Comprehending Aggressive Behavior Following A Brain Injury:

An Explanatory Framework For Neurobehavior

J. Kupfer, P. Killeen, & R. Buzan

"Why is he behaving this way?" is the central question family members of patients with TBI pose to our clinical team concerning extreme agitation, antisocial behavior, insensitive interactions, or other manifestations of his condition. We give various answers devolving from the disciplines of our team members. Accurate though these explanations may be, they often don't hang together without satisfying the questioner. What is wrong with our explanations? Was something lost in translation? Perhaps some features that could provide a complete explanation were omitted. This paper presents a framework for explanations that permits a more integrated and complete picture, and reminds practitioners of aspects that should be included in a thorough understanding of behavior after TBI.

PART ONE: Explaining a behavioral event: "How did that lamp break?"

Consider the following family situation: a Sunday afternoon family brunch, post-meal conversation around the dining table. Suddenly we hear the laughter of children, footsteps running down the stairs and through the living room. The front door slams, followed by the sound of the lamp crashing to the floor in the foyer. Table 1 organizes the diversity of explanations by the family members for this household accident.

Table 1. Dialogue amongst family members following a behavior event.

Event is Described	Focus	"Cause"
	Focus on the behavior	
"I've told them not to run in the house"	Running describes the form of behavior	Formal
"Joey led the charge out the front door"	Trigger was Joey	Efficient
"They were bored in here with all the adult talk"	State of the system: Arousal ready for displacement	Material
"And they were eager to play with that new hoop set you got for Joey's birthday."	Purpose, function,	Final
"Well let's not forget the sugar high from that excellent dessert"	State of the system: Arousal ready for displacement	Material
	Focus on environment	
"It's smithereens now—no way even grandpa could fix it"	Describes current status	Formal
"It's not completely their fault, Helen. That old lamp was pretty tippy: A strong wind would knock it over"	Many possible ways for it to break	Efficient
"It was Joey who bumped it over"	The particular trigger that tripped it	Efficient
"Helen! It was missing its fourth leg!!"	Lack of structural integrity	Material
"Joseph, I think you loosened it just to make this happen, given how you hated that old lamp!"	The reason the leg was loosened and broken off	Final

We see that an unexceptional event may be examined from various points of view, all which may be correct. Similarly, brain and behavior sciences provide scientific explanations of events from various points of view, but even they typically fall into several classes. These are the classes of explanation identified by Aristotle that are required before we may claim to truly understand a phenomenon (Hocutt, 1974).

Aristotle's framework for explanations

Aristotle's name for these classes of explanation was mistranslated as "Causes", a proper title for only one type (efficient cause). This led to his schema being dismissed as confusing and even teleological. A better class name is *reasons for*, or *becauses* (Killeen, 2001). Aristotle's framework addresses the broad range of possible explanations for any phenomenon, and coordinates these explanations to arrive at a more integrated understanding. We can utilize this model to describe behavior following a brain injury.

Formal causes (names, forms, and models) are the ways we talk about, represent and describe events. They translate their essential form into words, numbers or diagrams. Simple descriptions, such as the example above ("running resulted in the lamp breaking") can get the ball rolling, but these can be extended to include models, metaphors, logical phrases, equations, schematics, blueprints, or flowcharts that help us organize, summarize, and communicate phenomena. Behavioral experts use DSM diagnoses as "formal causes" to describe and explain patient behavior, and brain injury professionals use the Glasgow Coma Scale or Ranchos Los Amigos Scale as formal descriptors of a patient's condition. Physicists and astronomers utilize differential equations as their formal models. Behavior analysts describe behavior with three-and four-term contingencies for simple and conditional discriminations (antecedent, behavior, consequence, A-B-C).

Efficient causes (triggers) refer to the necessary and sufficient conditions to bring about a change in state (factors triggering an event). These are commonly what is meant by "causes" (Joey running in the house caused the lamp to fall). Efficient causes of reckless behavior identify events or people that trigger action, as well as events that can minimize or prevent its occurrences. Efficient causes are conditions sufficient to trigger the phenomenon being explained that were operative at the critical moment. There may be many possible sufficient conditions, just as there are many possible roads to Rome; functional analyses clarify which ones were operative in a particular case. Necessary causes are usually invoked to explain failures of expected outcomes: Why didn't the car start? It needed gas (electricity, functional starter, etc.), which are necessary to get the show on the road. Explanations that rely only on efficient causes may become overly *mechanistic*, thereby distracting investigation from the substrates and underlying mechanisms.

