.

4.2. Unpredicted effect on another party's behavior

When a party *a* misuses a word in an unfamiliar language or gives someone faulty driving instructions, the consequence would be an unpredicted effect on the behavior of another party. When a word is misused, the consequence might be puzzlement by the other party. When faulty driving instructions are given, it might be the other party getting lost

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[20] When the act's agent would also predict the act's consequence, one might say that the consequation is intentional. However, as was explained in section *2.13*, terms relating to intentionality, as well as expectations, hopes, visualizations, goals, awareness, etc. are not needed.

and complaining. In both cases, the actual consequence is negative for a.

If aA is uttering the wrong word and $C_{\text{wrong word}}$ is the utterance of that word perceived (heard) by b, it is b's puzzled reaction "huh?" to the word

$$aA_{\text{utters}} \rightarrow \begin{bmatrix} bC_{\text{wrong word}} \\ b^{a^x}A_{\text{"huh?"}} \rightarrow {}_aC^{a-}_{\text{sound of "huh"}} \end{bmatrix}$$

that would constitute the negative consequence for a, not $C_{\text{wrong word}}$.
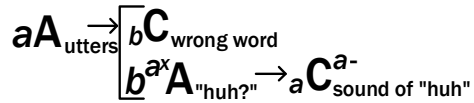
If the listener b nods in spite of puzzlement (see diagram), a might misperceive the nod as indicating that b understood. The consequence of the

$$aA_{\text{utters}} \rightarrow \begin{bmatrix} bC_{\text{wrong word}} \\ bA_{\text{nod}} \rightarrow {}_{ba^x}C^{a+}_{\text{sight of nod}} \end{bmatrix}$$

nod is positive for a because of a's misperception of it. If b predicted a's misperception, as indicated by the b in the upper left of the a^x, the nod would constitute a form of deception by b.
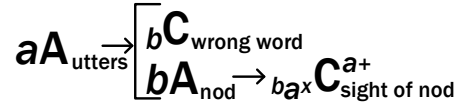
4.3. When nuances determine the meaning: Setting a trap

In this diagram, C_3's valence is negative for b. The two negation symbols $\tilde{b}$ show that b would not predict C_3 or perceive the warning signal C_4. This could be described as a setting a

$$aA_1 \rightarrow \begin{bmatrix} bA_2 \rightarrow {}^{a\tilde{b}}C^{b-}_3 \\ \tilde{b}a C_4 \end{bmatrix}$$

trap for b. The a in the upper left of C_3 shows that a would predict that bA_2 would consequate $\mathbf{C}^{b-}_3$ and would therefore have set the trap "intentionally," as one might say. Additional nuances or emphases could be indicated by showing a's in the upper left quadrants of either or both $\tilde{b}s$ (in C_4 and C_3), to show that a would predict b's non-perception of C_4 and non-prediction of

$\mathbf{C}^{b-}_3$. Nuances like these can assume great significance in legal matters.
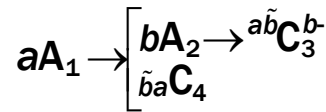
4.4. Probability of a consequence: Creating a hazard

The assignment of probability p to $C_3{}^{b-}$, as an additional attribute, defines the contingency as a hazard. The a in the upper left quadrant of b means that
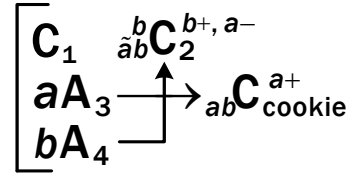
$$aA_1 \rightarrow \begin{bmatrix} {}^a b {}^a A_2 \rightarrow {}^{ab}C^{b-,\,p}_3 \\ {}_aC_4 \end{bmatrix}$$

a would predict that b would be the agent. The a in the upper left quadrant of A_2 means that a would predict A_2 regardless of who does it. The b in the upper left quadrant of C_3, in addition to the a, means that both a and b would predict that A_2, if it occurs, will consequate C_3 and its attributes, which include p. Would a and b then also be predicting that C_3's probability is p? The distributivity rule (that the modifiers *perceive* and *predict* apply also to the entity's attributes) says that they would. An ${}^{\tilde{a}}p$ in C_3's attribute
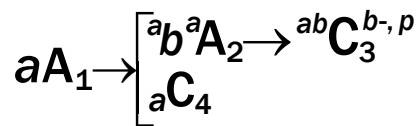
quadrant would override the distributivity rule, meaning that a would then *not* predict p. $^{\tilde{a}b}p$ would mean that b still would.

4.5. Theft

If b takes the cookie out of a's lunch box (bA_4) before a does (aA_3), a would be prevented (vertical cutting arrow) from doing so. (The fact that the cookie is in a's lunch box in the first place (C_1) would have been consequated by the act of an external agent, eA, not shown). Since only b would predict that b will end up with the cookie (C_2), and since $\tilde{a}$ shows that a would not perceive that the cookie is in b's possession, bA_4 would represent a theft. This example makes the additional point that a rigorous definition of the concept of theft, especially from a legal standpoint, requires specification of the perceptions and predictions of both parties, and the valences of the consequences.
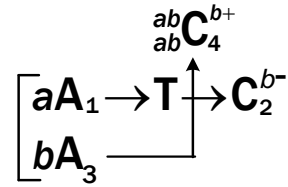
4.6. Applications in therapy

To achieve desired clinical results, therapists (psychotherapists, psychoanalysts, behavior therapists, cognitive-behavior therapists, coaches, or counselors) often seek to understand the contingencies involved in the patient's interactions with others (Erickson and Achilles, 2004; Wachtel, 1997). Such contingencies can be generated in part by the interactions themselves, including their reverberations at higher levels of the recursion hierarchy.

Family therapy in particular is an area where modifiers of modifiers can be important. In dealing with family dynamics, the therapist may analyze the contingencies that parents, siblings, and related parties create for each other. These often involve multiple levels of regress of each other's perceptions, mis-/non-perceptions, predictions and mis-/non-predictions of acts and their consequences, as well as of their valences and magnitudes. Since all of these are the result of the parties' histories, one of the therapist's challenges is to modify the effects of such histories, an endeavor in which a detailed behavioral contingency analysis can be useful.

4.7. Consequence of omitting an act: Failure to pay a bill

There are situations where failure to perform an act has a significant consequence. In such cases C would be consequated by a $T\rightarrow$ or an $A\rightarrow$ or

by another (sometimes external) party. For example, if a phone bill is not paid by the end of time T, the phone company will shut off service. Here, b would be the agent of the preventive act. The vertical arrow shows that bA_3 would avert C_2 by terminating the $T{\rightarrow}C_2$ contingency. Non-performance of bA_3 would permit C_2 to occur.

$$\begin{array}{l} {}^{ab}_{ab}C^{b+}_4 \\ \left[\begin{array}{l} aA_1 \rightarrow T \dashrightarrow C^{b-}_2 \\ bA_3 \end{array}\right. \end{array}$$

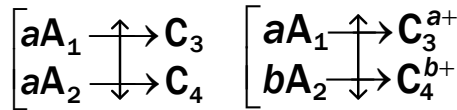The legend, indexed to the subscripts might read:

> 1. If phone company a threatens to cut off service after time T
> 2. Service would be cut off.
> 3. (If) customer b pays the phone bill within time T
> 4. Service would continue.

The consequence C of the termination, with all of its modifiers, can be shown at the end of the terminating arrow.

4.8. Reciprocal vertical arrows: Decision making and competition

When each of two consequences prevents the occurrence of the other, as in decision making and certain types of competition, reciprocal vertical arrows are required (see diagram). This notation is an abbreviation (Mechner, 1959) [21] that prevents the essential elements of the diagram's structure from being obscured.

$$\left[\begin{array}{l} aA_1 \uparrow\rightarrow C_3 \\ aA_2 \downarrow\rightarrow C_4 \end{array}\right. \qquad \left[\begin{array}{l} aA_1 \uparrow\rightarrow C^{a+}_3 \\ bA_2 \downarrow\rightarrow C^{b+}_4 \end{array}\right.$$

The diagram on the left represents a making a decision. The reciprocal vertical arrow is needed to show that either decision precludes the other. The diagram on the right shows a and b competing to achieve different consequences (as in any zero sum game). Here, the reciprocal vertical arrow is required to show that once a has achieved C^{a+}, b can no longer achieve C^{b+}, and vice versa. If the vertical arrows were omitted, the occurrence of either $A{\rightarrow}C$ would not prevent the subsequent occurrence of the other.

4.9. Simultaneous multiple discrimination: Multiple choice items

The term *multiple discrimination* refers to the behavior produced by

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[21] The unabbreviated way would be to show two separate vertical arrows that cross each other, each one emanating from one of the two originating events and cutting the horizontal arrow of the other.

contingencies in which the consequences
of different acts depend on the prevailing
stimuli (signals) and on the party's history
with respect to those signals. The choices
can be presented simultaneously or
sequentially. When taking a multiple
choice test, the student may be confronted
with a question C together with simultaneously available choices (acts), as
in the above diagram. The external agency e that presents (consequates) the
C may be a teacher, a computer, or the student himself turning a page. The
reciprocal vertical arrows show that each of the three acts terminates the
availability of the others.
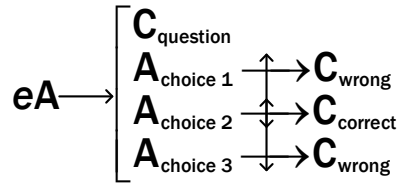
4.10 Two interrelated time intervals: The roast in the oven

The diagram shows a situation where a put a roast in the oven and left
the house without turning the oven off (aA_1). The roast will burn ($C_5{}^{a-}$),
unless the oven is turned off (A_8)
within time T_4. If the oven is
turned off (A_8) after T_7 and before
T_4, the roast will be done. But the
oven will get turned off only if a
asks (aA_6) her neighbor b to do so
before T_4. T_7 and aA_6 therefore
have an "and" relationship.
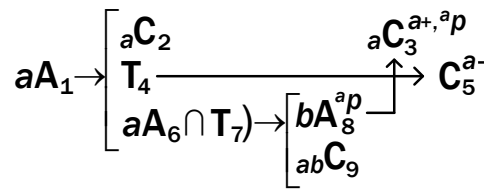
Legend:

aA_1	If a leaves the roast in the oven on leaving home...
$_aC_2$	The roast would be in the oven with the oven on.
T_4	Time after which the roast would burn.
T_7	Time after which the roast would be done.
$C_5{}^{a-}$	Burnt roast
aA_6	If a calls her neighbor b and leaves her a message...
$_{ab}C_9$	Message to turn off the oven after time T_7.
$bA_8 \rightarrow$	If b turns off the oven after T_7 and before T_4...
$C_3{}^{a+}$	The roast is done and $C_5{}^{a-}$ is averted.

The b in $_{ab}C_9$'s lower left quadrant implies that b got the message. The
^ap attributes of A_8 and C_3 represent a's prediction/estimation of the
probability that b will actually do bA_8 and that the roast will therefore be
taken out in time.

