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Narrative Review

Logic in Healthcare: Narrative Review

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Abstract

Introduction: In this narrative review, the author explored aspects of logic which is a dimension of critical thinking which is essential for evidence based clinical practice (EBCP). This article's aim was to elucidate these aspects of logic and show applicability to healthcare.

Methods: Literature review was based upon Pubmed search of "logic" related terms and "healthcare" limited to free full text, RCTs, systematic reviews and narrative reports. Convenience sample of materials were included.

Results: Deliverables include A. List of deliverables; B. definitions table; C. updated table of critical thinking; D. terminology relations figure; E. sources of logic; F. sentence types; G. symbolism; H. first principles; I. types; J. arguments; K. forms; L. details of types; M. application.

Discussion: Areas of concern are addressed in this section related to a lack of uniform, defined criterion in logic and its complexity limits widespread usage.

Conclusion: This article provides a foundation for enhanced understanding of logic as part of critical thinking and how it can be used in healthcare.

Keywords: *Critical Thinking; Logic; Modus; Arguments; Literature Search; Evidence Based Medicine; EBM; EBCP; Education*

Introduction

Background work, introductory definition of logic, aims

Regarding background work, I authored an article on critical thinking [1] where I explored the definitions of critical thinking and provided a limited explanation of 44 related sub-dimensions. According to Rigel and Crossetti, these sub-dimensions included logic [2]. Critical thinking, which relies heavily on logic is essential for evidence based clinical practice (EBCP) [3-5]. The information can be in the form of sentences or unverbalized messages that need to be clarified. Unverbalized messages can be in the form of indoctrination by repetition, rhetoric, one sided argumentation, silencing dissent, unmerited applauding their view and "making fun of" the contrary viewpoint. It becomes critical to determine what information gets through our filters so we can concentrate on the most important issues. These important issues require careful dissection of the statements and arguments. This is such an enormous task that it is necessary to have our own collection of trusted individuals to help in this endeavor of critical thinking. Critical thinking is considered a skill that is necessary to meet the demands of 21st century career path [6p1,4] and logic should be used in every step. It is necessary for filtering information streams (determining priorities and reliability) and defining our beliefs and implementing actions for our highest priorities.

In this article, I condensed the sub-dimensions where necessary and added other sub-dimensions into an updated chart. Then I focused on the aspects of the sub-dimension called logic.

As an introductory definition, logic is the rules for determining if sentences and the way they are combined are right. In slang, logic is how to determine if something said or written is junk, wacky or makes no sense. Broken down analytically, logic is a way to determine if a thought or conclusion makes sense by: 1. Determining if the sentences before the conclusion are true and 2. Determining if the correct method was used to combine the sentences to form a good conclusion. Regarding 1, logic is a collection of rules to determine if each sentence is true in a group of sentences. Regarding 2, logic helps to correctly combine sentences to reveal more truth. Logical forms can be deductive/inductive. In the next sentences, I will use terminology before the slash mark ("/") related to deductive while after the slash mark the term is related to inductive. Now we will say the same thing using the language of logic. Logic is the use of rules that determine if each premise is true in a group of premises and how to use valid/strong forms to reveal sound/cogent conclusions. Since there are valid/strong forms, there must be invalid/weak forms. Bad forms are called formal/informal logical fallacies.

The author's aim regarding this article's aim to elucidate aspects of logic and show applicability to healthcare. These aspects include the following: A. List of deliverables; B. definitions table; C. updated table of critical thinking; D. terminology relations figure; E. sources of logic; F. sentence types; G. symbolism; H. first principles; I. types; J. arguments; K. forms; L. details of types; M. application. Healthcare information streams (research databases, internet, etc.) are exposing humans to an overwhelming volume of information at a rapid pace. Critical thinking which includes logic is essential to prioritize, filter and seek information. Many articles and books have been written regarding logic; however, narrative summaries from Pubmed that provided an overview of logic was lacking. I will use the EBCP critical thinking model to explore this topic: ask, acquire, appraise, apply, access. First I asked the question, "What aspects do I need to know about logic?" I formed a list of aspects and then I expanded the list based upon my findings. Secondarily, I acquired resources regarding logic as per the methods. Others have written books on the subject yet I want to put the material "on the lower shelf". In other words, I wanted to explore it and make it more understandable using plain language. I wanted to explore it and wanted to put it more into my own words for myself and to share with others. Next, I will appraise my information to determine its quality. Hopefully, I will be able to apply the information in the following way: 1. Help others see the breadth of logic; 2. apply it to healthcare scenarios and 3. be able to use it in further publications. I have used an open source journal to place it in the hands of others faster than a book format. Perhaps I will get some feedback to access the usefulness of this information and how it can be expanded.

Methods

Literature review was based upon convenience sample of materials used to teach the subject and Pubmed search.

Pubmed search limits where as follows:

1. Free full text
2. English
3. Meta-analysis, RCT, review, systematic review.

Term results and trials included with limit 1 only:

- 17757 logic … ignored, too many
- 1687 logic healthcare … ignored, too many

- 191 logic healthcare thinking … ignored, too many
- 4 logic healthcare AND "critical thinking" … captured 4
- 7 modus ponens … captured 6.

