Use of the Machine Metaphor Within Autism Research

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ORIGINAL ARTICLE

Use of the Machine Metaphor Within Autism Research

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Abstract Traditionally, metaphor has been viewed a literary trope standing in opposition to literal forms of writing in the natural and social sciences. In recent decades, however, a multi-disciplinary field of cognitive linguistic research has developed. This research finds metaphor at the heart of both everyday and scientific thinking. Metaphor is understood to be vital to the development of useful theories within the sciences. In this paper, the authors analyze the use of the machine metaphor in recent autism research, allowing for an interrogation of that research in terms of generativity and utility.

Keywords Student-machine · Autism · Machine metaphor

> The human body is a machine which winds its own springs. (La Mettrie 1748)
>
> "Analogy and metaphor are central to scientific thought." (Gentner and Jeziorski 1993, p. 447)

Researchers Heflin and Simpson (1998a, p. 202) use the words "behavioral output" to describe the actions of a student with autism. Hurth *et al.* (1999, p. 25) use the word "input" to describe the actions of parents and family that are directed toward the young person with autism. Charman *et al.* (1997), Koegel *et al.* (1999), and Horner *et al.* (2002) use the word "production" as a synonym for the behavior of a student with autism. Do these researchers literally mean that a person with autism

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is a mechanized system that processes *inputs* of energy and materials into productive *outputs*? One might assume that scientific writing is simply literal, using words that directly relate facts without the decorative embellishment of figurative language (Baake 2003; Brown 2003). Yet it is clear that the autism researchers quoted do not literally mean to say that persons are machines. They are using *input*, *output*, and *production* as metaphorical expressions. In this case, the child or adolescent with autism is being described through an overarching *human as machine* conceptual metaphor that maps common meanings about machines onto our understanding of flesh and blood persons.

Researchers in cognitive science, philosophy, and the sociology of science have adopted a concept of metaphor as primarily cognitive and only secondarily linguistic (Lakoff 1993; Lakoff and Johnson 1999; Ortony 1993). Within this approach, a metaphor is an "ontological mapping across conceptual domains, from the source domain...to the target domain...(Lakoff 1993, p. 208). One idea or concept is used as a way of framing, filtering, organizing, and featuring another idea or concept. If the target domain is A, and the source domain is B, then the cognitive activity of metaphor involves "seeing A as B" (Schon 1993, p. 148). In this case, the target domain *human* is cognitively constituted with the rich array of features and themes of the source domain *machine*.

A casual observer might assume that metaphors are rarely used within scientific research, and more specifically, the *human as machine* metaphor is an infrequent aberration from the usual language use of autism researchers. To the contrary, a growing research literature is documenting and analyzing not only the common use of metaphor within scientific work but the centrality of metaphors to effective model-building and theorizing within the advancement of knowledge in scientific fields (Baake 2003; Brown 2003; Leary 1994; Ortony 1993; Radman 1995). Further, as will become evident in this study, readers of the current scientific literature in the field of autism are met with repeated instances of terms and phrasings that cast persons with autism within the general conceptual metaphor *human as machine*. Additionally, it should be noted that the mechanistic metaphor, while prominent, is not the only active metaphor in autism research. Many metaphors are used. In this analysis, given the limitations of one study, only the machine metaphor will be examined.

What is salient here is not only whether a given metaphor pervades autism research but how that metaphor is used, the theoretical directions and opportunities that it provides or fails to provide, how it furthers or fails to further scientific development and allied professional practices. In this inquiry, we conduct a systematic metaphor analysis (Schmitt 2005) of a series of prominent research articles in the current scientific literature on autism in order to examine the use of the *human as machine* metaphor in multiple instances. Our general purpose is to illuminate current use of the machine metaphor and interrogate that use in light of the scientific goals of advancing knowledge and improving professional practices. Any metaphor used within an endeavor of medical, psychological, or educational science should serve to push the field forward toward models, theories, and further inquiry that generate more useful knowledge. How is the human as machine metaphor used within autism research? How well is this *human as machine* metaphor serving the goals of knowledge and professional service? In addressing these two questions, this study suggests both the limitations of the metaphor and possible opportunities for the use of more productive, generative metaphors in autism research.

Metaphors in Science

> (I)n the work of the active scientist there are not merely *occasions* for using metaphor, but *necessities* for doing so...the necessity built into the process of scientific rationality itself, an epistemological necessity that covers the search for and use of metaphors. It is simply the limit of induction. Where logic fails, analogic continues. (Holton 1995, p. 268)

For many years, scientists and language scholars alike assumed that language consisted of literal and non-literal forms, the former filling the needs of the natural and social sciences for descriptions that matched lexical strings to "the ways things are," and the latter fulfilling the more diversionary and aesthetic purposes of literary writing (e.g., Baake 2003). Metaphor, as a linguistic trope, seemed to be "a deviation from rational sense" (Hesse 1995, p. 351), adequate to the purposes of literature, offering little or nothing to the scientific pursuit of accurate and useful knowledge.

More recently, the traditional wall between literal and non-literal language and the banishment of metaphor to decorative poetics has been challenged by the development of a multi- and interdisciplinary stream of research on the use of metaphor within cognition and language. Contributions from philosophy, linguistics, anthropology, and cognitive science built a field of inquiry that seeks to understand how metaphors operate on the cognitive and linguistic level.