4.11. Types of "or" relationships: Achieving priority, putting out a fire

One kind of "or" relationship is where either one of two or more acts can result in a given consequence. Another is where a single act can result in either one of two or more consequences. Both can in turn be divided into exclusive (*either, or*, but *not both*) and inclusive (*either, or*, or *both*) "or" relationships.

Diagram on the left: An exclusive "or" relationship shown by a merging of the horizontal arrows. The consequating entities in such diagrams can be As and/or Ts. This diagram could represent two parties competing to consequate C, where whoever gets there first

$$\begin{bmatrix} a\mathbf{A_1} \\ b\mathbf{A_2} \end{bmatrix} \!\!\!>\!\!\!\rightarrow \mathbf{C}_{\text{priority}} \qquad a\mathbf{A_1} \cup b\mathbf{A_2} \rightarrow \mathbf{C}_{\text{fire out}}$$

obtains the only available C (as when parties compete for priority in applying for a patent or in reaching the South Pole).
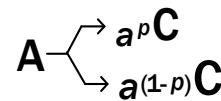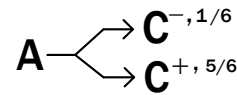
Diagram on the right: Either one of two parties or both together can put out the fire—the inclusive "or," represented by the union symbol ∪.

$(aA_1 \cup bA_2) \rightarrow (aA_3 \cap bA_4) \rightarrow C^{ab+}$ would be read as, "If either a or b or both (note the inclusive "or" symbol ∪) create a situation in which cooperation between a and b (note the ∩ symbol for "and") can occur, the consequence would be C^{ab+}

4.12. Probabilities of alternative consequences: Russian roulette

Another type of "or" situation is where a single act A (e.g., the tossing of dice) consequates two or more possible outcomes with different probabilities. In "Russian roulette" there is a 1/6 probability of the consequence "bullet in chamber" occurring. If the focus is on the two alternative scenarios, the arrow can be shown as branching, with the other branch consequating the complementary probability 5/6. In general, contingencies involving alternative consequences are represented by a multi-pronged fork with two or more arrows pointing to the different possible Cs.

$$A\!\!\!<\begin{matrix} \rightarrow \mathbf{C}^{-,\,1/6} \\ \rightarrow \mathbf{C}^{+,\,5/6} \end{matrix}$$

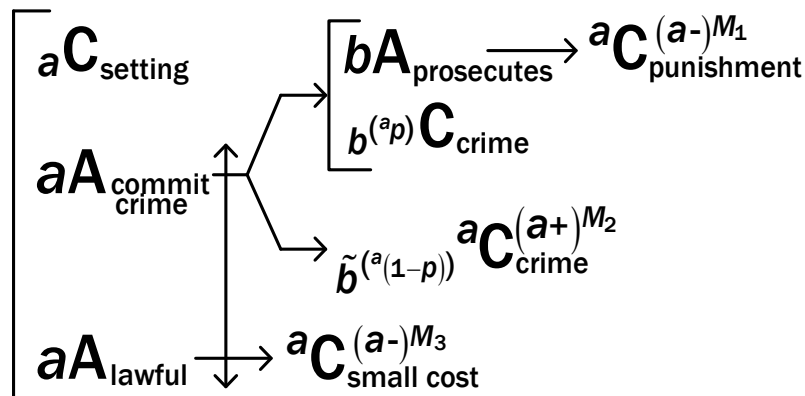$$A\!\!\!<\begin{matrix} \rightarrow a^{p}\mathbf{C} \\ \rightarrow a^{(1-p)}\mathbf{C} \end{matrix}$$

The analyst may sometimes wish to show that a modifier like *perceive* and *predict*, or a valence, has an "if" in front of it. For example, he may want $_aC$ to be read as "*If a would perceive C*"rather than the standard "*a would perceive C.*" He would then show the two possibilities as the branches of an "or" fork.

4.12.1. Crime and Punishment

An important instance of this contingency is the one to which a party a is subject when considering whether or not to commit a crime.

The circumstance C_{setting} for the crime is shown as perceived by a and as setting the occasion for a's choice between the lawful act aA_{lawful} and the criminal act $aA_{\text{commit crime}}$. If a chooses the latter, society, represented by b, would either perceive or not perceive the crime C_{crime}. The forked arrow shows that the act $aA_{\text{commit crime}}$ can have either of those two consequences. (The reciprocal vertical arrow shows that the two choices are mutually exclusive.)

$$
\begin{array}{l}
aC_{\text{setting}} \qquad\quad bA_{\text{prosecutes}} \longrightarrow aC_{\text{punishment}}^{(a-)M_1} \\[4pt]
\qquad\qquad\qquad\quad b^{(^a p)}C_{\text{crime}} \\[6pt]
aA_{\text{commit}\atop\text{crime}} \Big< \\[6pt]
\qquad\qquad \tilde{b}^{(^a(1-p))}\, aC_{\text{crime}}^{(a+)M_2} \\[6pt]
aA_{\text{lawful}} \longrightarrow aC_{\text{small cost}}^{(a-)M_3}
\end{array}
$$

Perception by b (note the b in the lower left quadrant of $_bC_{\text{crime}}$) is shown as having probability p. Non-perception by b (note the $\tilde{b}$ in the lower left quadrant of $_{\tilde{b}}C_{\text{crime}}$) is shown as having probability $1-p$.) The potential perpetrator a would have an estimation/prediction of these two probabilities (note the a s in the upper left of p and $1-p$).

The perception by b of $_bC_{\text{crime}}$ would set the occasion for the prosecution activity $bA_{\text{prosecution}}$ and consequent punishment $^aC_{\text{punishment}}$. The punishment and the magnitude M_1 of its negative valence $a-$ is shown as predicted by a. Non-perception by b of consequence $_{\tilde{b}}C_{\text{crime}}$ is shown as having a positive valence for a, of magnitude M_2.

This analysis considers only some of the most essential elements of this contingency. For example, society's action bA could be shown as merely noting the crime, and then making a choice between prosecuting or not prosecuting it. The perpetrator could then be shown as estimating/predicting the probabilities of these two possibilities, and their consequences. If relevant to the focus of the analysis, society's estimations/predictions of these estimations/predictions could also be considered.

Key variables in this type of analysis are the probabilities of the various

consequences and the relationships between the predicted and actual values of M_1, M_2, and M_3 (not shown in the above diagram). Those are the diverse, often qualitative, variables that Gary S. Becker's utility concept encapsulates in a single quantitative dimension (Becker, 1976, 1995, 1997).

This example illustrates how the types of economic analyses performed by Becker and others, and their potential ramifications for all of the involved parties, can be codified as behavioral contingencies that identify the key variables that may be operative, and their interrelationships.

4.13. Sequential multiple discriminations: Traffic lights, naming people

In a sequential multiple discrimination, signals appear one at a time. *Example*: We stop when the traffic light is red and proceed when it is green, and call different people by their respective names.

To codify this type of contingency we first ask how the circumstances for the acts are consequated. Traffic lights are controlled by timers, and telephone equipment transmits the voices of people we may want to name when they call us. In both cases external agencies *e* consequate the situations in an "or" manner—the traffic light is either red or green, and we receive phone calls from one person or another.
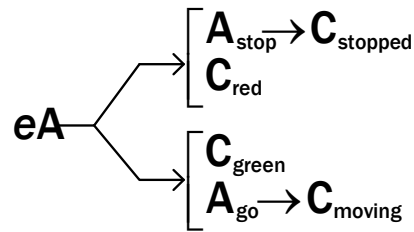
Again, the "or" relationship is represented by a fork. When the multiple discrimination involves more than two signals, the fork would have correspondingly more branches.

4.14. Misperception of C: Mistaken identity

If policeman *a* sees a suspicious character *b*, he may try to arrest him. If *b*, claiming mistaken identity, reached into his pocket ($bA_{reaches}$) for his identification ($_{ab}C_{ID}$), then in the *T* seconds this might take, the policeman could misperceive the visual consequence ($_{a^x}C_2$) of
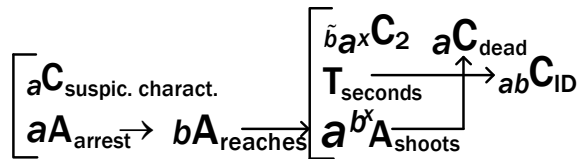

($bA_{reaches}$) as pulling out a gun, and shoot *b* dead, mispredicted by *b*. The $\tilde{b}$ term means that *b* would not predict *a*'s misperception.

4.15. *Misperception of a missile test*

A similar diagram could describe a misperception by country *a* in response to a missile test by a hostile power *b*, and the associated mispredictions by *b*.

In the diagram at the right, $_{a^x}^{\tilde{a}}C_{test}$ shows *a*'s non-prediction and misperception of the

$$bA_{tests} \rightarrow \begin{bmatrix} b^x {}_{a^x}^{\tilde{a}}C_{\,test} \\[4pt] a^{b^x}A_{attacks} \xrightarrow{} abC^{ab\text{-}}_{blast} \end{bmatrix}$$

test. If *a* responds with $aA_{attacks}$, the consequence would be negative for both parties. The b^x in the upper left quadrant of the a^x shows that *b* would mispredict *a*'s misperception of the test. The b^x in the upper left of $A_{attacks}$ shows that *b* would mispredict the attack by *a*. If it were desired to show that *b* would *not* predict rather than mispredict *a*'s misperception, $\tilde{b}$ would replace b^x in a^x's upper left quadrant.
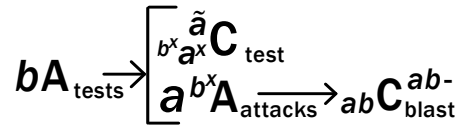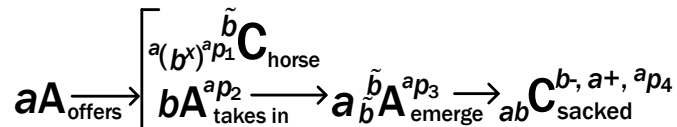
Many types of situations that involve misperception, and misprediction of misperceptions, are of great concern to societies and nations, as well as in interpersonal relationships. Behavioral contingency analysis helps identify the critical variables whose effects can then be studied by various methods.

4.16. *Concatenated probabilities in systems analysis: The Trojan horse*

If Homer had been the analyst, he might have shown Odysseus—the general of the besieging Greeks—as party *a* scheming the following contingency:

"If we build a giant hollow wooden horse and leave it for the Trojans to find (aA_{offers}), the Trojans (*b*) may misperceive the horse (as being empty rather than filled with soldiers). If the Trojans thereupon take the horse into their city ($bA_{takes\,in}$), our soldiers hidden inside the horse may be able to emerge from the horse during the night (aA_{emerge}) and open the gates for the rest of us to enter and sack the city, thereby winning the war."