Added convenience selection of articles which were derived from previous research efforts [1] and teaching an evidence-based clinical practice (EBCP) course. Obtained ebooks and hardcopy texts on the subject from the local library.

Results

List of deliverables

Deliverables from the literature search follow including: A. List of deliverables; B. definitions table; C. updated table of critical thinking; D. terminology relations figure; E. sources of logic; F. sentence types; G. symbolism; H. first principles; I. types; J. arguments; K. forms; L. details of types; M. application. The terminology relations figure (D) illustrates how inductive logic and working definitions provide premises for hypoductive (abductive, non-abductive) and deductive logic. First, I will begin with forming a working definition of logic.

Definitions

Definitions of logic are numerous, and I have included four of them in table 1. The plain language summary of definition 1-2 and 4-1 of "Logic" is in the manner of a "process" and is expanded in table 2. Please note the discussion of the definitions in the table. As per the definitions of logic and reason, it seems that they are the same. Terms such as "deductive reasoning" and "deductive logic" further demonstrates this significant overlap. Derivative terms of logic include analogical, biological, cosmological, deontological, ecological, epistemological, logical, logos, methodological, morphological, ontological, psychological, phenomenological, technological, and teleological.

Number	Definition	Discussion	Source
1	1-1 "Reasoning conducted or assessed according to strict principles of validity. 1-2 "A system or set of principles underlying the arrangements of elements in a computer or electronic device so as to perform a specified task".	In this article we are starting our search for a definition with definition 1-1 and 1-2 because it was from a popular search engine [7]. Definition 1-2 describes application to programming computers and will be put on hold. Since the term reasoning seems integral to definition 1-1 of logic, here is the definition of reasoning. Reasoning = "the action of thinking about something in a logical, sensible way". Able to "think, understand, and form judgments by a process of logic".	[7]
2	2-1 "the process of forming conclusions, judgments, or inferences from facts or premises".	When the definitions of logic and reasoning are compared, they had elements of circularity. Please consider the following summary. Logic is reasoning with strictness and reasoning is thinking in a logical way Therefore, I will consider reasoning and logic as interchangeable for this article although future articles might delineate differences based on higher level sources. Nevertheless, I am left without a suitable definition. Therefore, I obtained the definition to the left which I shall call 2-1. From this definition, I will make the following basic formula representation of it: 2-2 Facts/premises → Put in forms → Conclusions/Inferences/Judgments "Good logic" would be: 2-3 "Formal/Informal Logic is when true-premises (facts) are put in valid/strong forms yielding sound/cogent conclusions. That which is contrary is called unsound/uncogent conclusions or illogical".	[8]

3	3-1 "a way by which human[s] can make an attempt to find the solution of some problems". [9p5] "Language for reasoning" [9p9]	This definition includes the humility of calling it a way to make an "attempt"; although this definition sounds like "critical thinking" which includes logic as per table 3. Definition 3 is rejected.	[9]
4 Working Definition	4-1 "Formal/Informal Logic is when premises are determined to be true or false by rules. True premises are put in valid/strong forms yielding sound/cogent conclusions. Otherwise, if the form is invalid/weak then the conclusion is deemed unsound/uncogent aka illogical".		

Table 1: *Definitions of "logic".*

Steps	5 As: Title of Step	Terms used in Definition 2	Plain language definition
0	Collect information	"Premises".	Statements are called premises. We collect premises at this point whether they are true or false.
1	Appraising premises	"Facts or premises".	The term "or" is misleading. Premises can be fact or fiction (true or false). Therefore, "facts or premises" could be replaced with "facts or true premises" which would make no sense to repeat. Determine which premises are true and false: Assumed to be True = Areas of no contention True = What God said is true "the conclusion logically follows from the premises" [10p541] First Principles (explained later) Evidenced by study in context Hill's criterion of causality Definition Induction Experimentation (inference) Deduction Valid forms (Attributes) Eg. modus ponens Modal logic (Existence, Knowing, Morality, Time, Belief, Tense, Dynamic, Geometry) Abduction (Events) Not a formal or informal fallacy False = Opposite what God said is true Formal fallacy (not a valid form) Informal fallacy (>300 such fallacies) [11]

	Processing facts	"The process of forming conclusions, judgments, or inferences from facts"	Only allow facts to go into processing step. Forming conditionals: If "fact" then ____ Try different combinations of premises with valid forms and avoid informal fallacies
3	Conclusions identified	"Conclusions, judgments, or inferences"	Conclusions seems to be an inclusive term for judgments, inferences and other. Judgments can be regarding law, ethics and value of objects. Inferences are often thought of as going from sample to population. Changing attributes seem to cause changes in other attributes of a population.
4	Expand	"The process of forming conclusions, judgments, or inferences from facts or premises".	Use conclusions as new facts and repeat and expand the process.

Table 2: *Plain language summary of definition 2-1 and 4-1 of "Logic" in the manner of a "process" as per the definition.*

Logics relationship to critical thinking

I have defined critical thinking as a process of finding a solution to a problem in the best possible way within the context of the problem [1]. Some problems will have the context of limited resources or time which will limit the ability of problem solvers to perform comprehensive critical thinking. Table 3 has been pulled from the previous article I wrote [1] and I have refined it by condensing parts of it, reworking it into steps and providing further details. Also, I have highlighted the sub-dimension of logic.