Cognitive research on metaphor use is often tracked historically to the work of Black (1962; 1993). Black, drawing from Richards (1936), put forward the *interaction theory of metaphor*. Black critiqued the prior theories of metaphor that had been built on the premise that a metaphor only accomplishes what a literal statement can do, a notion that reduced metaphor to a nonessential, aesthetic role. Black proposed that the meanings of the two subjects (the target domain and the source domain) within a metaphor *interact* such that the meaning of each subject is projected with features and properties of the other subject. For example, in the metaphor *man is a wolf*, the primary subject *man* is invested with meanings (aggression, savageness, coldheartedness, etc.) borrowed from our cultural repertoire of understandings about the secondary subject, *wolf*. Simultaneously, although perhaps to a lesser extent, the secondary subject *wolf* gains new meanings from the semantic association with the primary subject.

Central to Black's theory was the notion of a metaphor, working within the dynamic interactions of the multiple meanings of the two subjects, thereby producing new emphases and insights into the character of each, accomplishing what literal language cannot. No literal statement can produce the exact range of possible meanings about either subject or the complex, active cross-domain dynamics that are produced in the simple metaphor *man is a wolf*.

The cognitive science of metaphor has investigated how metaphors operate within the thought processes of everyday persons (e.g., Gibbs 1996; Boroditsky 2000) and also within the investigations and theorizing of scientists (e.g., Baake 2003; Brown 2003; Knorr Cetina 1999; Leary 1994). The latter strand of research documents how scientists utilize an everyday cultural repertoire of common metaphors within their daily research practice and within important theoretical developments in their fields. Brown (2003) provides a detailed analysis of the use of metaphors in the development of models and theories in physics, chemistry, and biology. Knorr Cetina (1999) examines the active use of metaphors within the daily work of laboratory scientists. Leary (1994) traces the historical utilization of metaphors in the field of psychology.

Current thinking within cognitive science holds that metaphors serve as a necessary component in the formulation of scientific theories and models that attempt to explain complex physical and social phenomena. "Metaphorical thought is what makes abstract scientific theorizing possible" (Lakoff and Johnson 1999, p. 128). At the bottom of the models and theories that supply the semantic structure and content of the modern sciences are metaphors that map a source domain of semantic content onto a target domain, thereby opening a possible door to scientific investigation and development. For example: (Boyd 1993; also see Gergen 1990) has described how the *mind as computer* has served as the basis for contemporary cognitive science, providing terms and concepts such as information processing, storage, retrieval, and feedback. In similar fashion, the field of brain science has developed models of neuropsychological activity based on a metaphor of *brain as cybernetic control system* (Pribram 1994). Brown (2003) has narrated how the metaphor of a *protein as chaperone* was important to the development of DNA research. In each case, the primary driving theory within a highly productive line of research springs from a fruitful metaphor.

Schon 1993 coined the term "generative metaphor" to describe a metaphor that allows one to carry over frames, concepts, and modes of interpretation from one domain to another, thereby providing opportunities for the reassessment of the prior conventions and the development of new theory, (p. 148). This kind of generative cognitive restructuring is important when scientists build new models and theories. This often occurs as when prior models fail to account for new data or try to when salient natural or social phenomena lie beyond the reach of direct scientific observation.

Boyd (1993, p. 486) proposes that a "theory-constitutive metaphor" provides the semantic content necessary for new theorizing. Once accepted, theory-constitutive metaphors then continue as the conceptual fulcrum of highly productive theories within the sciences. What begins as a novel mapping from one domain to another is gradually adopted, standardized, and utilized within a specific discipline or line of research. Like fertile ground, a "good" or useful metaphor in this regard supports productive investigation into new areas, stretching beyond the reach of prior terminologies.

> Indeed, the utility of theory-constitutive metaphors seems to lie largely in the fact that they provide a way to introduce terminology for features of the world whose existence seems probable, but many of whose fundamental properties, have yet to be discovered. Theory-constitutive metaphors, in other words, represent one

> strategy for the accommodation of language to as yet undiscovered causal features of the world. (Boyd 1993, 489–490)

What is typically called progress or scientific advancement, in Boyd's view, depends on the fecundity of the metaphorical cross-mappings that scientists utilize. One metaphor may lead to intellectual and practical dormancy, while another may support promising initiatives, inquiries, and discoveries. One key to the vitality of a research program lies in the analytic richness and usefulness of the metaphors employed and the theories or models built.

Systematic Metaphor Analysis Method

The research method employed in this investigation is called systematic metaphor analysis (Schmitt 2005), an approach to analyzing metaphor use in written documents or spoken speech in order to unearth and examine the underlying cognitive frames and assumptions at work. The goal of systematic metaphor analysis is "to bring the use of metaphors and the practices associated with this to the conscious level" (Schmitt 2005, p. 360).

> We as individuals, groups, and in our culture have unconscious metaphorical thinking patterns, which are simply taken as "givens." The analysis of metaphors aims to shed light on these metaphorical thinking patterns. (Schmitt 2005, p. 360)

Once illuminated, the cognitive activity underlying the linguistic domain cross-mappings are analyzed in relation to the overall goals of scientific research in the field of autism, the mission of improving understanding of autism and the lives of persons with autism in order to improve professional practices and social policies.

Language samples for this analysis are nine prominent autism research articles drawn from the current scientific literature. Autism research currently involves the focused efforts of a variety of human science disciplines, including medicine, psychology, and special education. In this analysis, while not contending that the various disciplinary groups are fully unified as one field of autism, we assume that substantial overlap and interaction (reading, discussion, intellectual cross-fertilization) among these groups as the loosely knit science of autism develops on many related fronts. For the sake of simplicity and feasibility, our analysis does not examine single disciplinary lines but treats the entire, multidisciplinary field of autism research as a whole.