The $\tilde{b}$ in the upper left quadrant of C_{horse} shows Odysseus's bet that
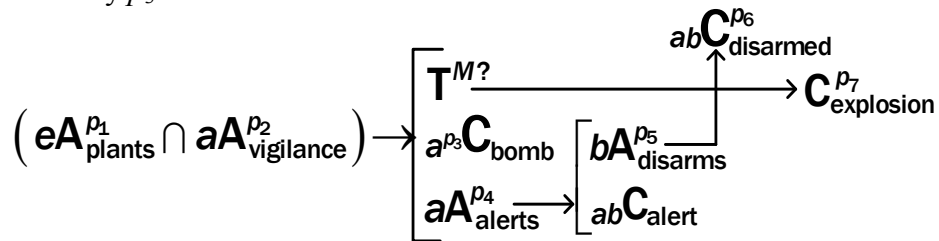
$$aA_{offers} \rightarrow \begin{bmatrix} a(b^x)^{a p_1}\, {}^{\tilde{b}}C_{horse} \\[4pt] bA^{a p_2}_{takes\,in} \xrightarrow{} a\,{}_{b}^{\tilde{b}}A^{a p_3}_{emerge} \xrightarrow{} abC^{b\text{-},\,a+,\,a p_4}_{sacked} \end{bmatrix}$$

the Trojans would not predict this "gift." The b^x in the lower left quadrant of C_{horse} shows *b*'s possible misperception, and the $^a p_1$ in b^x's attribute quadrant shows Odysseus' prediction/estimation of the probability of this misperception. Odysseus might also have predicted/estimated the probabilities of various subsequent events— $^a p_2$ for the act $bA_{takes\,in}$, and $^a p_3$ for aA_{emerge} (e.g., the Trojans might discover the ruse, or the horse's door

might jam). The $\tilde{b}$ symbols in the two verb quadrants of aA_{emerge} show that b would not perceive or predict aA_{emerge}. The attributes quadrant of C_{sacked} shows that this consequence would be negative for b, positive for a, and that a would have predicted/estimated its probability as p_4.

     If Odysseus had indeed performed this analysis and considered the product of the four probabilities, he might have concluded that his scheme was very (too?) risky.

4.17. Vigilance [22] and the analysis of interrelated probabilities

     If (p_1) e plants a bomb (eA_{plants}) that has probability p_7 of going off after unknown time $T^{M?}$, and if ($aA_{\text{vigilance}}$) shows that a is probably (p_2) engaged in vigilance/detection activity, then a will detect (perceive) $_aC_{\text{bomb}}$ with probability p_3.
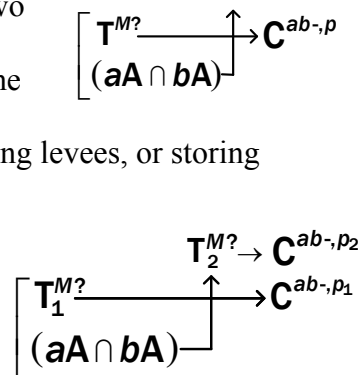
$$\left(eA_{\text{plants}}^{p_1} \cap aA_{\text{vigilance}}^{p_2} \right) \rightarrow \begin{bmatrix} T^{M?} \xrightarrow{\quad} & \begin{matrix} _{ab}C_{\text{disarmed}}^{p_6} \\ \end{matrix} \rightarrow C_{\text{explosion}}^{p_7} \\ _aP_3 C_{\text{bomb}} & \begin{bmatrix} _bA_{\text{disarms}}^{p_5} \end{bmatrix} \\ aA_{\text{alerts}}^{p_4} \xrightarrow{\quad} & \begin{bmatrix} _{ab}C_{\text{alert}} \end{bmatrix} \end{bmatrix}$$

     If a thereupon alerts (aA_{alerts}) the bomb squad b (probability p_4) with a signal ($_{ab}C_{\text{alert}}$), the bomb squad will probably (p_5) attempt to disarm the bomb ($_bA_{\text{disarm}}$), with p_6 being the probability of doing so successfully.

4.18. Modification of contingencies: Mitigating a danger

     This diagram shows a situation in which two or more parties cooperate to avert a threat. Again, C^{ab-} can come after an unpredictable time $T^{M?}$ with probability p. By acting cooperatively ($aA \cap bA$) (e.g., by exercising vigilance, building levees, or storing provisions), a and b can prevent C^{ab-}.

$$\begin{bmatrix} T^{M?} \xrightarrow{\quad\quad} \uparrow \rightarrow C^{ab-,p} \\ (aA \cap bA) \end{bmatrix}$$

     To show that ($aA \cap bA$) merely reduces the probability of C^{ab-} from p_1 to p_2, rather than to zero, the changed contingency would be shown at the end of the vertical arrow with the new probability p_2, as in the

$$\begin{bmatrix} & & T_2^{M?} \rightarrow C^{ab-,p_2} \\ T_1^{M?} \xrightarrow{\quad\quad} & \uparrow & \rightarrow C^{ab-,p_1} \\ (aA \cap bA) \end{bmatrix}$$

---

[22] Experimental studies of vigilance and observing behavior and the associated contingencies include Dinsmoor (1983), Dinsmoor et al. (1972), Case and Fantino (1989), and Nevin et al. (2005).

diagram. Here ($aA \cap bA$) would change both the timing and the probability of the terminated contingency. If the new contingency requires a bracket, the arrow would point to the bracket.
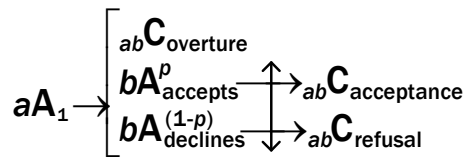
4.19. Risky choices: Thinking ahead in a game

The risks that a chess, checker, or go player takes when choosing between moves are the uncertainties regarding (1) how accurately or completely he identified the opponent's possible responses, (2) which of these the opponent will actually choose, and (3) the valence of the outcomes of these possibilities.

If a considers two possible moves aA_1 and aA_9, and thinks two moves ahead in considering b's possible responses, a would be uncertain as to whether, in response to aA_1, b would choose bA_3 (say, a particular identified move) or bA_5 (say, a possible unidentified move), or whether in response to aA_9, b would choose bA_7 (say, another particular identified move) or bA_{10} (say, another possible unidentified move). Furthermore, a would be uncertain regarding the valences of the resulting situations (note the a s in the attribute quadrants of the question marks).
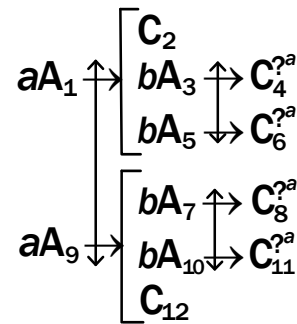
4.20. Divergent contingencies for two parties: A sexual overture

If a makes a sexual overture aA_1 to b, the two possible outcomes, from a's point of view, are that b would accept (probability p) and that b would decline (*1-p*). The reciprocal vertical arrow is needed to show that $b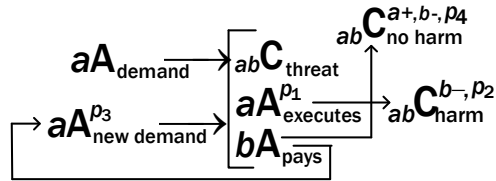$'s accepting and declining are mutually exclusive. From b's point of view the issue is whether to accept or decline, rather than a probability issue. This type of examination of two divergent perspectives can be useful in fields like law, business (see section *6.7*), economics, or public affairs, where the differences in the contingencies for each party can be important.

4.21. Game theory situations and bluffing: Blackmail and kidnapping

If blackmailer a threatens to harm b unless b pays, the probability of the

harm actually occurring, even if $aA_{executes}$, might be p_2,. If aA_{demand} stated that b can avert harm by bA_{pays}, then the probability that a would do no harm if b pays is p_4, and the

$$aA_{demand} \rightarrow {}_{ab}C_{threat} \quad {}_{ab}C_{no\ harm}^{a+,b-,p_4}$$

$$\rightarrow aA_{new\ demand}^{p_3} \rightarrow \begin{array}{l} aA_{executes}^{p_1} \\ bA_{pays} \end{array} \rightarrow {}_{ab}C_{harm}^{b-,p_2}$$
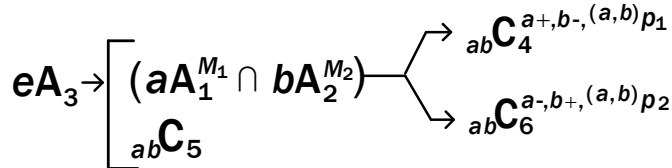
probability that a would actually execute the threat if a doesn't pay is p_1, that is, a is bluffing. The probability that bA_{pays} would consequate a recycling of the entire contingency is p_3. When a contingency recycles, all components of that contingency are restored for the next cycle, including ones terminated by vertical arrows in the preceding cycle.

The same diagram could also describe hostage taking or kidnapping. This example and many of those that follow illustrate how behavioral analysis can serve as a tool for identifying the variables and their relationships that would be considered in the types of economic analyses proposed by G.S. Becker (1976, 1995, 1997).

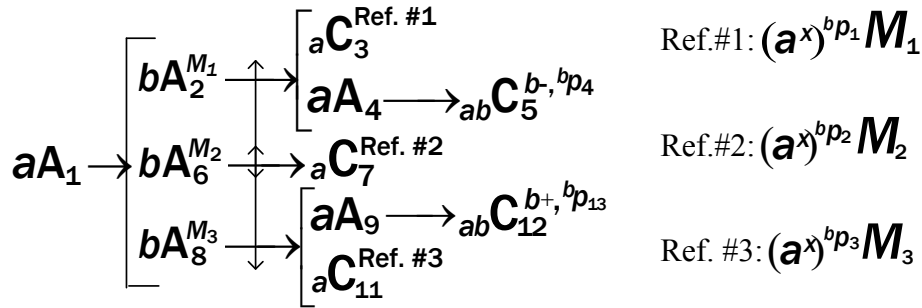### 4.22. Predictions/estimations of p: The basis for a wager

Here aA^{M1} and bA^{M2} represent bets that a and b can place in situation $_{ab}C_5$ on, say, the outcome of a ball game. The external agency e could be two ball teams producing one of the two possible consequences. The attributes M_1 and M_2 of the bets can be the amounts of money a and b would be betting. The symbol ∩

$$eA_3 \rightarrow \begin{bmatrix} (aA_1^{M_1} \cap bA_2^{M_2}) \\ {}_{ab}C_5 \end{bmatrix} \begin{array}{l} \rightarrow {}_{ab}C_4^{a+,b-,(a,b)p_1} \\ \rightarrow {}_{ab}C_6^{a-,b+,(a,b)p_2} \end{array}$$

indicates the "and" relationship of the bets, as in a contract. The notations $^{(a,b)}p_1$ and $^{(a,b)}p_2$, with commas between the a and b, show that a and b have different predictions/estimations of p_1 and p_2 (they wouldn't be betting unless they did). If there were no comma, just ab, it would mean that a and b have a joint prediction/estimation.