Material causes (machinery) refer to the substrates and underlying mechanisms. These causes are of most interest to medical and health professionals who are trained to understand, diagnose, and treat problems with underlying mechanisms. For instance, high blood glucose may be due to diabetes (formal cause) that may result from insufficient production of insulin (material cause), complicated by eating Twinkies (efficient cause). Analogously, parents often turn to material causes to explain challenging behavior in children, particularly when the efficient causes and triggers are inconspicuous and difficult to pin down accurately. "Character" is too often the scapegoat. Explanations that rely exclusively on material causes can become *reductionistic*, omitting relevant connections to triggers and consequences.

Final causes (functions) are the purposes of an event, what has brought about or sustained a phenomenon or process. Not all phenomena have final causes, but like cerebral edema, may represent break-down or failure modes of systems that serve an important function in normal circumstances. Proximate final causes may refer to the immediate consequences of some behaviors or misbehaviors, such as ones that may sometimes occur with the syndrome of TBI: escape and avoidance of difficult situations. Ultimate final causes may involve a learning history that has resulted in current maladaptive behavior.

PART TWO: Applying Aristotle's framework to neurobehavior treatment and the role of Behavior Analysis

When a person becomes agitated following a brain injury, we try quickly to comprehend this event. We start with a description such as: "He struck the therapist during his therapy session." This event triggers communication with the family, therapists and staff, the physician and other medical professionals, the case managers, insurance adjusters, and so on. The descriptions of the incident set us on our respective paths to explain behavior in order to derive an effective intervention. Agitation has crossed the formal threshold to aggression: physical or verbal behavior directed at another person with the intention to cause harm. We want to know about the specific necessary and sufficient conditions that triggered the aggression (efficient causes), underlying mechanisms (material causes), the function or purpose it served (final causes), and best ways to talk about it, both for treatment, and for communication with family members (formal causes). We may require details about immediate (proximate) variables, as well as enduring variables from the past (personal history, family history) suggesting ultimate reasons for such aggression. In short, we need to communicate much in a brief period of time for intervention to commence, and we need to continue dialogue throughout treatment to be sure that the stakeholders share our framework.

A Case Study

Sam is a 50-year old male who received a significant brain injury when he was struck by a motor vehicle at the age of 14. Prior to admission to our facility, Sam spent most of his adult life residing at institutional settings where he exhibited physical and verbal aggression, requiring an increased level of staff supervision, and occasional temporary placement in isolated sections of the referring facility.

Upon admission to our program, a functional assessment of problem behaviors (Questions About Behavior Function - QABF) was conducted. The results suggested physical and verbal aggression were functionally related to attention delivered by caregivers or therapists: When caregivers' and therapists' attention to Sam decreased, the probability that he would engage in physical and verbal aggression that resulted in attention from others (e.g., redirection, physical intervention or containment) increased. He had the staff on a schedule of negative reinforcement: their lack of attention generated an increase in the frequency of aggression that resulted in a swift staff reaction to escape or delay his aggressive behavior.

On the basis of the functional assessment, differential reinforcement of alternative behavior (DRA) was introduced to treat aggression. Under this procedure all caregivers and therapists: (1) provided little or no attention upon physical and verbal aggression by Sam; and (2) shifted the schedule of reinforcement to deliver attention contingent upon Sam's use of more cordial, alternative attention-requesting behaviors. During the course of treatment his antipsychotic medications were tapered and discontinued as aggressive behaviors decreased.

Figure 1 summarizes the medication adjustments for Sam during treatment. Data for verbal and physical aggression were recorded according to a 30-min partial interval count for occurrence/non-occurrence of target behaviors.