Our goal in selecting articles for review was to choose a series of recent, prominent research articles that would stand as a representative sample of the best scientific work in the autism field. Articles selected had to meet the following criteria:

1. Recent—Published within the last 10 years.
2. Important to the field—Either synthesized existing research in a specific area of intervention or described new advances building on existing knowledge base.

3. Highly regarded by other North American researchers—Received a significant number of citations in other research or authored/co-authored by a researcher whose work had received many citations in the North American field. (Citations were tallied through the Web of Science database.)
4. Relevant to child and youth issues—Included research that had implications for school-age populations.

From hundreds of total articles, approximately 50 were found to generally meet these criteria. This pool was furthered narrowed through selection of the nine articles that most closely matched the selection criteria (see Table 1).

Table 1 Selected autism research articles

Author(s) & publication year	Title and source
Charman, T., Baron-Cohen, S., Swettenham, J., Cox, A., Baird, G., & Drew, A. (1997).	Infants with autism: An investigation of empathy, pretend play, joint attention, and imitation. *Developmental Psychology*, 33(5), 781–789.
Fillipek, P. A., Accardo, P. J., Baranek, G. T., Cook, E. H. Jr., Dawson, G., Gordon, B., Gravel, J. S., Johnson, C. P., Kallen, R. J., Levy, S. E., Minshew, N. J., Prizant, B.M., Rapin, I., Rogers, S. J., Stone, W. L., Teplin, S., Tuchman, R. F., & Volkmar, F. R. (1999).	The screening and diagnosis of Autism Spectrum Disorders. *Journal of Autism and Developmental Disorders, 29*(6), 439–484.
Fombonne, E. (1999).	The epidemiology of autism: A review. *Psychological Medicine, 29*(4), 769–786.
Heflin, L.J., & Simpson, R.L. (1998a).	Interventions for children and youth with autism: Prudent choices in a world of exaggerated claims and empty promises. Part 1: Intervention and treatment option review. *Focus on Autism and other Developmental Disabilities, 13*(4), 194–211.
Heflin, L.J., & Simpson, R.L. (1998b).	Interventions for children and youth with autism: Prudent choices in a world of exaggerated claims and empty promises. Part 2: Legal/Policy analysis and recommendations for selecting interventions and treatments. *Focus on Autism and other Developmental Disabilities, 13*(4), 212–220.
Horner, R.H., Carr, E. G., Strain, P. S., Todd, A. W. & Reed, H. K. (2002).	Problem behavior interventions for young children with autism: A research synthesis. *Journal of Autism and Developmental Disorders, 32*(5), 423–446.
Hurth J., Shaw, E., Izeman, S.G., Whaley, K., Rogers, S. J. (1999).	Areas of agreement about effective practices among programs serving young children with Autism Spectrum Disorders. *Infants and Young Children, 12* (2), 17–26.
Iovannone, R., Dunlap. G. Huber, H., & Kincaid, D. (2003).	Effective educational practices for students with autism spectrum disorders. *Focus on Autism and other Developmental Disabilities, 18*(3), 150–165.
Koegel, L.K., Koegel, R.L., & Harrower, J.K. (1999).	Pivotal response intervention 1: Overview of approach. *The Journal of the Association for Persons with Severe Handicaps, 24*(3), 174–185.
Lord, C., Risi, S., Lambrecht, L., Cook, E.H., Leventhal, B.L., DiLavore, P.C., Pickles, A., & Rutter, M. (2000).	The Autism Diagnostic Observation Schedule—Generic: A standard measure of social and communication deficits associated with the spectrum of autism. *Journal of Autism and Developmental Disorders, 30*(3), 205–223.

Use of the Machine Metaphor in Autism Research

Systematic discourse analysis of the nine selected articles yielded a set of five conceptual metaphors that reside within the larger machine metaphor: (1) programming, (2) implementation, (3) engagement, (4) controls, and (5) maintenance. Each of these metaphors brings a machine vocabulary marked by precision, regularity, and standardization to the interpretation of human activities (see Table 2).

Programming

An effective model/program includes comprehensive *programming* (Hurth *et al.* 1999, p. 19). In describing the programs they surveyed, the authors note, "Comprehensive programming was defined as addressing IEP/IFSP needs across multiple developmental domains and in multiple environments" (p. 20). Programming as understood by the authors encompassed all the components of effective educational practice which included among others, early intervention; family involvement; specialized curriculum; structured teaching, and intensity of engagement (Iovannone *et al.* 2003; Hurth *et al.* 1999). As Heflin and Simpson (1998b) remind us, at the center of this concerted effort was the student. "Tantamount to beneficial and reasonable resolution of conflicts related to treatment choice and other policy issues is that the focus of the discussion remains on the individual student whose programming is being determined" (Heflin and Simpson 1998b, p. 215). The student then is conceptualized as the machine that requires programming. Merriam-Webster defines "programming" as *a sequence of coded instructions that can be inserted into a mechanism (as a computer)*. In modern technology, programs are necessary for computers that are essentially general purpose machines whose structure must be specified from the outside. A program may be understood as a complex set of instructions that spells out step-by-step how a job is to be done by a computer. It uses a code—a set of rules that establishes correspondences between the characters of two different alphabets—to accomplish its objectives. When this code is applied to linguistic expressions it is understood as a translation. When it accounts for the transformation of one kind of signal into another kind of signal it may be seen to describe an input–output device, such as a computer. The program, then, through a certain type of language, specifies and actively sustains the actual relations between the different components of the machine, i.e., the structure of the machine, so that a requisite form of output can be generated. The various components of "best practice" in autism constitute the elaborate code which is systematically applied to the student. Structured teaching and systematic instruction recur repeatedly in much of the literature as critical components of good programs. The student's programing is constituted by this systematic delivery of instruction.