4.23. Perceptions of M: tipping a service provider

If customer b has received a service (aA_1) from a (say, a waiter), the magnitude M of the tip b gives (bA^M) may be $M_1, M_2,$ or M_3. The three tips are $C_3, C_7,$ and C_{11}, and a may have subjective/idiosyncratic perceptions of their magnitudes.

$$_bA_2^{M_1} \xleftrightarrow{\uparrow} \begin{bmatrix} _aC_3^{\text{Ref. \#1}} \\ aA_4 \longrightarrow _{ab}C_5^{b-,\,bp_4} \end{bmatrix}$$

$$aA_1 \rightarrow _bA_6^{M_2} \xleftrightarrow{\updownarrow} _aC_7^{\text{Ref. \#2}}$$

$$_bA_8^{M_3} \xleftrightarrow{\downarrow} \begin{bmatrix} aA_9 \longrightarrow _{ab}C_{12}^{b+,\,bp_{13}} \\ _aC_{11}^{\text{Ref. \#3}} \end{bmatrix}$$

Ref.#1: $(a^x)^{bp_1}M_1$

Ref.#2: $(a^x)^{bp_2}M_2$

Ref. #3: $(a^x)^{bp_3}M_3$

The magnitudes are attributes of the three Cs and the idiosyncratic perceptions of the magnitudes (indicated by a^xs in the Ms' lower left quadrants), are shown in the three references, a technique used because if these attributes were scaled to the size of the main diagram and inserted, they would be hard to read.
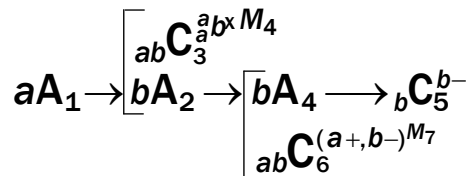
The fact that the two sets of three Ms have the same (lower right) subscripts means that they represent the same amounts of money. (The three-way reciprocal vertical arrow shows that these three possible consequences are mutually exclusive.) The legend might elaborate that a would idiosyncratically perceive M_1 as too small, M_2 as acceptable, and M_3 as generous. These three idiosyncratic perceptions have probabilities p_1, p_2, and p_3 respectively, which b might predict/estimate, as shown by the bs in the upper left quadrants of the three probabilities.

a's possible reactions aA_4 and aA_9 would consequate C_5 or C_{10}, which b would perceive and whose respective probabilities b would predict/estimate as p_4 and p_5. C_5 might be an insult and C_{10} might be an expression of gratitude.

These and many other intricate social and cultural variables at play in many tipping situations have been discussed by Green et al. (2003), and a brief review of the relevant literature is presented in Lin (2007).

4.24. Misperception of the M of a C: Perpetration of a fraud

If seller a offers (aA_1) to sell b a counterfeit painting, C_3, a would perceive the value of the painting to be M_4 (as indicated by the a in the lower left quadrant of C_3, which is distributive to C_3's attribute M_4), while b would misperceive its value, indicated by the b^x in M_4's lower left quadrant. Note that both a and b perceive the painting, but only b misperceives its value. The a's in the two left quadrants of the b^x indicate that a would perceive and predict b's misperception of the value, which is

$$aA_1 \rightarrow \begin{bmatrix} _{ab}C_3^{\,_a^b{}^x M_4} \\ _bA_2 \rightarrow \begin{bmatrix} _bA_4 \longrightarrow _bC_5^{b-} \\ _{ab}C_6^{(a+,b-)M_7} \end{bmatrix} \end{bmatrix}$$

what makes the transaction a fraud. The description of aA_1 in the legend might include history events responsible for b's misperception.

   If b accepts a's offer aA_1 and buys the painting (bA_2), paying a the asking price M_7 (an attribute of C_6's valence), then $a+$ would be a receiving the M_7 and $b-$ would be b parting with it. If b subsequently gets the painting appraised (bA_4) and consequently learns its true value $_bC_5{}^{b-}$, the valence of that information would be negative for b. If a third party c witnessed the fraud and stood to benefit from it, c would face the choice of warning b, or letting the fraud occur, thereby becoming an accomplice.

4.25. Symmetrical reciprocal recycling contingencies: Feuding

   This diagram represents a feud where parties a and b alternate hurting each other. The crossing diagonal recycling arrows show the symmetry of this type of contingency. Attempts to end the feud can be made at any point by A_1 or A_6 (peace overtures) that have probabilities p_1 and p_2 of being effective.

   Other examples of contingencies that have symmetrical recycling structures: bargaining, where two parties take turns making each other offers and counteroffers; situations where two parties take turns assisting each other.
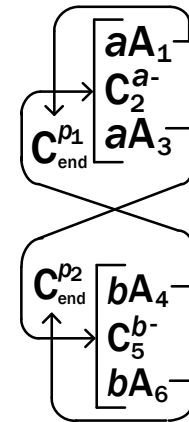
4.25.1 Clocked games with time limits

   Games like chess, go, or checkers may involve timing of each player's moves so as to impose a limit on the total time that can be used. In the diagram on the right, A^t represents a move of duration (thinking time) t. Each move A^t stops the player's own clock and starts the other player's. If a player exceeds his limited allotted time, he loses.

   Each player's time register displays the total amount of time that player has used up after every move. The external agent e, which can be a clock
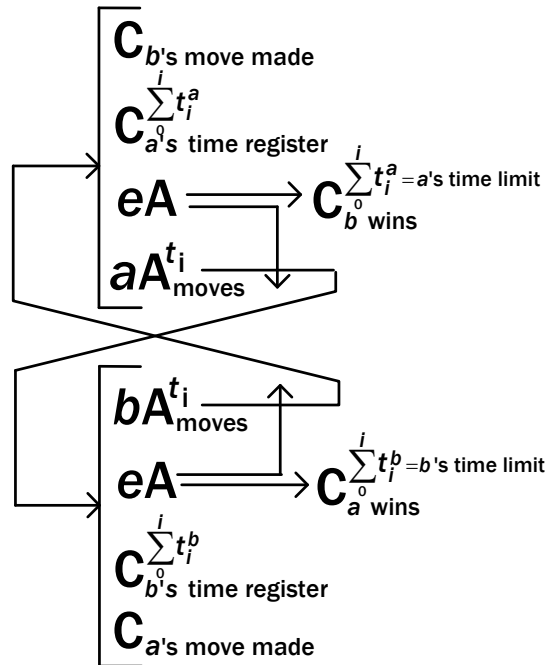
mechanism such as a flag that drops or a beeper, indicates the winner and the end of the game when the other player has reached his time limit.

4.26. Mutual deterrence and first strike

Mutual deterrence is another type of symmetrical recycling contingency rife with game theory dynamics that can occur in military confrontations and other situations in which there can be standoffs. Two factions, a and b, both have the option of launching a first strike A_{attack}. If a attacks first, b will retaliate unless a's attack terminates b's ability or willingness to do so.
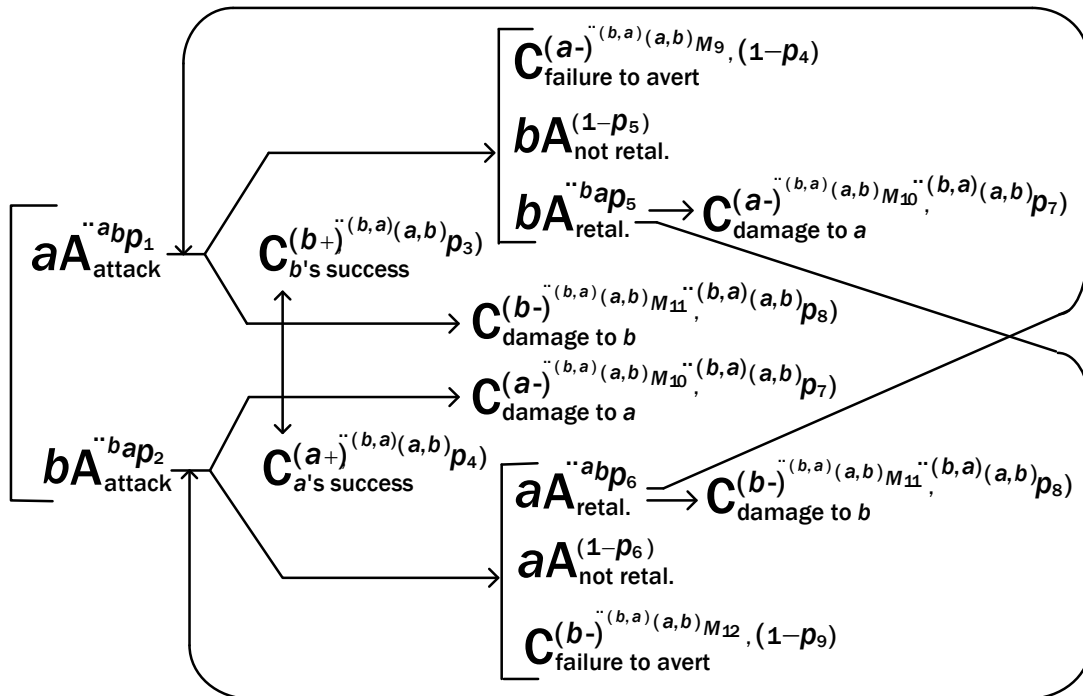
In the above diagram, the forking arrows indicate that a first strike by either side can result either in a retaliatory attack or in the prevention of one. The prevention possibilities, $C_{a\text{'s success}}$ and $C_{b\text{'s success}}$, having probabilities p_4 and p_3 respectively, are shown as consequated by the reciprocal vertical arrows, each of which prevents the C_{damage} consequence to itself. The complements of these probabilities $(1- p_4)$ and $(1- p_3)$, are shown as the attributes of $C_{a\text{'s failure}}$ and $C_{b\text{'s failure}}$ respectively, where the other party, in both cases, has the choice of whether or not to retaliate.

(Note that the two $C_{\text{damage to } b}$ terms are identical and refer to the same event, as do the two $C_{\text{damage to } a}$ terms).

The protagonists may differ in their predictions/estimations regarding the magnitude of any damage that would be inflicted on the other party or on itself, as well as the various probabilities that (a) the other party would execute a first strike, (b) that there would be retaliation for each attack, (c) that the first strike would avert retaliation, and (d) that any given retaliation would end the cycle of exchanges. Each party would also have its own prediction/estimation of the other party's prediction/estimation of its own predictions/estimations of the various probabilities and magnitudes, for several levels up the recursion hierarchy. The two dots at the upper left of the last pre-superscript shown indicate that the recursion hierarchy can, in principle continue. Another and supplementary approach to analyzing this type of contingency (not used here) is to consider the possible misperceptions, mispredictions, and uncertainties regarding the modifiers of these entities, again for several levels up the recursion hierarchy.