#	Tier 0 Dimensions	Tier 1 Sub-Dimensions	Tier 2 Sub-Sub-Dimension	Details
1	Preparation	Executive function [12p11]		As per Miyake., *et al*. quoted by Dean [12p2]: Set-shifting ability, Inhibitory control, working memory updating, Reason is dependent upon memory [12p19]
2		Intelligence		IQ testing questions deal with memory of number sequences, manipulation of memorized sequences (repeat backwards, add 2 to all numbers), missing parts of a picture, vocabulary words
3		Logical, Reasoning [13p2]		Includes Formal, Informal, and Non-classical logic. Logic steps are in Table 2. Logic can become overridden by complexity and believability [17]
4		Other cognitive functions [12p11]		The catch all for other stuff.
5		Self-regulation		Not "going crazy" in response to stress. Avoiding aggressive acts unless mortal or morbid threat to self or other.
6		Self-awareness		"Attitude about resolving social issues" [14]
7		Flexibility [13p2]		Able to negotiate with others while maintaining integrity, able to work around problems and not get too upset, ability to change action or thought as new information develops or priority changes

8		Tentativeness [15p3]		Understanding that scientific findings are "inherently uncertain, temporary and revisionary" [15p3]
9		Analytical spirit in balance		The drive and interest to seek deeper analysis without paralysis of action, "adopt a critical attitude" [16p2]
10		Cognitive maturity		Tension between maturity defined as accepting revelation from God or human's wisdom. Accepting elite's view or own. Who can you trust? Has God or the elite's let you down or did you just blame them or have an unrealistic expectation.
11		Inter-reflection, Reflection [13p2]		Done during (inter) the process of critical thinking, perceptual and cognitive biases [17], Being true to one's own belief system. Tension between belief as true or cognitive bias.
12		Curiosity [13p2]		Interest in what things are at a deeper level (their essence, definition), and how things work and interact with other things
13		Search for truth		Realization that absolute truth exists otherwise this statement would be meaningless. Search for the truth that exists because it matters in this life and afterlife.
14		Self confidence		Believe that you have been given the abilities to do great things. Belief that you can develop abilities if you work hard at it.
15		Ethics		Prioritizing needs of patients, families, and communities [13p4], Safety [13p4], Quality [13p4], Credibility, Trust, Intellectual integrity [13p2] Deontic logic is the type of modal logic that deals with moral obligations.
16		Attention		Paying attention to environmental cues (intuition), Keeping mind working on a particular task, setting aside time to contemplate
17		Creativity [13p2]		Able to "think outside the box", avoid false dichotomies; visualize the outcome and plan how to achieve it
18		Widening of thinking		Seeking widening, accepting, being able to think about an idea without believing it, using different thinking methods
19		Love		Feeling other's pain or feeling sad regarding another's situation. Trying to relieve discomfort, maximize goodness, and helping others to become a masterpiece. Caring for others. Making win-win situations.
20		Thinking style (intuitive, analytical thinking)		Intuition [13p2] being able to not ignore important cues, involves talking to yourself. Being able to think about something without believing it or rejecting it.
21		Perseverance [13p2]		Not giving up due to attention, fatigue, breaks
22		Interpretation		Interpreting language such as ASL (including converting speech to express idea, mood with face and body)
23		Contextual perspective [13p2]		Appraising information in the context that it came from (history, culture, audience, language styles), Individualized criterion [16p2]

24		Dialogic dimension		How to communicate with humor, charm, wisdom, restraint. Perhaps, should include self-talk. Limitation of rhetoric opposed to truth. Possibly part of informal logic.
25		Practical reasoning		Practical reasoning includes discernment [13p2] and discretion [18p255]. Practical reasoning and discretion ought to be done in a real situation. [18p255] Professional discretion [18p255] is "bounded practical reasoning that differs from free fantasy due to a knowledge base that is recognized as relevant for the specific professional practice". [18p255] Discretion has the central feature of the "ability to rapidly and accurately identify situational cues while accessing personal theories". [18p259]
26		Academic performance		Ability to accomplish outcomes by learning as evidenced by testing (assessments: quiz, exam, OSCE) well. Which leads to levels of learning/academic performance and process.
27	Process			The process of critical thinking can be applied using the 5 A's: Ask, Acquire, Appraise, Apply, Access.
28		Ask, Define issues	List issues	"Recognition of diverse social issues" [14]
29			Substantive- Focus on what matters to you	1. General A. Existence B. Meets threshold of importance to cause action 2. having substance: involving matters of major or practical importance to all concerned [19] A. having a firm basis in reality and therefore important, meaningful, or considerable B. having a separate and independent existence Reaching a threshold of belief resulting in action. Ignore the insignificant battles (non-essential doctrines, decoration) and win the significant battles (Glorifying God, Salvation, sanctification, making sure your family knows you love them, stopping evil from taking over)
30			Activism and civic engagement [20p903]	Determining the priority problems of community and self, using most effective and ethical methods for good, countering others' methods
31			Prioritize issues	
32			Working issue/ time	
33			Determine results	Determine MCID, risks (cost, side effects, collateral damage). Identifiable metrics for the measurements.
34		Acquire	Knowledge sources	Knowing what applications are the best and how to access them, how to work with computer applications, how to extract and store information in an organized fashion