Implementation

Plans must be "implemented" by "intervention agents," (Koegel *et al.* 1999; Hurth *et al.* 1999; Horner *et al.* 2002). "Implement" is defined by Merriam-Webster as *a device used in the performance of a task* while an agent is *a means or instrument by which a guiding intelligence achieves a result*. Different types of agents enable

Table 2 Human as machine metaphor terminology

Metaphorical terms	Referred articles in which metaphorical terms recur	Dictionary meanings (unless specified otherwise, all meanings are drawn from Merriam-Webster Dictionary)
Programming/ programmatic	Hurth *et al.* (1999), Lord *et al.* (2000), Heflin and Simpson (1998a, b), Iovannone *et al.* (2003), Horner *et al.* (2002)	"a sequence of coded instructions that can be inserted into a mechanism (as a computer)"
Engagement, engage	Hurth *et al.* (1999), Charman *et al.* 1997), Heflin and Simpson (1998a, b), Iovannone *et al.* (2003), Horner *et al.* (2002), Koegel *et al.* (1999), Fillipek *et al.* (1999)	"to come together and interlock (as of machinery parts);" "be or become in gear"
Components	Hurth *et al.* (1999), Heflin and Simpson (1998a, b), Iovannone *et al.* (2003), Koegel *et al.* (1999)	"one of the necessary data or values on which calculations or conclusions are based" "one of the factors determining the outcome of a process" "a constituent part"
Rate/rating	Hurth *et al.* (1999), Charman *et al.* (1997), Lord *et al.* (2000), Iovannone *et al.* (2003), Horner *et al.* (2002), Koegel *et al.* (1999), Fillipek *et al.* (1999), Fombonne (1999)	"a fixed ratio between two things" "a quantity, amount, or degree of something measured per unit of something else" "to estimate the normal capacity or power of"
Input	Hurth *et al.* (1999), Heflin and Simpson (1998a, b)	"power or energy put into a machine or system for storage, conversion in kind, or conversion of characteristics usually with the intent of sizable recovery in the form of output" "information fed into a data processing system or computer"
Output	Heflin and Simpson (1998a, b)	"power or energy produced or delivered by a machine or system (as for storage or for conversion in kind or in characteristics" "something produced;" "the information produced by a computer" "the amount produced by a person in a given time" "the act, process, or an instance of producing"
Level	Hurth *et al.* (1999), Lord *et al.* (2000), Heflin and Simpson (1998a, b), Iovannone *et al.* (2003), Fillipek *et al.* (1999), Fombonne (1999)	"a device for establishing a horizontal line or plane by means of a bubble in a liquid that shows adjustment to the horizontal by movement to the center of a slightly bowed glass tube" "a measurement of the difference of altitude of two points by means of a level"
Agents	Hurth *et al.* (1999), Horner *et al.* (2002), Koegel *et al.* (1999)	"a means or instrument by which a guiding intelligence achieves a result"
Design	Hurth *et al.* (1999), Charman *et al.* (1997), Lord *et al.* (2000), Heflin and Simpson (1998a, b), Iovannone *et al.* (2003), Horner *et al.* (2002), Koegel *et al.* (1999), Fombonne (1999)	"to create, fashion, execute, or construct according to plan" "to conceive or execute a plan"
Centrality, central	Hurth *et al.* (1999), Charman *et al.* (1997), Horner *et al.* (2002), Koegel *et al.* (1999)	"situated at, in, or near the center" "centrally placed and superseding separate scattered units" "controlling or directing local or branch activities"