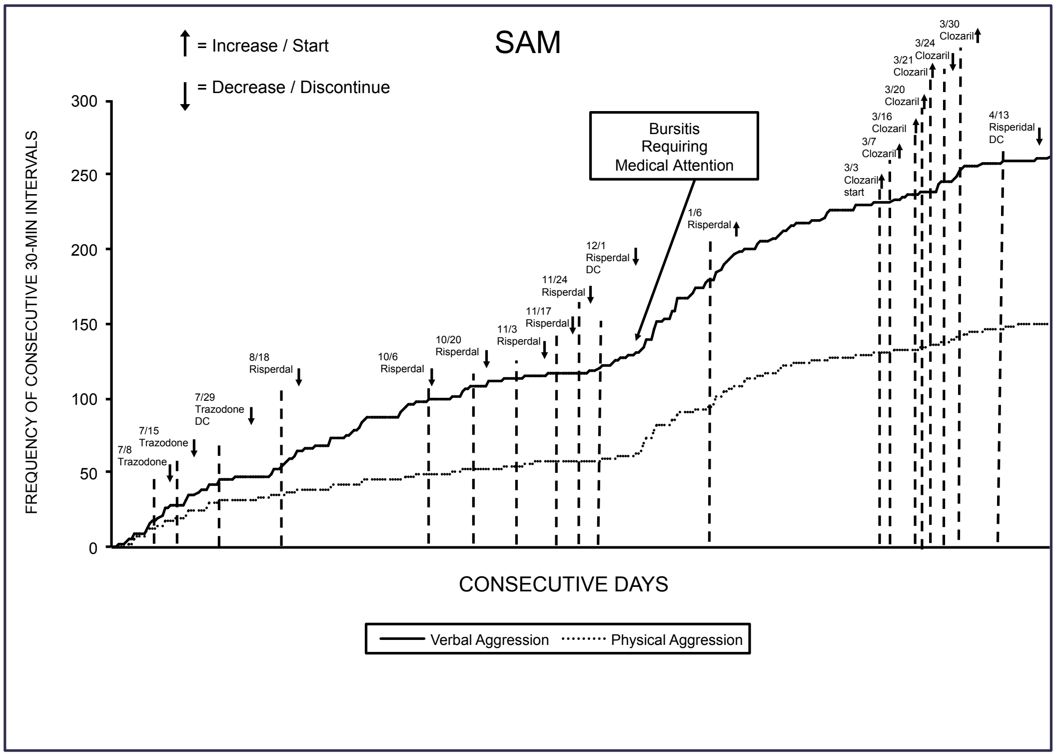

Figure 1. Cumulative curves for Sam. Graph shows a point in treatment is which resident received brief inadvertent attention contingent upon verbal aggression. Physical aggression curve (dotted line) and verbal aggression (solid line) are shown for ten months of treatment. ***(From Kupfer, Eastridge, Buzan, & Castro, 2012)***

Vertical dashed lines indicate medication adjustments during the course of treatment, and labels indicate the name of the medication and the adjusted dose. Down-arrows preceding medication labels indicate reductions and discontinuations; up-arrows preceding medication labels indicate increases or initiations. From the slope of the curve we may infer changes in response rates— decreases in the slope of the curve over time (negative acceleration) indicate decreases in the occurrence of aggression. In general, these data show variable but negatively accelerating trends; physical aggression rates (dashed line) were lower than those for verbal aggression (continuous line).

Reductions in trazodone and risperidone often occasioned brief bursts of verbal aggression, which gradually decreased to low or zero rates until the next medication taper. Concurrent with the discontinuation of risperidone, Sam developed bursitis in his elbow from an infection that required medical attention. This brief delivery of attention was correlated with extreme verbal and physical aggression in response to pain in his elbow. After medical treatment was administered, DRA treatment was reinstated for the remainder of the study. However, it was unclear whether this brief delivery of medical attention inadvertently produced and sustained higher rates of aggression that lasted for approximately five weeks, at which point risperidone was reinstated, producing a gradual reduction in the frequencies of target behaviors. When these target behaviors approached zero rates, clozapine was introduced and substituted for risperidone, producing brief but decreasing bursts of target behaviors. Subsequently, risperidone was discontinued without any increase in aggression.

In this example the search for efficient causes (decrease in level of staff attention) and final causes (attention received) resulted in an intervention to change the triggers and consequences. Aggression gradually decreased as a function of shifting the contingencies of reinforcement. This functional relation was confirmed inadvertently when the brief, but intense complaints of pain by Sam produced an unavoidable medical attention to treat bursitis. Additionally, a material explanation (chemistry potentially more responsive to clozapine than to risperidone) produced an intervention based on a review of the current medications and a gradual taper to determine therapeutic effectiveness, and eventual substitution of medications that was either more effective or had fewer agitating side effects.