35			Search for information [13p2]	Will to search. The process of searching for information. Advanced searching. Seeking contrarians to established viewpoint.
36			Avoiding non- reasoned bias, force	Avoid political, governmental, commercial pressures contrary to other sub-dimensions [16p1], everyone has bias yet how close is it to the truth?
37			"Multi-lateral information processing skills" [14]	List of Parts 1. Extraction 2. Organization/Categorization 3. Status determination Details: 1. Extraction: Excel and Microsoft Word (Microsoft Corp) provide excellent tools for this process. Include columns for topic, reference, page 2. Organization/Categorization: Create 4 columns for 3 categorization levels and a numeral code to reorganize numerally 3. Status determination: Scope and depth: As the scope and depth of a topic is realized then the learning can develop the material into higher levels of learning. Gap identification and filling: The person may be able to notice gaps and fill them until higher levels are reached.
38			Product Formation	Distributable form is created which goes through editing and feedback from those exposed to the content
39		Levels of Learning	LEVEL 1: Knowledge, Understanding [13p2] [18p255], Bloom's Verb [21], This does not seem to be critical thinking, it is memory of facts which will help with critical thinking. If you know 1+1=2 is that really "critical" thinking? What are you being critical about? I would be critical if you said it equaled 4.	Sublevel 1: 1 to 1 memory [12p11], rote memory, Eg. uric acid increased = gout Sublevel 2: 2 to 1 memory, column A and row 1 to field. Eg. Secondary hyperthyroidism = pituitary tumor Sublevel 3: 2 to many, Eg. Macrocytic normochromic anemia = Vit B12, Folate deficiency, hydantoin ingestion and/or chemotherapy Each of the Bloom's Verbs can be applied to any topic (biology, math, language, technology, EBCP). Regarding EBCP (Hill's criterion of causality, scientific method). These verbs show higher levels of critical thinking with knowledge at the lower end [21] There are different grades of knowledge too. This includes: definitions/equalities, categorizations (not categorizing based on criterion), lists Eg1: Using Microsoft Excel for storing text vs using equations for advanced calculations and graphing, Eg2: 1 + 1 = 2 Eg3: 3 x 4 = 12, Eg4: tan (26.6) = approx. 0.50076 … knowledge claims are premises. Existence of physical, energy, minds, ideas. Physical things, attributes of things (proximity to others, texture, color except gases), how they interact with other things, how their parts work to make their attributes.

40			LEVEL 2: Application, Bloom's Verb	Apply an abstract idea to a concrete situation to solve a problem [21] E.g. 1 egg + 1 egg = 2 eggs. Eg 4 If you are looking at a flag pole top from the ground at a 26.6 degree angle then the height of the pole is half the distance you are away from the pole. FYI: try 45 degrees and the height is the same. If standing then 45 degree and add your height to your eyes.
41			Knowledge transfer between instances [18p255]	applying knowledge gained in one situation to similar situations [18p255] or altering previous protocols to fit situations requiring modification
42			LEVEL 3: Comprehension, Bloom's Verb	Understand main idea and express in own words [21], explaining, expressing in own words seems to be what is unique (i.e. understand is verb level 1) therefore a person would know the material well enough to communicate it [22p1] Communication (Providing written, verbal, digital, video critical answers) Supply answers at different levels of Bloom's verbs: information, Explain. Although Debate would be at level 6. Expressing information in a more widely distributive manner E.g. Teach a child until the child knows 1 + 1 = 2; ask the child how many eggs you have when you have 2 eggs and they say 2; ask the child if you put an egg beside another then how many are there
43		Appraisal	LEVEL 4: Appraisal … Analysis, Bloom's Verb [13p2]	"Decompositional reasoning" [23], Break down concept into parts and show relationships [21] … "discerning the root cause" [14], performing partial correlations or multi variant analysis … E.g. Use excel to list pros and cons of a decision, condense overlapping pros or cons. Eg2. When px believes + with instance zd; while px believes - with instance zr. Difference seems to be d and r. Although the issue might be zdw vs zrn and the real reason is w and n. w and n would cause correlation to be low and higher random error in difference of means tests (ANOVA, MANOVA). Still need to interpret/evaluate this information.
44			Supposition identification	Identify the assumptions, hypothesis
45			Systematization	Ability to organize processes into identifiable steps in a logical order
46		Appraisal	LEVEL 5: Appraisal … Synthesis, Bloom's Verb	Bring together parts to build relationship for new situation. [21] Discuss [24p1], Debate [25p1] (defend with counter), invent, statistical model building Eg. Using Microsoft Excel or Access for storing debate topics and using it in a debate
47			Ability to reply to arguments with minimal rhetoric	Listening, Self-regulation, logic on the fly, preparation by reading other person's material ahead of debate, communicate response, site logical fallacies, ignoring of arguments and rhetoric of opposition