Systems	Hurth *et al.* (1999), Heflin and Simpson (1998a, b), Iovannone *et al.* (2003), Horner *et al.* (2002)	"a group of interacting bodies under the influence of related forces" "a group of devices or artificial objects or an organization forming a network"
Operationalize, operational, operate	Hurth *et al.* (1999), Lord *et al.* (2000), Heflin and Simpson (1998a, b), Koegel *et al.* (1999), Fombonne (1999)	"a method or manner of functioning" "any of various mathematical or logical processes (as addition) of deriving one entity from others according to a rule" "a single step performed by a computer in the execution of a program"
Differentiate, differential	Hurth *et al.* (1999), Lord *et al.* (2000), Iovannone *et al.* (2003), Koegel *et al.* (1999), Fillipek *et al.* (1999), Fombonne (1999)	"to obtain the mathematical derivative of" "relating to quantitative difference; producing effects by reason of quantitative differences"
Functioning, functional, functionality	Hurth *et al.* (1999), Charman *et al.* (1997), Lord *et al.* (2000), Heflin and Simpson (1998a, b), Iovannone *et al.* (2003), Horner *et al.* (2002), Koegel *et al.* (1999), Fillipek *et al.* (1999),	"used to contribute to the development or maintenance of a larger whole;" " also designed or developed chiefly from the point of view of use"
Implement	Hurth *et al.* (1999), Heflin and Simpson (1998a, b), Iovannone *et al.* (2003), Horner *et al.* (2002), Fombonne (1999)	"a device used in the performance of a task;" "one that serves as an instrument or tool"; "to provide instruments or means of expression for"
Controls, controlled, control, controlling	Charman *et al.* (1997), Lord *et al.* (2000), Horner *et al.* (2002), Fillipek *et al.* (1999), Fombonne (1999)	"a device or mechanism used to regulate or guide the operation of a machine, apparatus, or system"
Production, produce	Charman *et al.* (1997), Horner *et al.* (2002), Koegel *et al.* (1999)	"the creation of utility; especially : the making of goods available for use" "total output especially of a commodity or an industry"
Monitoring	Charman *et al.* (1997), Lord *et al.* (2000), Heflin and Simpson (1998a, b), Iovannone *et al.* (2003), Horner *et al.* (2002), Koegel *et al.* (1999)	"a device for observing a biological condition or function"
Application, applicability, apply	Charman *et al.* (1997), Heflin and Simpson (1998a, b), Iovannone *et al.* (2003), Horner *et al.* (2002)	"to put into operation or effect" "to bring into action" "to put to use especially for some practical purpose"
Measure	Charman *et al.* (1997), Lord *et al.* (2000), Heflin and Simpson (1998a, b), Iovannone *et al.* (2003), Horner *et al.* (2002), Koegel *et al.* (1999)	"to estimate or appraise by a criterion"
Display	Charman *et al.* (1997), Iovannone *et al.* (2003), Horner *et al.* (2002), Koegel *et al.* (1999)	"an electronic device (as a cathode-ray tube) that temporarily presents information in visual form" "a clear sign or evidence"
Procedure, procedural	Charman *et al.* (1997), Heflin and Simpson (1998a, b), Iovannone *et al.* (2003), Horner *et al.* (2002), Koegel *et al.* (1999)	a series of steps followed in a regular, definite order
Effects	Charman *et al.* (1997), Lord *et al.* (2000), Horner *et al.* (2002)	"something that inevitably follows an antecedent (as a cause or agent)"
Presses	Lord *et al.* (2000), Fillipek *et al.* (1999)	"an apparatus or machine by which a substance is cut or shaped, an impression of a body is taken, a material is compressed, pressure is applied to a body, liquid is

Table 2 (continued)

Metaphorical terms	Referred articles in which metaphorical terms recur	Dictionary meanings (unless specified otherwise, all meanings are drawn from Merriam-Webster Dictionary)
		expressed, or a cutting tool is fed into the work by pressure" "to act upon through steady pushing or thrusting force exerted in contact"
Coded, coding	Charman *et al.* (1997), Lord *et al.* (2000)	"a system of signals or symbols for communication" "a set of instructions for a computer"
Instrument	Charman *et al.* (1997), Lord *et al.* (2000), Fombonne (1999)	"a measuring device for determining the present value of a quantity under observation" "a means whereby something is achieved, performed, or furthered"
Tool	Lord *et al.* (2000), Heflin and Simpson (1998a, b), Fillipek *et al.* (1999)	"a handheld device that aids in accomplishing a task" "something (as an instrument or apparatus) used in performing an operation or necessary in the practice of a vocation or profession"
Structure	Hurth *et al.* (1999), Lord *et al.* (2000), Heflin and Simpson (1998a, b), Iovannone *et al.* (2003)	"something that has been made or built from parts" (Cambridge) "the aggregate of elements of an entity in their relationships to each other"
Competent, competence, competencies	Lord *et al.* (2000), Heflin and Simpson (1998a, b), Iovannone *et al.* (2003), Horner *et al.* (2002), Koegel *et al.* (1999)	"having the capacity to function or develop in a particular way"
Equivalent, equivalence	Lord *et al.* (2000), Iovannone *et al.* (2003)	"a relation (as equality) between elements of a set (as the real numbers) that is symmetric, reflexive, and transitive and for any two elements either holds or does not hold"
Maintain, maintenance	Lord *et al.* (2000), Heflin and Simpson (1998a, b), Iovannone *et al.* (2003), Horner *et al.* (2002), Fillipek *et al.* (1999)	"to keep in an existing state (as of repair, efficiency, or validity)" "preserve from failure or decline"
Mechanism	Heflin and Simpson (1998a, b), Horner *et al.* (2002), Koegel *et al.* (1999), Fombonne (1999)	"a piece of machinery" "the fundamental physical or chemical processes involved in or responsible for an action, reaction, or other natural phenomenon (as organic evolution)" "a process or technique for achieving a result"
Priming	Iovannone *et al.* (2003), Koegel *et al.* (1999)	"to put into working order by filling or charging with something" "to apply the first color, coating, or preparation to"
Factor	Lord *et al.* (2000), Horner *et al.* (2002), Fombonne (1999)	"one that actively contributes to the production of a result" "a good or service used in the process of production"
Index	Fillipek *et al.* (1999), Horner *et al.* (2002), Fombonne (1999)	"a device (as the pointer on a scale or the gnomon of a sundial) that serves to indicate a value or quantity" "something (as a physical feature or a mode of expression) that leads one to a particular fact or conclusion"
Emissions, emit	Koegel *et al.* (1999), Fillipek *et al.* (1999)	"substances discharged into the air (as by a smokestack or an automobile gasoline engine)"

different results. “The magnitude of behavior reduction is greater when the intervention is implemented by typical agents (families, teachers) than when atypical agents and settings (e.g., hospitals, specialists) are involved” (Horner *et al.* 2002, p. 429). Agents—families, teachers, specialists—execute the plans created and designed by others—medical and educational professionals.As instruments to achieve desired results, parents are offered dual roles—not only as tools that can serve the expression of another’s purposes, but also as possessing mechanical energy. Their involvement in the programming is conceptualized as “input” (Hurth *et al.* 1999, p. 19)—*power or energy put into a machine or system for storage, conversion in kind, or conversion of characteristics usually with the intent of sizable recovery in the form of output* (see Table 2). Not surprisingly, the “output” is desirable social behaviors of the student (Helfin and Simpson 1998a).