4.27 The representation of complex contingencies

The complexity of this contingency and the number of interrelated variables involved puts it at the edge of two-dimensional representability. For highly complex interactive situations, in which the analyst wishes to consider multiple levels of recursion for modifiers, two-dimensional representation becomes difficult or even unfeasible. If more variables were to be considered in the above analysis, the representation of the contingency would have to be abstract—a set of interrelated statements that can serve as the ingredients of a computer simulation. Section *7.2.* discusses an approach to the analysis of such complex situation—an approach that will make behavioral contingency analysis of highly complex situations useful in operations research or computer simulation, where it can help identify and confront relevant variables that could easily be overlooked, and facilitate the projection of the behavioral dynamics that can be expected.
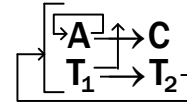
5. Behavioral contingency analysis as a research tool

5.1. Widely studied contingencies: Schedules, the "matching law"

The basic contingencies for the widely studied fixed or variable interval schedules and fixed ratio schedules (Skinner, 1938) would be codified as $\rightarrow T \rightarrow A \rightarrow C^+$ and $\rightarrow nA \rightarrow C^+$ respectively, where the *n* represents the

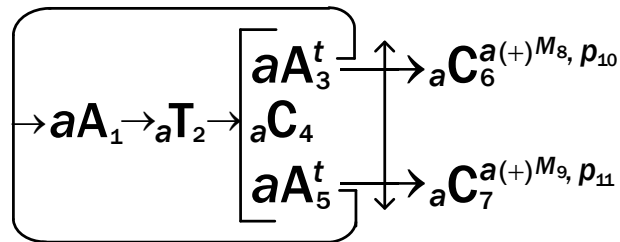number of consecutive As rather than the agent of A (Mechner, 1959).[23]

In the contingency shown at the right, there is a limited time window T_1 during which $A{\to}C$ can recycle (e.g., "Make hay while the sun shines"), or be allowed to occur only once (termed "limited hold" in Ferster and Skinner (1957)). T_2 is the parameter that distinguishes a free operant situation from a trial situation. It would be a free operant situation if T_2 were zero. The usual possible modifiers of the As, Cs, and Ts can suggest independent variables in experimental analyses of this general contingency.

Another widely studied contingency is the one to which the "matching law" applies (Herrnstein, 1970; Baum, 1979), which states the observed relationship (often hyperbolic, e.g., Mazur, 2001) between measures of behavior and measures of consequences. The diagram represents a generic "matching law" experiment—one that studies behavior allocation or other manifestations of choice as a function of the magnitude or probability of consequences. The contingencies represented by this diagram are seen in most situations that involve choice or decision making, and in many that are the subject of behavioral economics research (Herrnstein et al., 1997; Camerer and Lowenstein, 2003; Becker, 1976, 1995, 1997). C_4 represents the two manipulanda or physical facilities for the two choices A^t_3 and A^t_5. The t attributes of the choices can refer to the amount of time allocated to each of the two choices, or to their rates, inter-response times, or latencies. M_8 and M_9 represent the magnitudes of the valences of the two consequences (e.g., amount of reinforcement), and p_{10} and p_{11} represent their probabilities (e.g., reinforcement probability or frequency). A_1 can be a changeover response (as when a switches from A^t_3 to A^t_5 or vice versa) and T_2 is the amount of time the experimental design allocates to the changeover.

5.2. Temporal discounting research

Temporal discounting research deals with the behavioral effects of the

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[23] The number n could also be shown as an attribute of the A. Either notation is an abbreviation for the notation that shows the A as recycling n times with the consequation of C^+ depending on the C register having reached n (see section 6.2 (C)).

relationships between the magnitude of a consequence and its delay (e.g., Commons, 1987, Lattal, 1987, Mazur, 1987, Critchfield and Kollins, 2001, Green et al., 2004, 2007, Rachlin, 2006). In many situations, less/sooner can be equivalent to more/later for certain values of time and magnitude of the consequence, with the equivalence contour often described by a hyperbolic function (e.g., Mazur, 1987). The trade-off between delay and magnitude of reward in this type of research has sometimes been associated with "delay of gratification" or "self-control" (Rachlin, 1995).

The diagram below is a generic representation of temporal discounting experiments that would use real, as opposed to verbally described, delays and consequences. One delay-magnitude combination is T_4 / M_{14}, and the other is T_8 / M_{15}. The two choices are aA_2 and aA_3. The diagram provides a road map for identifying this research area's potentially operative variables besides the basic ones of delay, valence magnitude, and probability of the consequence. For instance:

• C_6 and C_9 signal the two delay intervals (which can be "filled or empty," MacInnis, 2007).

• The acts aA^t_5 and aA^t_7 indicate the possibility of filling the delay intervals with alternate behavior maintained by various possible contingencies.

• The +/- valences show that the consequences can be positive or negative.

• The probabilities p_{15} and p_{16} of the consequences are shown as a possible alternative or supplement to the valence magnitude variable.

• All of the time intervals and consequences are shown as modifiable by perceptions and predictions that could be a function of signaled or experiential history variables (e.g., number of repetitions).

• Not shown in the diagram but also possible variables are misperceptions or mispredictions and non-perceptions or non-predictions of any of the entities.

The diagram also highlights the issue of using, as the independent variables, real delays and consequences (as Mazur did with rats and pigeons, Mazur (1987) versus verbally described (sometimes termed "hypothetical") consequences and/or time delays (e.g., Kowal et al., 2007, Johnson and Bickel, 2002). When the independent variable is
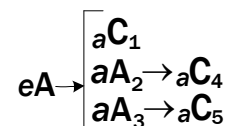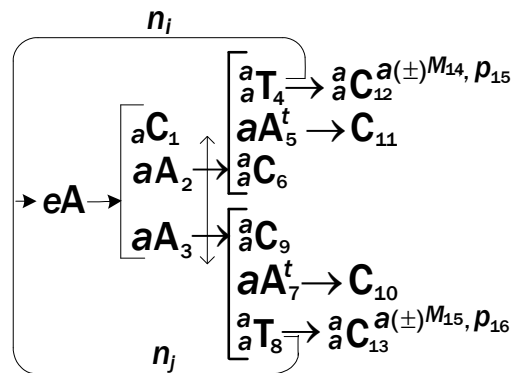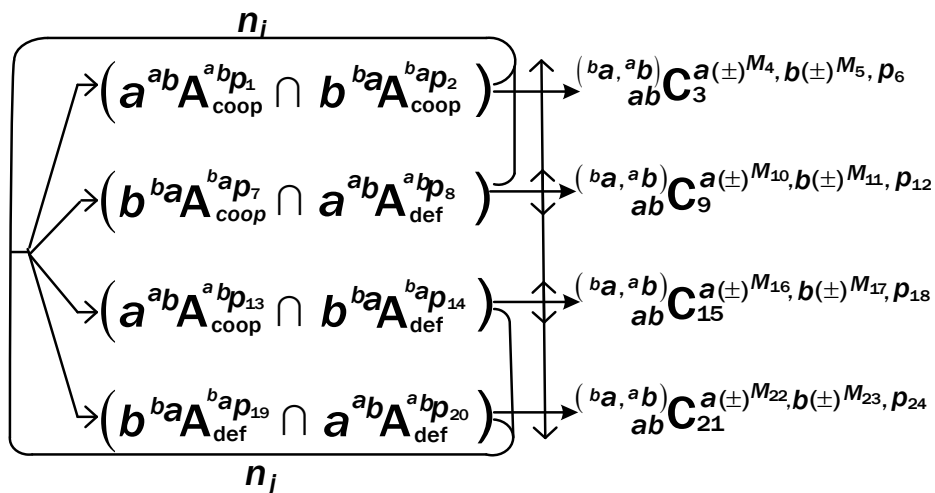
embodied in a verbal statement, $_aC_1$, presented simultaneously with the choice contingency, and the consequences of the choices are also verbal statements, C_4 and C_5, the diagram reduces to the one at the right. In this type of experiment, a description of $_aC_1$ in the legend would explain the experimenter's assumptions regarding the subjects' behavioral and verbal histories with respect to the described delays and consequences. A key issue here would be the assumed correlation between the behavioral effects of (a) real delay/consequence combinations and (b) verbal descriptions of these, given certain verbal histories. Some of these issues are discussed in Hertwig and Ortmann (2001), Johnson and Bickel, (2002), and Fantino et al., (2007).

5.3. Research on the prisoner's dilemma

This class of behavioral contingencies, which is of sweeping importance in the social sciences, is very well explained in the Wikipedia article (*http://en.wikipedia.org/wiki/Prisoner's_dilemma*) entitled "Prisoner's dilemma." The central theme of such situations is the decision on the part of a party to "cooperate or defect" (Rapoport and Chammah, 1965). This dynamic is present to some extent in many social situations, especially choice situations that relate to short-term versus long-term self-interest (sometimes termed "selfish versus altruistic") (Rachlin et al., 2001), in situations involving predictions as to choices that others will make (e.g.,Yi and Rachlin, 2004), and in many types of game-theoretic situations that involve social acts like voting in elections, coalition formation (Gelman, 2003), or behavior related to global warming (e.g., Clemons and Schimmelbusch, 2007).

The generic prisoner's dilemma diagram that follows shows four combinations of *a* and *b* cooperating or defecting, with four possible consequences.

$$n_i$$

$$\left(a\,^{ab}\mathbf{A}_{coop}^{ab p_1} \cap b\,^{ba}\mathbf{A}_{coop}^{ba p_2} \right) \quad \overset{\left(^{ba},^{ab}\right)}{_{ab}}\mathbf{C}_3^{a(\pm)^{M_4}, b(\pm)^{M_5}, p_6}$$

$$\left(b\,^{ba}\mathbf{A}_{coop}^{ba p_7} \cap a\,^{ab}\mathbf{A}_{def}^{ab p_8} \right) \quad \overset{\left(^{ba},^{ab}\right)}{_{ab}}\mathbf{C}_9^{a(\pm)^{M_{10}}, b(\pm)^{M_{11}}, p_{12}}$$

$$\left(a\,^{ab}\mathbf{A}_{coop}^{ab p_{13}} \cap b\,^{ba}\mathbf{A}_{def}^{ba p_{14}} \right) \quad \overset{\left(^{ba},^{ab}\right)}{_{ab}}\mathbf{C}_{15}^{a(\pm)^{M_{16}}, b(\pm)^{M_{17}}, p_{18}}$$

$$\left(b\,^{ba}\mathbf{A}_{def}^{ba p_{19}} \cap a\,^{ab}\mathbf{A}_{def}^{ab p_{20}} \right) \quad \overset{\left(^{ba},^{ab}\right)}{_{ab}}\mathbf{C}_{21}^{a(\pm)^{M_{22}}, b(\pm)^{M_{23}}, p_{24}}$$

$$n_j$$

Every act and the probability of every act is subject to prediction by the other party, and every possible consequence and its M and/or p for each party can be perceived and predicted by both parties, with all predictions being subject to further prediction by the other party at an indeterminate number of levels up the recursion hierarchy. Not shown in the diagram (due to graphical limitations) is that every prediction can also be a mis- or non-prediction, and can be further modified by an uncertainty on the part of the predicting party.

As in the case of temporal discounting research, behavioral contingency analysis of these types of situations helps identify the numerous operative variables that can be studied experimentally or used in simulations, and that can easily escape notice absent such analysis. Some of these are:

- The number of times the contingency has recycled with resulting learning history effects, as seen in studies that showed stabilization of choice behavior (e.g., Thomas and Feldman, 1988)
- Effects of other types of experimentally imposed learning histories.
- Different numbers of recyclings for different choices and consequences.
- Differences in the possible positive or negative consequences for each party (the consequences needn't be symmetrical for the parties)
- The effects of the magnitudes of the valences, which can also be asymmetrical.
- The probabilities of the consequences, as distinct from those pertaining to the choices, that is, the same sets of choices need not always result in the same consequence, or in consequences that have the same modifiers.