48		Appraisal	LEVEL 6: Appraisal … Evaluation, Bloom's Verb	Make informed judgments about value. [21] Application of standards [13p2][21] Defend (without counter from another in real time), Premise evaluation by logic (inference/inductive logic). From sample to population by statistics, particulars (sample or individuals) to generalization (population of interest) Argument evaluation in logic, Decision making (weighing options) E.g. Use excel to assign values and then sum values to make decision
49		Application		Applying the corpus of information to a particular scenario. "Making a path to resolve issues" and executing steps in path" [14] Provide warnings regarding intervention [14] Give options and get informed consent. Create resolution path for individuals that are negatively impacted.
50		Assess	Post-Reflecting, Reflecting" [14]	Obtain results in a measurable format. Determine if your solution solved problem and minimized the formation of other problems. Determine how to lessen or even eliminate other problems (safety, convenience and cost) [16p2]. "Knowing one's own thoughts" [14], SWOT analysis (Strength, Weakness, Opportunity, Threat)

Table 3: *Dimensions of critical thinking V02 updated form previous review [1] in step order.*

Now that I have defined logic and shown that it is part of critical thinking, I must add that logic is used in all the subdimensions of critical thinking. As noted in table 3, logical reasoning [13p2] has many types including (not limited to) the following: formal, informal, and modern logic. Unfortunately, what was modern will become otherwise in time; thus the term "non-classical" may be used as well. Formal logic involves logical syntax, premises, and argument forms. Basic examples of formal logic "argument forms" include modus ponens and modus tollens. Informal logical reasoning includes the following: argumentation, rhetoric, dialectic and avoiding logical fallacies. Modern logic includes propositional logic and modal logic in its various forms. As noted in table 3, a mode of modal logic called "deontic logic" is the type of logic used with ethics. When moral qualifiers such as "ought" are used in a statement, deontic logic is applicable. The use of deontic logic in ethics, provides an example of how logic is used in other subdimensions.

Terminology relations

The connection between induction, definition, abduction, hypoduction and deduction are illustrated in figure 1. Also, I have included formal and informal logic within this figure.

Elementary terminology

Nouns include person, place and things. Although, these are not mutually exclusive categories as the following example will reveal. If a captain asked "Is there anything in the bombing range?", a private should not say "No, there is nothing in the bombing range!" when there is a person in the bombing range. Thus the term "anything" does not exclude "persons" or "place". For logic we will have to use more precise language. Defining elementary terminology will be a task for a future article. In the meantime, here is a list of elementary terms:

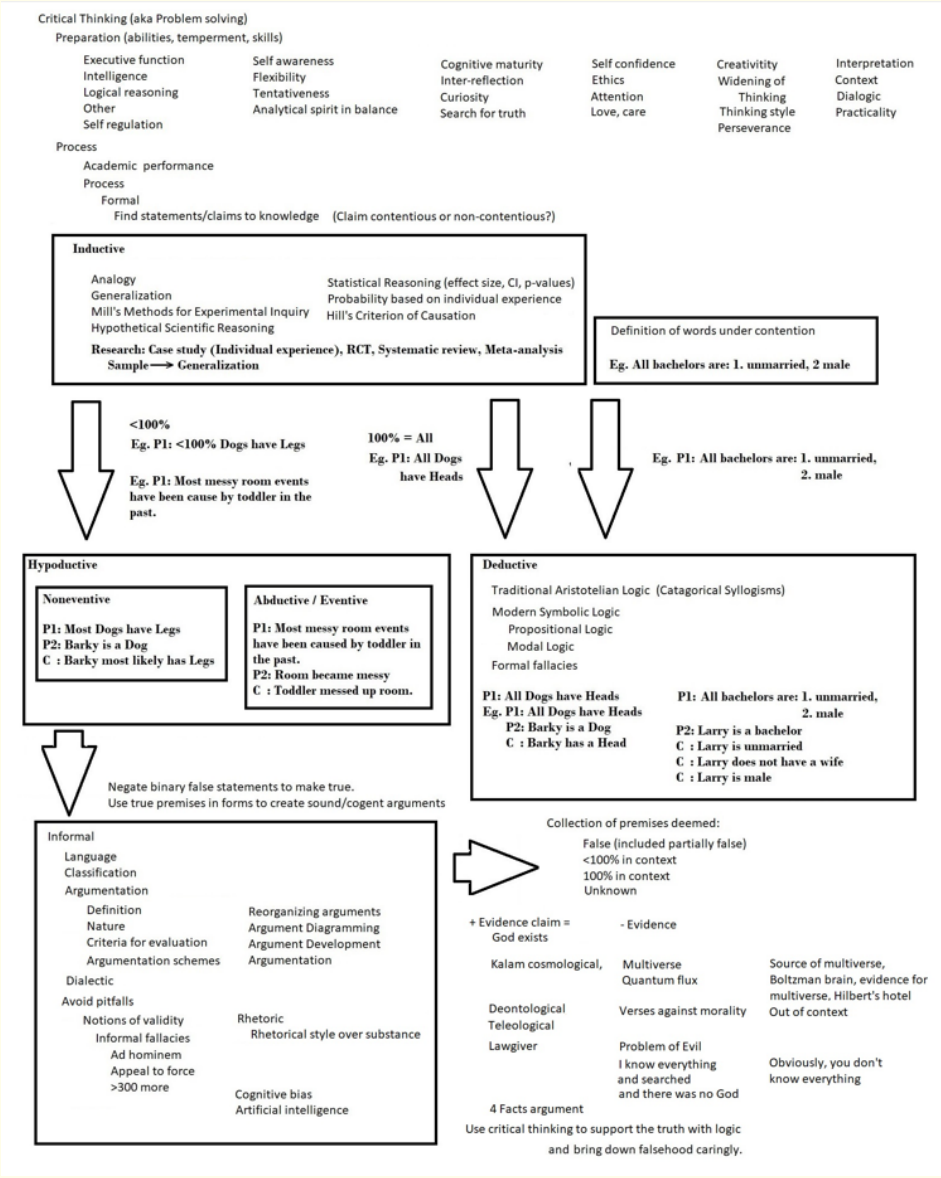


Figure 1: *Logic/Reasoning: The connection between reasoning (induction, definition, abduction and deduction) and logic (formal, informal, non-classic).*

- Imaginaries (Hallucinations, Dreams, Virtuals) VS Reals
- Possibly-livings
    - Person

- Non-person

- Never-livings (with material substance and coordinate location)
  - Example: Stuff (prions, viruses, bookshelves, laptops), Places, Event
- Time:
  - Unit of times from the reference point attempted to be Jesus' birth (BC, AD)
  - Tense: past, present, future, next, before, after
- Actions (verbs)
  - Example (verbs such as ran, graduated, ate, danced, etc.
- Attributes (predicate, adjectives: shape, color, texture, abilities, mood)
  - Attribute could be having a head yet that is a part
  - Shape, color, texture, abilities is a derived characteristic of the physical materials
  - Soul, spirit has attributes
  - Location
  - Tense (time relationship)
  - Percent association
  - Level of measurement
  - Essentiality.

Sources of logic

Sources of logic include: revelation, experience, rationalization, intuition, pragmatics, determinism.

Revelation

The majority of humans believe that God taught humans through revelation. Theistic religions note that ultimate logic is to believe what an immensely powerful, intelligent, non-material, spaceless, timeless, unembodied mind called God has revealed. Since I am a Christian, I will relate this to Christianity. I welcome others to create articles from their perspective. Christianity derives ultimate logic from the Old and New Testaments which they believe the Holy Spirit had more than 40 writers record. In the Old Testament, reverent fear of God is considered the beginning of wisdom. In the New Testament, Jesus is even called the logos in John 1:1. Some believe that 1st principles were revelated from the scriptures such as: Law of non-contradiction, Titus 1:2 [26]; Denial of the consequent Gal 5:18-21; 1 Cor 6:9-11; 2 Cor 5:17 [26]. Titus 1:2b of abc reads as per KJV "which God, that cannot lie". This shows that for God to lie it would be a contradiction to His character. 2 Cor 5:17 states "Therefore if any man be in Christ, he is a new creature". 2 Cor 5:17 shows that conditional statements ("If,

then") are represented in the bible. The denial of the consequent would read: "If He is not a new creature; then He is not in Christ". Other followers of various religions consider their sacred texts as sources of wisdom or logic: Hinduism (Vedas); Islam (Koran via Muhammad, Haddith); Judaism (Old Testament via many, Midrash, Talmud); Others. Since Christian apologeticists such as William Lane Craig [27] and John Lennox [28] do well in debate with leading atheists, Christianity is not an idea to be dismissed. Since it has survived for a long time with such rigor, it should be considered a theory worthy of attention.

Intuition

Intuition (heuristics) [29p1] is another method that works in many situations (is pragmatic). However, this can cause people to endorse an invalid argument when its conclusion is believable [29p2] and reject a valid one when its conclusion contradicts one's belief. [29p2] For example,

"A bat and a ball together cost $1.10. The bat costs $1 more than the ball. How much does the ball cost?"

What is the cost of the bat?

Give yourself time to determine a solution before moving on.

Most intuition says [29p1]

the bat is $1 and the ball is $0.10 [29p1]

The correct answer if different: [29p1]

x = cost of ball, 1.10 = x + x +1, 1.10 … 0.10 = 2x … x = .05 … cost of ball is 0.05, bat is 1.05.

Even though the intuitive response is incorrect is this circumstance; realistically (pragmatically) the person will find out the correct price on the price tag or at the cash register. Also, the difference is negligible in real life. Also, that is a very cheap bat and ball! This is more of a tricky question than a realistic situation. Reality would certainly hit them like a bat when they get to the register. Intuitive responses often work despite this unrealistic situation and they are used by people everyday with some element of success. Where did these intuitive responses come from? Perhaps genetic and experiential. Intuitive responses happen more efficiently (quicker, more accurate) with engagement in real situations.

Experience

Experience can be considered a result of God giving us ways to sense, learn and express ideas. Experience can be brought to a more rigorous level called experimentation which is part of the scientific method. This method is limited to what can be observed, tested, repeated and accessed. The scientific method attempts to single out the effect size of individual variables that are related to an effect. Multiple sources of bias are systematically eliminated by design.