Attempts at efficient and material explanations expose a range of variables that can contribute to understanding complex behaviors ranging from ADHD (Killeen, Tannock, & Sagvolden, 2012), to hypnosis (Killeen & Nash, 2003).

Further benefits from analyses of efficient causes

Closer examination of subtle environmental triggers and contingencies reveals interesting and unexpected efficient causes for behavior that can inform neurobehavior treatment. For example, recent research, (Mace, McComas, Mauro, Progar, Taylor, Ervin, & Zangrillo, 2010), has suggested that DRA procedures may actually prolong extinction effects (causing "extinction bursts") due to *behavioral momentum*, thereby prolonging the persistence of target behaviors. Conducting a DRA procedure in a separate context from which learning the target behavior occurred can, however, decrease resistance to extinction. Similarly, there are situations in which the extinction component of the DRA procedure cannot be implemented— combative behavior may be too intense to stop or directed toward others in ways that cannot be ignored. In a series of experiments Athens and Vollmer (2010) demonstrated that behavior treatment plans that involve manipulating reinforcer duration, quality, delay, or a combination of these in ways that favors appropriate behavior rather than problem behavior can still produce more appropriate responses, even though problem behavior received occasional (albeit, lower) reinforcement. In both of these cases, the procedures have some risks consequent on implementation (increases in target behavior), but these can be minimized with refinement of the consequences (final causes) thereby averting the need to use medications (material necessary causes) to address the problem.

Behavior analysis techniques can yield benefits in addition to merely addressing problem behaviors as in the above example. An analysis of triggers and consequences can produce more robust effects when teaching adaptive living skills. Decades of research in applied behavior analysis has generated instructional methods for teaching in homes and classrooms, as well as vocational and rehabilitation settings, such as errorless learning (Chandonnet & Kupfer, 2014; Sidman, 2012), fluency and precision teaching (Binder, 1996), and stimulus equivalence training (Sidman, 1994). Research suggests that efficient and final explanations are primarily useful when there is a problem behavior to reduce or eliminate, but other formal explanations (e.g., TBI patients often lack social competence) help clarify potential deficiencies in appropriate responding that may be the result of environmental contingencies that sustain inappropriate behaviors. Thus, if the individual with brain injury could acquire skills in PT, OT, SPL, and so on more quickly and effectively by changing teaching methods, problem behaviors might be less likely to occur. Teaching methods derived from ABA (efficient and final causes) thereby complement those methods used to increase brain, body, and sensory health (material causes).

A thorough bibliography of evidence-based teaching methods for persons with brain injury is located on the Brain Injury Webpage for the Cambridge Center for Behavioral Studies: www.behavior.org.

Pursuing interrelationship between efficient and material causes

What are the interactions between efficient causes and material causes? In the example of the broken lamp, one family member focused on reckless behavior in the home, but another alluded to the causes involving the environment—a wobbly lamp, an accident waiting to happen. In neurobehavior treatment, proximate (temporally immediate, relevant and conspicuous) influences over behavior are revealed during initial assessments and ongoing progress reviews, but access to past environmental events or historical influences (medical records, psycho-social histories, interviews, and verbal reports) are relevant as well. Expanding the causal time frame, an examination of family history may reveal generational patterns that implicate ultimate genetic influence. Neurobehavior does not simply treat a person with a brain injury; it provides treatment within a context of immediate and historical influences.

Figure 2 represents the broader influences of both ultimate variables (across multiple generations) and proximate variables (most recent or conspicuously present) on the Aristotle's Four Causes to explain the causes of ADHD (Killeen et al, 2012). In this figure, the inner set are proximate (molecular) causes and the outer set ultimate (molar) causes. Triggers of symptoms (states) are proximate efficient causes; whereas, triggers of the phenotype (traits) are ultimate efficient causes. Material causes comprise the hardware underlying the behavior (proximate, neurophysiology) and the syndrome it instances (ultimate, genetic). Recursive arrows show outcomes can modify the system to change the sensitivity to correlated stimuli and responses through shifts in attention, learning, and even reframing of the situation.