In mechanical systems, input may be understood as an event external to a system which modifies it in any manner. When different systems (such as persons, computers, machines) interact, there are two components to the interaction. Input is what enters the system from the outside and output is what leaves the system for the environment. But in order to speak in terms of input and output the system must be clearly distinguished from the environment. The system and the environment are separated by a boundary, so for example, the skin of living systems can be considered the boundary. An output then may be understood as a record left behind by a system of its own behavior. Intrinsic to the functioning of an input–output device is a control system. The agent operates within this control system, which includes two subsystems—the controller and the controlled. They interact but their effects on each other are different. The controller seeks to change the state of the controlled in different ways. The action of the controlled element results in perceptions that build a representation of itself for the controller. The controlled element cannot affect the controller in any other way. The actions of the controlling agent are then determined by the information that flows to it from this representation. The asymmetry of control in this relation is an integral part of the system.

Within such control systems, the agent is the carrier of will, the entity that chooses between possible actions. In computer technology an agent is a program that performs some information gathering or processing task in the background (www.webopedia.com). It is a computer code that has a well-defined task. *We do not see agents, we see only what they are doing*. The agent is further influenced by another element: goal. The agent is required to compare the representation with the goal and take the appropriate action that will minimize the distance between the two. This is regarded as purposeful behavior. Control can be exercised directly or through statements and commands. For example, when driving a car, the driver is the controller and the car is the controlled system. The road and the environment would be associated with the controlled system. The driver receives sensory messages from the environment and from the movement of the car and varies the position of the car to keep it on the road. This form of action is a direct change that is applied to the controlled system. The controller can also effect change through the use of statements and commands. The steering wheel may also be seen as an information channel through which the driver sends commands to the wheels. A computer’s output may be specifically altered through the use of different commands. Different agents—parents, service providers—are charged with the goal of transforming the behavior of the student-machine.

Engagement

Almost all the surveyed articles record the critical necessity of ensuring student engagement. To engage may be defined *as to come together and interlock (as of machinery parts)* or *be or become in gear* (see Table 2). Gears are everywhere where there are engines and motors that produce rotation. If we open a VCR and look inside we will see that it is full of gears. Many types of clocks contain gears especially if they have bells or chimes. Gears, then can be used to achieve different results: To reverse the direction of rotation; to increase or decrease the speed of rotation; to move rotational motion to a different axis; and to keep the rotation of two axes synchronized. For example, in a car the gears help the driver to increase and decrease speed as he/she changes the gears with the gear stick. The windshield wiper on a car also uses gears to generate the force needed to move the wiper at different speeds. A fundamental rule of gears is that if a large gear turns a small gear the speed increases. On the other hand, if a small gear turns a large gear the opposite happens and the speed decreases. To ensure that the gears do lock together successfully—when gear teeth actually make contact-precise measurements of the teeth (in both gears) have to be made. Citing the study by Hurth *et al.* (1999), Iovannone *et al.* (2003) emphasize: “Engagement of students with ASD will be unlikely unless there is some deliberate design, such as carefully planning changes to the physical environment, systematically using materials and/or activities, incorporating preferred materials and activities and capitalizing on a student’s spontaneous interests and initiations” (p. 157). It is this systematically planned program that will interlock with the student and drive him/her to achieve the intended result—in this case, desirable behaviors. Consequently, Iovannone *et al.* (2003) can emphasize that “engaged time can be *provided* (italics added) at different levels of intensity and in a wide range of settings using a range of strategies based on students’ individual needs and characteristics” (p. 157). But student engagement must also be quantified and measured to estimate the success of the interlocking mechanism. “Engagement refers to the *amount* of time that a child is attending to and actively participating in the social and nonsocial environment. Intensity of engagement is sometimes expressed as the *percent* of enrolled time that is spent in teaching interactions, or in activities in which the child is actively learning” (Hurth *et al.* 1999, p. 21) Using the formula suggested by Hurth *et al.* (1999), the “behavioral output” (Heflin and Simpson 1998a, p. 202)—the *power or energy produced or delivered by a machine or system* (see Table 2)—of the student must be precisely calculated in order to ensure that engagement has occurred. This output demonstrates the “power” (Hurth *et al.* 1999, p. 19) and efficacy of the programs/models applied to the student.

Controls

The surveyed articles are in agreement that student behavior has to be brought under control. Control is defined as *a device or mechanism used to regulate or guide the operation of a machine, apparatus, or system* (see Table 2). Controls, then, can assume different forms. They can constitute the group against whose performance the students with autism are evaluated (Charman *et al.* 1997; Fombonne 1999; Horner *et al.* 2002); they can comprise the statistical procedures used to analyze data (Charman *et al.* 1997); they can consist of variables in the physical and social environment (Horner *et al.* 2002; Koegel *et al.* 1999); and they can also reside in specific student behaviors (Fillipek *et al.* 1999). As the machine whose every step in the operation needs to be controlled, the student's every response must be calculated prior to the "production" (Charman *et al.* 1997; Koegel *et al.* 1999; Horner *et al.* 2002) of the desired effect. In terms of input–output processes, it is difficult, if not practically unfeasible, to anticipate or identify all the effects generated by the input—the programming applied to the student. So extraordinary efforts must be exerted in order to control for those effects. If we seek to control those side-effects of the input, then we need to anticipate with accuracy the action of other parts or mechanisms and enact a correction at the precise moment. In real systems, this is rarely possible. A computer prints or displays only the final results of a complex computation, raising the distinction between output (the display) and internal (inaccessible) variables. Human cognitive processes similarly remain hidden from view unlike observable human behaviors such as words, gestures and actions—output. Monitoring the output is thus easier and therefore more common. However, the flaw in this approach is that we can only measure the output after those inaccessible variables have already exercised their effects.