Also, as in the case of temporal discounting research, this analysis highlights the issue of using "real" versus verbally described consequences.

5.4. Specifying independent variables in neuroscience research

Mapping the functions of neural structures, particularly in the brain, is one of the important research areas of neuroscience. This type of research has often involved the establishment of correlations between some behavior and some neural activity. Goal directed action (Balleine and Dickenson, 1998), imitation (Decety, 2002), visual and auditory perception (Frost, 2002), doing arithmetic (Fehr et al., 2007), reasoning about beliefs of others (Saxe and Kanwisher, 2003; Grèzes et al. 2003), observing others interacting (Nelissen et al., 2005), focusing attention (Osaka et al., 2007), reading a story in which the action hinges on false beliefs (Saxe and Baron-Cohen, 2007), have been studied in this type of research.

Various techniques and methods, often including verbal instructions, have been used to generate the behaviors studied. The presumptive

independent variables would then be those instructions and experimental conditions, and the behaviors studied would then be dependent variables correlated with neural events. For example, when Kandel cites the study showing that "… the hippocampus is activated during imagined travel, when a taxi driver is asked to recall how to get to a particular destination," he implies that the independent variable included verbal instructions to the driver (Kandel, (2003), p. 306). The presumptive independent variables in such research are verbal instructions in conjunction with other experimental conditions (Dickins, 2005). These, together, comprise the prevailing behavioral contingencies.

Schaal (2003, p. 95) cites the example of research on the neuronal effects of stress, where specification of the behavioral contingencies that generate the presumed stress would always be critically important. The same is true of any research on neuronal activity during delay periods between various types of stimulus events, as in the Goldman-Rakic (1995a, 1995b) types of experiments, as well as in research on attention, automatization, and other behavioral phenomena often termed "cognitive."

The interpretability and replicability of a neuroscience experiment, or, for that matter, of any experiment, depends on how the independent variable is specified (Sidman, 1960). The goal, generally, is to specify it as operationally and quantitatively as possible, so that it will not be subject to varying interpretations. In the types of research described above, the presumptive independent variable is comprised of the entire set of conditions, including verbal instructions and relevant history variables, that can be presumed to affect the behavior and neural phenomena being studied.

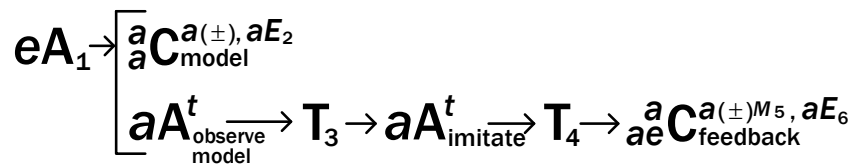### 5.5. Behavioral contingencies in neuroscience research

The present language provides a tool for codifying such contingencies and making their details explicit, precise, and replicable. Behavioral contingencies are presumed to be under the experimenter's control, and, depending on how well they are specified, able to be replicated. Putting the focus on the behavioral contingency puts the spotlight on such details as the precise wording of the instructions; the subject's prediction and/or perception of consequences within the contingency; the valences of consequences and their magnitudes; the precise specification of the subject's specified acts including their history, effort level, duration, and repetitiveness; incidental consequences like the act's valence (the intrinsic aversiveness or pleasurableness of performing it, independently of experimentally arranged consequences); the act's social significance; its

history of consequences imposed in the past by others; possible perceptions of the subject's acts by other parties; etc. The subject's relevant history regarding all of the above is always an important feature of the behavioral contingencies, and the contingency analysis would reveal the history's relevance and importance, and what is known or not known about it.

5.6. Example: The behavioral contingencies for imitation

Neurons that have come to be called "mirror neurons" (Rizzolati and Craighero, 2004) fire when the subject sees a certain type of action or activity being performed, like a monkey seeing a peanut being picked up, a dancer seeing a dancer perform (Calvo-Merino et al., 2005), or observing facial expressions of others. The neurons that fire during such observation are the same ones that would fire during performance of that same act by the subject (Ramachandran, 2000; Arbib, 2005). The discoverer of "mirror neurons," Giaccomo Rizzolati, used the term "affordances" –opportunities to mirror—presumably a type of behavioral contingency—for the independent variable of mirroring.

The diagram below (*a* is the subject and *e* is the experimenter) describes a general type of behavioral contingency that can function as an independent variable in an experiment on imitation.

$$eA_1 \rightarrow \begin{bmatrix} {}^{a}_{a}C^{a(\pm),\,aE_2}_{model} \\ \\ aA^{t}_{\underset{model}{observe}} \longrightarrow T_3 \rightarrow aA^{t}_{imitate} \Longrightarrow T_4 \rightarrow {}^{a}_{ae}C^{a(\pm)M_5,\,aE_6}_{feedback} \end{bmatrix}$$

This type of systematic behavioral contingency analysis can put the spotlight on many of the independent variable's detailed components that can easily escape attention. It is presented here to illustrate the complexity and the number of details that might need to be considered in a full specification of a possible experiment on something as straightforward-seeming as imitation. The above diagram prompts questions and issues like those listed below. This list is not intended be exhaustive, only illustrative.

 Regarding the model. The legend for the diagram would describe the model to be imitated, its presentation and exposure, the instructions to the subject relating to the model, the model's history for the subject, and its valence for both the subject and the experimenter.

Does the model consist of acts of another individual?

If yes, specify those acts.

Has the model been perceived previously?

Has the model been imitated previously?
If so, how long ago? How often?
How was the model consequated?
Regarding perception of the model:
Is the model visual, auditory, tactile, conceptual, other?
Does the model have any emotional connotations (E_2) for the subject?
Specify all relevant attributes of the model
If the model is physical, how far away is it?
If auditory, how loud?
If visual, how large? How bright?
What is the medium of exposure?
Is the perception of the model one-time or repetitive?
How long after perceiving the model is the imitative act initiated (T_1)?
Does the model remain available during imitation?
Is the duration of each exposure of the model experimentally controlled?
If so, how long is it?
Regarding the imitative act:
What are the instructions regarding the imitative act itself?
Does the imitative act involve a movement of body parts?
If so, what kind?
Is it a choice? If so, what are the choice alternatives?
Is it an utterance? If so what kind?
If it is verbal, what is the utterance?
If it is comprised of sounds, what are they?
What is the length or duration of the imitative act?
What is the contingency regulating the duration of the imitative act?
Has the imitative act been performed or practiced previously?
If so, how long ago and how many times?
How automatized is it?
Regarding consequences of the imitative act:
How long after the act is the consequence perceived (T_2)?
What is *a*'s prediction of the consequence and its attributes?
Do others (e.g., the experimenter) perceive the act and its consequence?
What is the valence of the consequence for the subject?
Does the consequence have any emotional connotations (E_6) for the
subject?
Has the subject been exposed to this consequence previously?
If so when and how many times?

5.7. *Methodological significance*

Clearly, some of these variables, all of which are possible features of the behavioral contingency for imitation, can be important in determining the neural effects that are observed as being correlated or not correlated with aspects of imitation. However, all of them would be appropriate for inclusion in a complete specification of the independent variable.

This type of systematic methodology may be useful in mapping the functions of neural structures and their correlations with behaviorally meaningful features of behavioral contingencies. In any such research, behavioral contingency analysis can provide road maps for the identification of the variables that can be isolated and selectively manipulated, including history variables (Schlund and Cataldo, 2005).

A further interesting opportunity for the application of contingency analysis in specifying the independent variable is presented by the growing literature on the neural correlates of the behavioral phenomenon termed "false belief" (e.g., Saxe, 2007; Greze et al., 2003). In the behavioral contingency language, the core dynamic of observing another party having

a false belief would be codified simply as $^{ab^x}C$ --party a's perception of party b's misprediction of consequence C. Again, the full analysis of this type of contingency would reveal the numerous associated variables that could play important roles.

This use of behavioral contingency analysis may also provide a methodology for comparing human and animal results in the mapping of brain functions, especially in non-verbal types of behavior.

6. Progressive Changes and Registers

6.1. *Pumping water into a bucket*

There are important contingencies in which a consequence keeps changing as a function of recyclings or other variables. The codification of such contingencies requires the use of a register that shows the changing magnitude of the consequence.
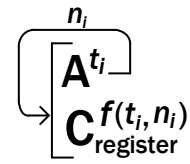
This diagram describes the water level in a bucket being filled using a hand pump. Every pumping act A increases the water level by one increment ΔL. The Σ expression in the $C_{register}$'s magnitude position (attribute quadrant) shows the amount of water in the bucket after every n_i such As, calculated as the

$$\begin{array}{c} n \\ \boxed{A \longrightarrow C_{\Delta L}} \\ C_{register}^{\sum_{0}^{i}(n_i \cdot \Delta L)} \end{array}$$
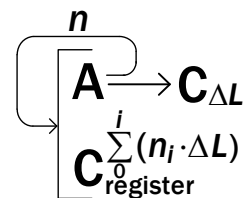
cumulative number of times (n_i) the *A* has recycled at every point times the change in the water level ΔL with each cycle.

6.2. Other registers of progressive changes

The diagram at the right shows the generic representation of contingencies that involve progressive changes as a function of i, $f(n_i, t_i)$. *Examples:*

$$\begin{array}{l} \overset{n_i}{\boxed{\begin{array}{l} \mathbf{A}^{t_i} \\ \to \mathbf{C}^{f(t_i, n_i)}_{\text{register}} \end{array}}} \end{array}$$

(A) When $f = \sum(n_i / t_i)$, the register represents the rate at which act *A* would be occurring at any given value of i, for a desired range. *Instances*: response rate in experiments, proficiency assessment when practicing a skill.

(B) When $f = \sum(t_i / n_i)$, the register could show the act's average duration after every n_i repetitions, within a desired range. *Instances*: indicator of speed when learning to do a job faster or practicing a skill, keeping track of the average time between contractions during labor.

(C) When $f = \sum(n_i)$, the register shows the total number of acts that have occurred at every value of *i*. *Instances:* points scored in a game, money saved up so far, number of votes so far during election coverage.

(D) When $f = \sum(t_i)$, the register shows the total elapsed time value of *i*. *Instances:* watching the clock, concern that a job is taking too long.

(E) Exponential functions could show progressive effects of various kinds of growth or proliferation, of exponential decay, or of other asymptotic functions.

6.3. Short-term and long-term contingencies: Global warming

When sustained repetition of a type of act has a cumulative long-term negative effect at individual, societal, or national levels, such acts are often maintained by their short-term positive consequences. There are also acts whose sustained repetition has short-term negative and long-term positive consequences, (e.g., IRA savings accounts, doing aversive work to accumulate money).