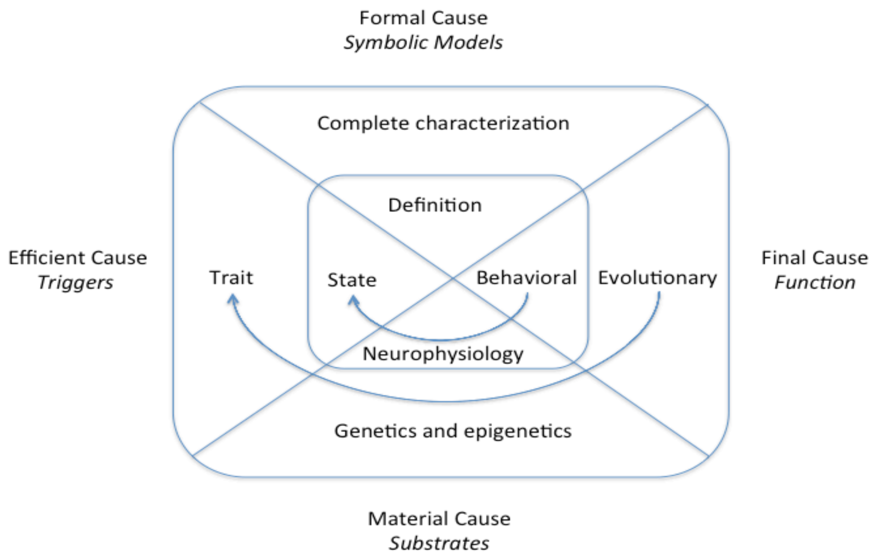

Figure 2. The causal framework. Each of Aristotle's four causes constitutes issues that must be addressed before a phenomenon is understood. The inner set are proximate, or molecular causes; the outer set are ultimate, or molar causes. Exposition begins with a simple definition or description, such as found in psychiatric manuals. These simple models map critical behaviors onto vernacular words and numbers. Triggers of ADHD symptoms (states) are proximate efficient causes; triggers of the phenotype (trait) are ultimate efficient causes. Necessary causes at each level are sought that, when removed, will lessen or remove the syndrome or symptom. Material causes comprise the machinery that causes the symptom (proximate: neurophysiology) and syndrome (ultimate: genetic). The events that maintain the behavior, such as immediate gratification, or the syndrome, such as enhanced fitness of the extended phenotype, are the final causes. The recursive *arrows* show that such outcomes can modify the system to change its sensitivity to correlated stimuli or responses; in the short term this is called attention and learning, in the long term it is called Darwinian evolution. A general theory of ADHD constitutes the highest level of formal cause. ***(From Killeen et al., 2012: The four causes of ADHD)***

For many reasons, isolating interactions between efficient and material causes of behavior is difficult; however, the topic is of paramount importance in behavior analysis, particularly in relation to interactions between: genes and environment (Suomi, 2002), consequences, genes and brain development (Schneider, 2012), unique conditioning histories and drug effects (Branch, 2006; Terrace, 1963), and behavioral and biological systems (Thompson, 2007). Accordingly, the language of the behavior analysis community continues shifting to accommodate the expansion of efficient and material explanations (Hineline, 1980; Hineline & Groeling, 2011). Skinner (1989) had pointed us in this direction:

> "There are two unavoidable gaps in any behavioral account: one between the stimulating action of the environment and the response of the organism, and one between consequences and the resulting change in behavior. Only brain science can fill those gaps. In doing so it completes the account; it does not give a different account of the same thing. Human behavior will eventually be explained (as it can only be explained) by the cooperative action of ethology [which we place as ultimate mechanism, an evolved organism in its niche], brain science [proximate machinery], and behavior analysis [formal, efficient and final causes]." (p.18)

Conclusion

When family members seek explanations about behavior changes observed in patients with brain injuries, there is a distinction between "what" is happening, "why" it is happening and "how" it is happening. Addressing the "what" question requires careful analyses to ensure that behavior is not mischaracterized, that it is not within the normal range of human actions. If the behavior is categorizable, it is essential that all plausible categories of explanation have been considered. These actions all address formal causes. A reference to "why" may lead to consideration of "under what conditions", which usually points to the necessary and sufficient triggers for behavior (efficient causes) or sustaining reinforcers (final causes). A reference to "how" may be a reference to "structure and underlying mechanisms" that govern the behavior (material causes). Neurobehavior treatment attempts to answer both sets of questions seeking out the purpose or functions of both, and the best way to talk about each. Addressing all four causes (Formal, Efficient, Material, and Final) can lead to more comprehensive and inclusive strategies, and a more convincing understanding of behavior for patients, their families, and clinicians.

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