In their research, Charman *et al.* (1997) clearly sought to regulate the effects of those inaccessible variables that might interact with the input. They examined the kinds of behaviors that infants with autism "produced" under highly controlled situations, which they believed might anticipate some of the behaviors that had been documented in older children. Their experimental design included comparison with two "control" groups—developmentally delayed and normal. Citing earlier studies, they state: "On joint attention tasks, infants with autism produced fewer gaze switches of visual attention in response to ambiguous toys than did *controls*, (italics added) consistent with the findings of studies with school-age children with autism" (p. 786). The children in these two groups are the mechanisms by which the researchers hoped to establish the validity of the output that they described in the group of children with autism.

In their synthesis of research on behavioral interventions for individuals with the developmental disabilities, Horner *et al.* (2002) infer that "children with autism appear to behave based on the same mechanisms (e.g., reinforcement, punishment, extinction) that control the behavior of children without autism" (p. 435). Mechanism refers to *a piece of machinery* or *a process or technique for achieving a result* (see Table 2). The external controls that Horner *et al.* list—reinforcement, punishment, extinction—are the integral parts of the program-machine that are applied to all students. In order for students to function efficiently, they have to be subjected to the regulating effects of external means applied to them. Fombonne (1999), however, appears to locate such mechanisms of control within those labeled with autism rather than outside them. In analyzing the possibility of a correlation between immigrant status and the incidence of autism, he offers this tentative conclusion: "Finally, it is unclear what *common mechanism could explain the putative association between immigrant status and autism*, (italics added) since the origins of the immigrant parents (especially in study 16) were very diverse and represented in fact all the continents. With this heterogeneity in mind, it is unclear what common biological features might be shared by those immigrant families and what would be a plausible mechanism explaining the putative association between autism and immigrant status" (p. 773) Even if these mechanisms resided *in* the students, since they were poorly understood, controls must necessarily be applied from the outside. Control mechanisms exerted by the program-machine can bring about desired effects, whereas control mechanisms applied by the student sustain undesirable behavior. In their detailed exposition of the condition of autism, Fillipek *et al.* (1999) focus on the latter. "Behavioral assessment by direct observation is used to address specific learning and behavioral problems, to establish the *functional or controlling relations of inappropriate behavior*, (italics added) to track behavioral progress, and to document the effectiveness of intervention" (Fillipek *et al.* 1999, p. 466). Reiterating an earlier statement, within the control system, the controlled element—the student—cannot affect the controller in any other way besides offering the controller the means to its own representation and thus any attempts to do otherwise are invalid.

Maintenance

Behaviors are conceived as requiring maintenance or if they are undesirable, as requiring to be evaluated for the factors that do maintain them. The concept of maintenance is thus used to understand both problematic and desirable behaviors. Merriam-Webster defines *maintain* as *to keep in an existing state (as of repair, efficiency or validity)* or alternately, to *preserve from failure and decline.* Maintenance activity for machines includes routine chores such as cleaning (usually with abrasives), lubrication, as well as careful and regular inspections and adjustment of controls. Good practice in the upkeep of machinery warrants the continual application of maintenance procedures as the machine is subjected to use. While the term is applied to the *behaviors* produced by the student, it is the student-machine that is seen to require the procedures of maintenance. However, the production of negative behaviors is perceived as jeopardizing the health not just of the student-machine, but of the program-machine itself. Examination of the environment is certainly a component in the maintenance procedures. "Functional assessment is the process of identifying the variables that *reliably predict and maintain* problem behaviors (Horner *et al.* 2002, p. 424). However, it is the complete elimination of undesirable behaviors that can safeguard the health of the student-machine and the program-machine. Consequently, citing other studies, Iovannone *et al.* 2003 underline the importance of making "problem behaviors ineffective, inefficient, and irrelevant" (p. 161).

Theory Generativity and Practicality

In this final section, we briefly examine the utilization of the machine metaphor in relation to the development of theories and research that bring benefit to the lives of persons with autism and their families. Drawing from the work of Boyd (1993) and

Schon (1993), we emphasize the role of metaphor in the constitution of theories in regard to their capacities to be generative and practical, supporting lines of scientific research that yield helpful, new understandings and ways of thinking. The question here is not the methodological soundness or epistemological foundations of the research but the practical fecundity, the extent to which the theories built on the machine metaphor framework generate ideas and practices that offer beneficial possibilities to diagnosed persons and their families.

The first issue concerns the highly limited model of learning adopted by the autism researchers. In casting students as machine systems, the researchers uphold a model of learning that has long been critiqued as unduly reductionistic and conceptually meager—the transmission model of learning. This model is atomistic and unidirectional; the instructor sends a signal through a specific channel to the receiver, whose passivity denotes the subordinate capacity assigned to his/her role. Students are envisioned as recipients of the superior knowledge vested in the controllers and agents, professionals and others selected to carry out professionally-driven goals. The main assumption within the transmission model is that "observation, listening to explanations from teachers who communicate clearly, or engaging in experiences, activities, or practice sessions with feedback will result in learning" (Fosnot and Perry 2005), in this case, the learning of desirable social behaviors (p. 9).