The diagram at the right shows some of the behavioral dynamics of global warming— the cumulative consequence of many individual acts like coal burning or burning of vegetation that are maintained by their short-

$$\begin{array}{l} \overset{n}{\boxed{\begin{array}{l} \mathbf{A} \to \mathbf{T}^V_{\text{short}} \to \mathbf{C}^{+}_{\Delta\text{temp}} \\ \mathbf{C}^{(-)\overset{i}{\underset{o}{\sum}}(n_i \cdot \Delta\text{temp})}_{\text{temperature register}} \end{array}}} \end{array}$$

term positive consequences with possible resulting long-term temperature change. In this diagram, there is no identified end point of the process, unlike in the case of filling a bucket with water. The register $C_{\text{temperature register}}$
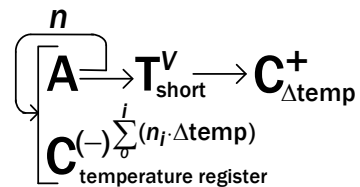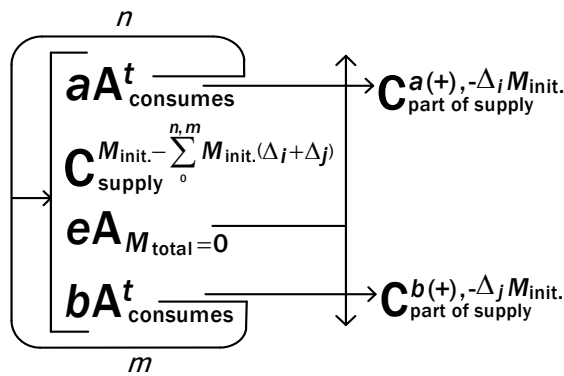
is shown as having the magnitude M of its negative valence (again represented by the formula in the exponent position) being cumulatively and progressively incremented as a function of the number i of repetitions. This type of analysis can help identify the roles of some of the variables that may affect global warming (e.g., Clemons and Schimmelbusch, 2007).

Other familiar examples of this same contingency structure are the possible long-term effects of smoking and the entire gamut of addictive behaviors, of consuming excessive sugar on health, or of dumping chemicals and wastes into waterways. All such contingencies involve repetitive behavior with positive short-term and negative long-term consequences, and differ only in the descriptions of the As and Cs and of the variable that is changing (e.g., Δh for health or $\Delta temp$ for temperature, as above). In all these cases, the $C_{register}$ would show the cumulative effect at every interim point.

6.4. Competitive depletion of a limited supply

If two parties concurrently and incrementally consume a limited supply, the ultimate consequence is depletion of the supply. *Examples:* cats lapping milk from the same bowl, overfishing in a body of water, overlogging a forest.
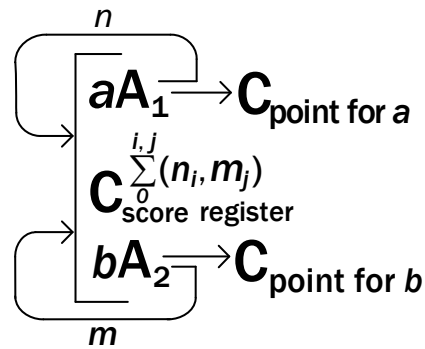
In the diagram below, the initial magnitude $M_{init.}$ of the limited supply C_{supply} would be progressively reduced by the amounts consumed by the two parties—a representing one party and b all the others. Every n_i^{th} of a's n consumption acts reduces the supply by an additional $\Delta_i M_{init.}$, and each m_j^{th} of b's m consumption acts reduces the supply by an additional $\Delta_j M_{init.}$[24] The t attributes of the consumption acts can represent rates or durations. When the M of the supply has thus reached zero or some other threshold, the external agency e terminates ($eA_{M=0}$) the consumption cycles. The description of the effects of this contingency can be tuned by the usual *perceive* and *predict* modifiers of the three Cs and by the values of their Ms or ΔMs.

$$n$$
$$aA^t_{consumes}$$
$$C^{M_{init.}-\sum_0^{n,m} M_{init.}(\Delta_i+\Delta_j)}_{supply}$$
$$eA_{M_{total}=0}$$
$$bA^t_{consumes}$$
$$m$$
$$C^{a(+),-\Delta_i M_{init.}}_{part\ of\ supply}$$
$$C^{b(+),-\Delta_j M_{init.}}_{part\ of\ supply}$$

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[24] The term could obviously be any function defining the magnitude of the change at each decrement.
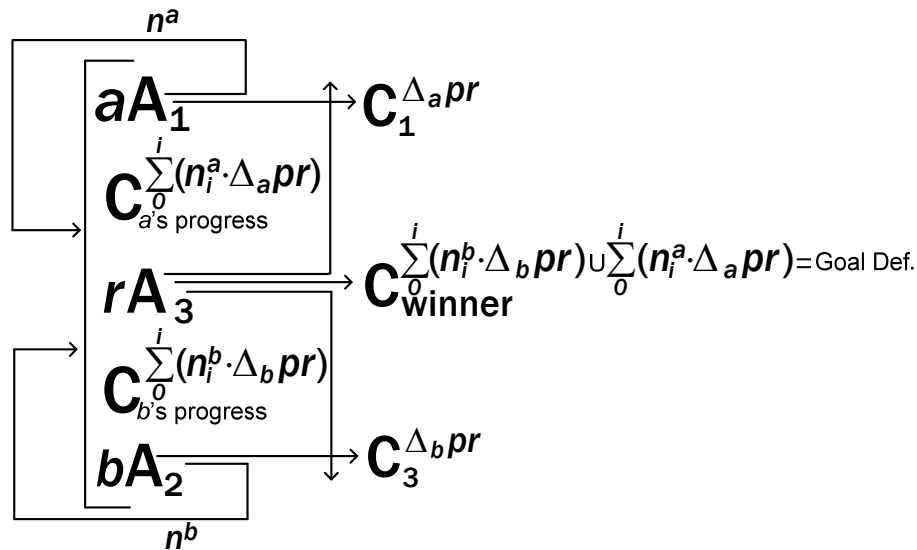
6.5. Registering points in a game: Keeping score and communicating it

In many kinds of games, like basketball, soccer, or football, the winner is the player or team that scored the most points, often by the end of a certain time period. In the diagram, every aA and bA represents the scoring of a point, and the register $C_{\text{score register}}$ shows the scores of the two teams during the game. The score, shown by the summation formula, is a magnitude dimension of the $C_{\text{score register}}$. The parties perceiving it are not shown in the diagram.

$$n$$
$$aA_1 \longrightarrow C_{\text{point for } a}$$
$$C_{\text{score register}}^{\sum\limits_{0}^{i,j}(n_i,m_j)}$$
$$bA_2 \longrightarrow C_{\text{point for } b}$$
$$m$$

6.6. Feedback regarding progress in races

Most games, races, or contests end when one of the parties has crossed a finish line, gained a certain number of points or more points than the other party at the end of time T, or has met some other definition of the goal whose achievement determines the winner.

$$n^a$$
$$aA_1 \longrightarrow C_1^{\Delta_a pr}$$
$$C_{a\text{'s progress}}^{\sum\limits_{0}^{i}(n_i^a \cdot \Delta_a pr)}$$
$$rA_3 \longrightarrow C_{\text{winner}}^{\sum\limits_{0}^{i}(n_i^b \cdot \Delta_b pr) \cup \sum\limits_{0}^{i}(n_i^a \cdot \Delta_a pr)} = \text{Goal Def.}$$
$$C_{b\text{'s progress}}^{\sum\limits_{0}^{i}(n_i^b \cdot \Delta_b pr)}$$
$$bA_2 \longrightarrow C_3^{\Delta_b pr}$$
$$n^b$$

In the above diagram, the $_aA$s and $_bA$s represent the contestants' acts that produce progress toward the goal. These can consist, for example, of a runner's strides or a rower's oar strokes. The two progress registers show each contestant's progress after any particular number of such acts, as the

summation of all progress increments up to that point. In such cases, the winner is declared, and the contest ended, by a referee or by automatically imposed rules.

The $\Delta_a pr$ symbol represents an increment of a's progress toward the goal, and similarly, $\Delta_b pr$ represents b's. Each contestant's total progress after any particular number of As is represented by the summation of all his progress increments up to that point, shown in the two registers of progress. The Goal Definition is the specification of how the winner is determined—by the crossing of a finish line, or by some other criterion of victory. The winner is the one whose total progress first reaches the Goal Definition (the $\cup$ sign means "or"), whatever that is. The agent r in rA_3 refers to "referee" or "rule," whichever best describes the agency of the declaration of the winner.

The pre-subscripts of the progress registers (omitted in the above diagram) would show whether each party has access to their own and/or each other's progress toward the goal, information that is usually important in such contingencies. *Examples of races or contests where each party knows only its own state of progress:* Two research teams racing to be first to publish an important discovery; two corporations competing to be first to bring a new product to market.

6.7. Divergent points of view: Loans and insurance

A loan agreement is a contract between a borrower and a lender, represented by the "and" expression for contracts. For the loan shown in the diagram below, interest is to be paid monthly ($T^{mo.}$) and the register shows the accumulation of interest while the loan is outstanding.
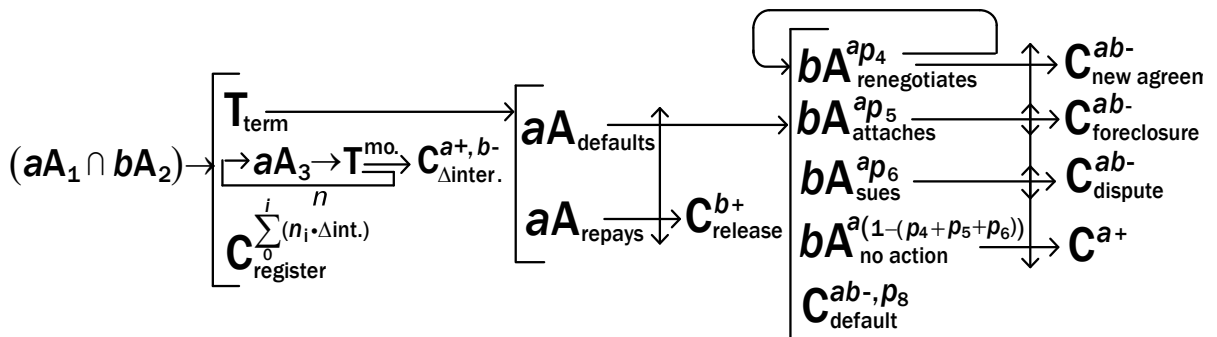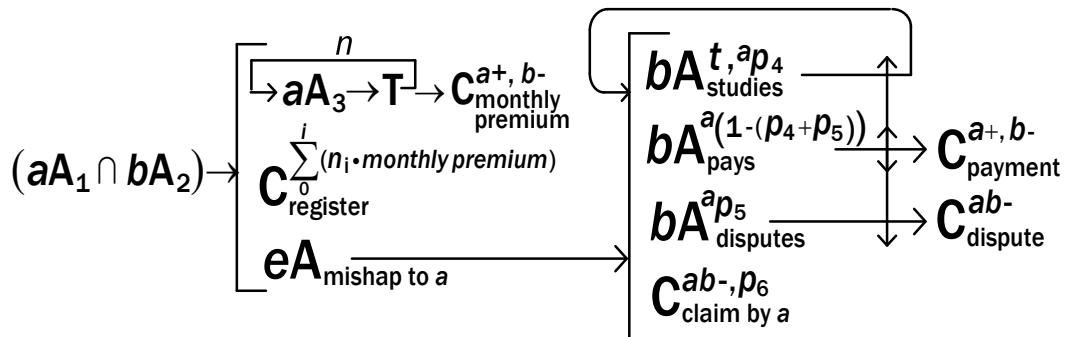

When the loan reaches its term T_{term}, the interest payment cycle is terminated and the borrower a either repays the loan or defaults. From lender b's point of view, these consequences of a's decision process would

have probabilities p and $1-p$.