Pragmatics

Pragmatics is where it is considered logical if the intended result happens through experience. The intended result is not just reaching the end in mind; since the result might include avoiding more problems. For example: if you want to keep others from stealing your car; you do not take it apart and bury it. Pragmatics is limited in its ability to determine the effect size of multiple variable and eliminate bias. Yet is works for many pragmatically.

Rationalization

Belief that humans have the ability to figured out truth over time through rigorous experience and logic. Others learned from other sources, never learned, expanded or forgot parts. Over time, the idea is that people can discover logic and hopefully teach others.

Determinism, complete

Theistic, complete determinism is where all is determined by God as an expression of His character. Incomplete determinism is where some things are determined. Atheistic, complete determinism includes the concept that logic is from chemical interactions including energy. Our thoughts and responses are driven by these programs in our mind (however complex) that are written from nature (genetics) and nurture (experiences). Experiential programs are determined by pain, reward centers and other stimuli.

Now that we have been introduced to probable sources of logic, I will discuss the basics of argumentation by introducing sentence types and symbolism.

Sentence types

Sentence types include atomic vs molecular. Sentences can become sentential formulas. Atomic sentences have only one sentence with: Case 1. a subject and verb OR Case 2. A subject and predicate (attribute) AND there are no variables (x), qualifiers (all) or Boolean operators (and, or). Atomic sentence is as follows for case 1: The dog ran. For case 2: The dog is brown. Molecular sentences are more than an atomic sentence. An example of a molecular sentence is as follows: "The dog ran and the cat ran". Notice that this sentence has a Boolean operator (and) and has greater than 1 sentence combined. Here are other atomic sentences:

That ball is a sphere. ….. Sphere (that ball) … S(tb)

The number 4 is even … Even(4)……E(4)

Barky is a dog …….. Dog (Barky) ……..D(B)

The ball is red ……. Red (Ball) ……..R(B).

A sentential formula is where a specific object is changed to a variable:

X is a sphere ……. Sphere (X) …….. S(X)

Z is even …… Even (Z) …… E(Z).

More complex sentential formula:

Z is even AND a whole number AND greater than 2 AND less than 8

W,>2,<4(Z) or W<2>4(Z)

Therefore, Z = 4.

Symbolism

As you probably already noticed, I have used symbols to represent some of the sentences above. Further in this article, I will be using this shorthand for more complex logical statements; therefore, it is recommended to familiarize yourself with the symbols in table 4. The example of "Barky" will be brought up again and I have converted it to symbolic language here:

Example 1: "Barky"

0. Definitions:
    a. Real: NOT imaginary (NOT hallucination, dream, virtual, cartoon, etc.)
    b. Live: NOT brain dead
    c. Other definitions might be necessary such as: All, dogs, have, heads
1. Premise 1 (P1): All real, live dogs have heads (general) …..
    a. All x where x is a real, live dog and x has a Head ……..∀x(R(x)^LD(x)^H(x))
    b. If x is a live dog then x has a head ……..If LD(x) → H(x)
2. Premise 2 (P2): Barky is a live dog …… LD(B)
3. Conclusion (C): Barky has a head (Specific) …….. H(B).

The importance of symbolism is the ability to identify typical arrangements and know how they can be logically rearranged to see the situation in another way. The above arrangement is a "if, then" statement or a conditional statement. Therefore, you could use this in any case where x is a real, live dog. If Rufus is a live dog; then Rufus has a head.

Arb ID	Symbol Category	Name	Symbol	Easy Symbol	Meaning	Example (Eg.)	Note
	Variable (aka facts, terms) [31p2]:		x, y, z, x0, x1				
	Logical connectives [31p2]	Conjunction	∧	^	AND		∧ look more like the A of AND
		Disjunction [31p2]	∨	v	OR		
	Other	Elements of	∈	"eo"	"Element of" a set	1∈{1, 2} means 1 is an element of the set {1, 2}	
		Contains as an element	∋	"st"	"Such that"		
		Existential qualifier	∃	"te"	"There exists"	∃x:P(x)"at least one x such that P(x) is true"	
		Negation	~ or				
		Implication (aka conditional) [31p2]	→	→	"Implies"	If p then q, p → q Eg. Kalam cosmological argument	Might mean: 1. Causes 2. Has attribute 3. Precedes event
		Biconditional	↔	←→	"Implies both ways"		

		Non-causal (notice the lack of the – before the >)	>, ~→		Does not cause		
		Identity	=				
		Material equivalence	≡				
		Equal by definition	$\stackrel{\text{def}}{=}$				
		Predicates	A, B, C … , A0, A1, …			R = Red a = apple R(a) = apple is Red	
		Universal quantifier	∀	ALL	"All"	All multiples of 2 are even = ∀nQ(n)→E(n)	
		Functions	a, b, c, … a0, a1				Put 0 and 1 as subscripts
		Parentheses	( )				Used for grouping, predicate relationships
	Set theory	Union	∪			{1, 2, 3}∪{3, 4} = {1, 2, 3, 4, }	U = Union
		Intersection	∩			{1, 2, 3}∩{3, 4} = {3}	Looks like an n for n-tersection, NOT the same as AND
	Modal logic qualifiers	White square	□		For the alethic mode it means "necessary"		Operators depend on the mode, other symbols may be used
		White diamond	◇		Alethic mode it means "possible"		