As a counterpoint, Hutchinson and Bosacki (2000) describe three possible learning models—transmission (e.g., Thorndike, Skinner), transaction (e.g., Dewey, Piaget), and transformation (e.g., Bruner, Vygotsky, Freire). Transaction adds a dimension of complexity to the transmission model by theorizing teaching and learning activity as mutual, interactive, and contextual. Within the conjoined experiences of two persons, teacher and student, each communicates, contributes, changes, and learns. The transformation model offers a subtle twist to the contextuality and mutuality emphases of the transaction theory by highlighting the social and experiential embeddness of the two human experiences within the single context. The learning and change experienced by one is inseparable from the learning and change experienced by the other. Each is a co-author of the learning experience, and the changes in either cannot be understood in isolation from that lived context.

The transmission model falls short in two ways. By envisioning learning as a communication process that operates in only one direction—from teacher to student—the transmission concept fails to attend to the interactive, mutual nature of teaching and learning, the sense in which both teacher and learner contribute to the social dynamics and the various meanings of the process. Additionally, this approach erases the subjectivity of the learner, attaching little significance to the goals, purposes and desires brought to the task by the student. McGee (2004), in reviewing the personal accounts written by persons with autism, has noted the powerful sense of self-awareness that many persons of autism present, a rich subjectivity that is frequently overlooked by researchers.

Since student subjectivities remain inaccessible within the framework of inquiry employed by autism researchers, they are construed as being irrelevant to the entire process. This persistent indifference to the role of the student in the learning process seems ubiquitous in autism research. As a result, while behavior change and psychometric classification efforts proceed full force, researchers continue to view students with autism as enigmatic, mysterious and even bizarre (Heflin and Simpson 1998a, b).

Parents and families are subject to instrumental interpretation, reduced to components that influence the successful outcomes of the program-machine. Researchers presume that various mechanized elements can be separately analyzed to understand their influences on the desired system output—the behavior of the student. Parents and families are viewed in an instrumental fashion, as one element whose "performance" must be engineered or primed so that the overall goals of the professionally-developed program can be furthered. Their contribution must then be precisely defined and configured in relation to the overall goals of the program.

> "Family involvement as reported by the respondent included defining goals, priorities and teaching strategies; *implementing* program components in home and community settings; *taking part* in parent-training and education; *participating* in regularly scheduled parent and sibling support group meetings; *taking part* in program advisory boards; and *responding* to consumer satisfaction surveys." (Hurth *et al.* 1999, p. 24; italics added)

By excluding any form of participation other than that conceived by professional notions of autism, the family's experiential understanding of their loved one and of autism are not afforded any hearing or legitimacy.

As a result, the research ignores the complex and informative ways in which students and families mutually constitute each other within the routine practices of daily life. By separating out parents and families as discrete, functioning elements in a designed system, parents are actually seen as being empowered only when they embrace professional understandings of autism (Koegel *et al.* 1999).

The preceding arguments suggest that the institutional structure of educational programming for students with autism is based on asymmetrical relations between students/families and researchers/practitioners. This ideological disposition, as enacted within the research practices, negates the goal of gathering and understanding authentic accounts of the experiences of persons with autism or their families. The subjectivities of students, families, and adults with autism are rarely sought as a strategy to expand the professional knowledge base.

Specific concepts of family, community, and society inform the programs to which students (and by extension, families) are subjected. The goals of intervention are then centered around "normalization," the adaptation of the person considered deviant to the dominant social norms, so that individuals with autism can blend into the social whole. Programs that do not adequately emphasize this critical element may not be readily endorsed (Heflin and Simpson 1998a, b). All program participants, including students and families, must embrace this principle in order to be understood as advancing the knowledge base of autism.

The result of this approach is the reification of dominant social norms as conceptualized by the professionals, interpretations of cultural codes of conduct as fixed and unambiguous rather than socially-produced, contextually-variable, and interpersonally negotiated. Individuals with autism are viewed as essentially unlike other persons, and then treatment programs involve adaptation to aspects of the artificially static norms. This tactic hypostatizes an abstract, homogeneous social order as normative, ethically sound, and politically unproblematic while persons with autism are enjoined to participate in a high stakes game of difficult self-alteration.

A common concluding paragraph in a research article makes the claim that more research is needed. On the topic of autism and the lives of persons with autism, we concur. But sometimes more of the same research yields more of the same hollow need for more research. Sometimes the very concepts (and metaphors) of which the science is built are inadequate to the task. More than just calling for more research, we must ask ourselves probing questions: What kinds of research might yield the greatest gains? What theories (of autism, learning, communication, behavior, families, education, society, etc.) might offer the greatest potency?

In this conclusion, we have articulated three areas of possible weakness within autism research: a conceptually thin model of learning, an orientation toward students and parents that ignores their perspectives and subjectivities, and an ideological disposition that champions professional accounts and a reified social homogeneity. Productive metaphors used within the sciences foster the development of theories marked by generativity and practicality, theories bearing sufficient complexity, flexibility, fecundity, and richness to drive research toward improved understandings of persons with autism while supplying educators and service professionals with concepts and practices that bring greater benefit to students and families. The problems that we have explored briefly in this final section provide indications of usage of a machine metaphor supporting a science effectuating limitation more than expansion, redundancy more than discovery, technical precision more than useful human understanding. This is not to say that machine metaphors cannot make productive contributions to theory development in useful lines of research. But in regard to these three specific areas of machine metaphor use within autism research, however, the generative and practical capacities of the metaphor-driven theories seem insufficient to the challenges of the science.

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