If a defaults, b can do one of four things: Renegotiate, attach the collateral, sue, or do nothing. These four acts are mutually exclusive, as shown by the reciprocal vertical arrows. Renegotiation is shown as either recycling the contingency with a return to the same four options, or it can result in a new agreement. Attaching consequates a foreclosure action. Suing consequates a dispute. All of these are negative for both parties. Taking no action, the probability of which is the complement of the sum of the other three, is positive for a.

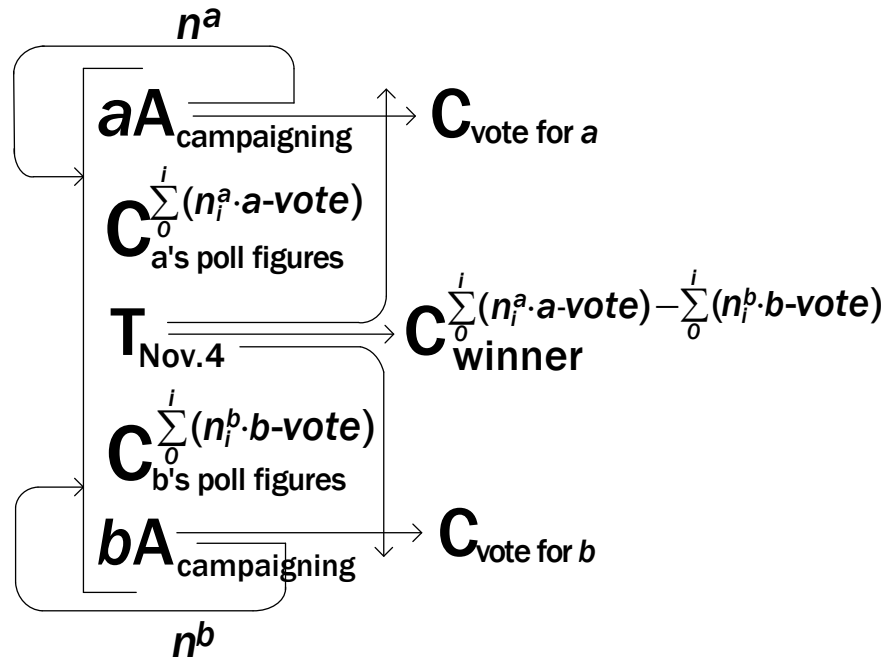### 6.7.1. Insurance contracts

A similar familiar example is an insurance contract between an insurer b and an insured a, which usually involves the payment (aA_3) of insurance premiums on a time cycle T analogous to that for interest payments. In the diagram below, a register for the accumulated monthly or yearly premium payments reflects the perspective of the insurer. An external agency e unpredictably (p_6) generates possible mishaps against which the beneficiary a is insured. Again, the possible acts of the insurer in case of such a mishap (e.g., paying the claim, disputing it, undertaking a study of circumstances), could be viewed from the beneficiary's point of view as mutually exclusive alternative consequences with different probabilities, or from the insurer's point of view as a choice or decision. The study can take time t and consequates a return to the three possibilities—payment, further study, or disputing the claim.

$$(aA_1 \cap bA_2) \rightarrow \begin{array}{l} \overset{n}{\underset{}{\rightarrow aA_3 \rightarrow T}} \rightarrow C^{a+,\,b-}_{\text{monthly premium}} \\[2mm] C^{\sum_0^i (n_i \cdot \text{monthly premium})}_{\text{register}} \\[2mm] eA_{\text{mishap to } a} \end{array} \rightarrow \begin{array}{l} bA^{t,\,^a p_4}_{\text{studies}} \\[2mm] bA^{a(1-(p_4+p_5))}_{\text{pays}} \rightarrow C^{a+,\,b-}_{\text{payment}} \\[2mm] bA^{^a p_5}_{\text{disputes}} \rightarrow C^{ab-}_{\text{dispute}} \\[2mm] C^{ab-,\,p_6}_{\text{claim by } a} \end{array}$$

6.8. Elections

In elections, the campaigning acts $A_{\text{campaining}}$ of each party are assumed to consequate votes for it. The summation term in the two registers shows the presumed number of votes each party has accumulated up to any point in time as a result of the number n of its campaigning acts, possibly as

indicated by poll figures. The winner is determined by the difference in the number of votes accumulated by the two parties by Election Day.

$$n^a$$

$$aA_{campaigning} \quad C_{vote\ for\ a}$$

$$C^{\sum_0^i (n_i^a \cdot a\text{-}vote)}_{a's\ poll\ figures}$$

$$T_{Nov.4} \quad C^{\sum_0^i (n_i^a \cdot a\text{-}vote) - \sum_0^i (n_i^b \cdot b\text{-}vote)}_{winner}$$

$$C^{\sum_0^i (n_i^b \cdot b\text{-}vote)}_{b's\ poll\ figures}$$

$$bA_{campaigning} \quad C_{vote\ for\ b}$$

$$n^b$$

7. Applying behavioral contingency analysis

7.1. The value of behavioral contingency analysis

The behavioral contingency language can be used to address practical problem situations in diverse fields of human affairs. If the behavioral outcomes of a situation are important—potentially very valuable or very threatening—the time and effort involved in analyzing the contingencies may be justified.

In practical applications, the analyst's goal would usually be to gain a better understanding of the contingencies that are at play in the situation so as to increase his ability to modify them and thereby come closer to achieving the desired behavioral outcomes. The result of the analysis may reveal that the contingencies are different from what they were thought to be or that there are some at play that weren't noticed, especially when the situation is complex and involves multiple parties. A systematic behavioral contingency analysis may also expand the list of the parties that could be considered, their possible acts and the consequences of those acts, the

probabilities and magnitudes of those consequences, and the parties' relevant perceptions, predictions, misperceptions, and mispredictions regarding aspects of the situation.

In research applications, the value resides in a clearer and more complete understanding of the behavioral contingencies, and in their objective and operational specification when they constitute independent variables, as discussed in section *5*.

7.2. Using prompts as an algorithm

The prompts listed below constitute an algorithm for guiding the process of performing a behavioral contingency analysis of any situation. These prompts help the analyst register every relevant thing he knows or assumes about the situation being analyzed. Each prompt is understood to be qualified by the words "where relevant to the analyst's desired focus." In practice, the answers to most of the listed prompts would not be relevant to the desired focus and therefore not needed.

- Identify and list the parties involved in the situation.
- For each party, indicate its possible act(s) *A*.
- For each act, indicate its possible consequence *C*.
- Indicate the valence of each *C* for each party.
- Indicate the magnitude *M* of each valence.
- For each act (where relevant) indicate a duration variable.
- For each *C*, indicate its probability *p*.
- For each *p*, indicate the party(ies) that might have a prediction/estimation of it.
- For each *C*, indicate the time lags *T*.
- For each *T*, indicate any *A* or *T* that might change or terminate it.
- For each *C*, indicate any *A* or *T* that might prevent or change it.
- For each termination, indicate the replacing *C* or contingency.
- For each *p*, indicate any *A* or *T* that might change it.
- For each *A*, *C*, agent of *A*, and their modifiers indicate the party(ies) that perceive, predict, misperceive, mispredict, or do not perceive or predict it.
- For each *M*, indicate the party(ies) that misperceive or idiosyncratically perceive it.
- Indicate all *A*s and *T*s that may initiate recycling arrows, and the termination points of these arrows.
- For each recycling arrow, indicate *n* where it has significance.
- Define any consequence that changes as a function of *n*.
- If the change in that quantity has an end point, define that end point, and

the consequence *C* of it being reached.

When responding to prompts that involve time, magnitude, or probability, the analyst may initially just note the variable, and only when known would he indicate actual or relative values.

Just going through the process of responding to these prompts would tend to improve an analyst's understanding of the operative contingencies, the parties to be taken into account, and the factors and variables to be considered. The analyst would also be prompted to identify and confront areas of ignorance or uncertainty about the situation.

7.3. The role of behavioral science

The contingency structures that an analyst produces when analyzing any given situation[25] would flow directly from the information, beliefs, and assumptions he registered and entered in response to the prompts. To predict the resulting behavioral outcomes, he would draw upon his knowledge of the behavioral effects of various types of contingencies, of various types of behavioral histories, of signaling positive or negative consequences having various relative magnitudes and probabilities, of cues regarding contingencies, and of time factors. The contingency diagrams themselves obviously do not embody such knowledge and therefore cannot generate predictions of behavioral outcomes. Such predictions require the application of knowledge provided by the behavioral sciences.

The analyst can iteratively revisit and readjust the contingency information he entered in response to the prompts when he sees a discrepancy between the predicted behavioral outcomes and his expectations. The modification and design of contingencies by this general method could become one of the practical uses of contingency analysis in operations research, computer simulation, and the management of behavioral contingencies in any area of human affairs. As the data base of knowledge provided by the behavioral sciences continues to expand, the usefulness of behavioral contingency analysis can be expected to increase

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[25] In practice, large and intricate diagrams are difficult to display in two dimensions. The analyst can bypass the need to do so by using the prompt method, which permits free use of the language's hierarchical/recursive features to express any desired nuance without the graphical and geometric constraints of printed diagrams. The creation of more complex diagrams will require computer software that can convert the registered information into multi-dimensional behavioral contingency structures. While these would exist only in the computer memory, two dimensional diagrams of particular portions could be printed out for use in checking and debugging. The development of software with these capabilities is in progress at the time of writing.

correspondingly.

7.4. The pedagogic value of behavioral contingency analysis

The sometimes-heard comment that behaviorism has limited relevance to complex human behavior or to practical concerns can be answered by pointing to the sweeping applicability of behavioral contingency analysis. Students who learn to use the present behavioral contingency language, and make efforts to apply it, quickly become persuaded of the great and general relevance of behavior analysis to human affairs.[26]

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[26] A PowerPoint tutorial on the behavioral contingency language and its application can be downloaded from the website www.mechnerfoundation.org. Estimated completion time: 3 to 15 hours, depending on time spent on the exercises. The course received a dry run at AILUN University in November of 2007 under the auspices of Prof. Giulio Bolacchi.

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