Table 4: *Symbolism (shorthand) for logical statements [30].*

First principles

First principles List

Many logical ideas are so basic that they are accepted. If a person denies the idea then they will affirm the idea at the same time. This is called self-refuting. These are called "First Principles" and are listed in table 5. Let us consider an instant of self-refutation (FP#1). If a person says that they do not exist then they are denying "The Principle of Existence". When they deny existence, they are affirming their existence since that which does not exist cannot raise a denial. Even if you said that you will ignore their nonexistent denial then what are you ignoring. In addition, can we pay attention to the infinite amount of things that do not exist? Let us consider denial of "The Principle

of Identity" (FP#2). If a person says that A = B then B is still A and you might as well call it A and not B. If a murderer M kills victim V, then murderer M would have a very week case if he used the excuse that he is no longer M; he is F. He could not simply change attributes without changing his DNA and claim another identity. It would be ridiculous for the judge or jury to accept such a defense.

FP#	First Principle Name	Idea	Symbolism	Notes	References
1	Existence, The Principle of Existence	Being Is	B is, B	By saying I don't exist, I am affirming what I deny. Existence does not require that we can sense it. We have discovered many things we did not know existed in the past.	[32p250]
2	Identity, The Principle of Identity	Being Is Being	B is B, B=B	Continuity of being although the being's attributes change over time. The being at time t is still the being at time t	[32]
3	Noncontradiction, The Principle of Noncontradiction	Being Is Not NonBeing	B is Not Non-B, B ≠ ~B	If you deny this then you contradicted me or are we both right? B has the same context when comparing with B (time, location)	[32]
4	Excluded Middle, The Principle of the	Either Being or NonBeing	Either B or Non-B	There is not an in-between of being and not.	[32], controversial [33p16]
5	Causality, The Principle of	NonBeing Cannot Cause Being	Non-B > B, Non-B ~ → B	Louis Pasteur's work against spontaneous generation	[32]
6	Contingency (or Dependency), The Principle of	Contingent Being Cannot Cause Contingent Being	Bc > Bc Bc ~→ Bc	I can't make another human out of nothing	[32]
7	Modality, The Positive Principle of	Only Necessary Being can cause a Contingent Being	Only Bn → Bc	Do NOT confuse with modal logic please.	[32]
8	Modality, The Negative Principle of	Necessary Being cannot cause a Necessary Being	Bn > Bn Bn ~→ Bn	Otherwise the Bn would not be necessary or would exist before it was created.	[32]
9	Existential Causality, The Principle of	Every contingent being is caused by a Necessary Being	Bn → All Bc		[32]
10	Existential Necessity, The Principle of	Necessary Being exists	Bn exists		[32]
11	Existential Contingency, The Principle of	Contingent Being exists	Bc exists	We exist and we certainly are contingent since non-being cannot cause being.	[32]
12	Analogy, Principle of	Necessary Being is similar to similar contingent being (s) it causes	Bn – similar →Bc		[32]
13	Absolute Truth			Are you absolutely true that absolute truth does not exist?	

14	Mathematics, utility of			Will you give me a $5 bill for $1 if you deny this principle?	
15	Moral objectivity	Objective morals exist	Bn – similar → Bmo	Is it just an opinion or is the worse thing actually bad?	
16	Basic reliability of sense perception			How can you deny this when obviously you sensed this principle. Senses are used daily.	
17	Myth of neutrality			Everyone has a bias; do you have a bias either way?	

Table 5: *First principles list with descriptions.*

Arguments

Introduction

Arguments are basic to human existence and I will show the parts of an argument. Humans make sentences whether in their minds to self or to others by different media (thought, verbal, written, video, etc.). These sentences can be evaluated whether they are true or false. The terms used in the sentences often need to be defined very precisely. I will consider this sentence:

E.g Cats have heads. (Premise 0, P0)

This sentence regarding "cats" is incorrect because "dead cats" might not have a head. Do we need to define these terms: cats, have, heads? I will call this "premise 0". Premise 0 is false as per the evidence given. I could look in the dictionary if I really needed to define cat: "a small domesticated carnivorous mammal with soft fur, a short snout, and retractable claws". The definitions are for the unaltered form of an object or vast majority. The amount of chromosomes is not unique: Cats 38, Baja California rat snake 38, pig 38. The type of genes, order and expression are important. Some cats have been declawed; however, we would still call them a cat. As a side note, note that definitions are mutable by societal pressures. I will try to improve the sentence as follows:

E.g Live cats have heads. (Premise 1, P1)

Even if the head is missing parts, the "live cat" still has a head. Therefore, I cannot find an instance where this is not true unless I get into imaginary cats and computer generated images (CGI). Thus, this premise is tentatively true until I can find a falsification. I will call that "premise 1" (P1). Now I will add another sentence.

E.g Misty is a cat. (Premise 2, P2)

That could be made a difficult sentence since Misty could pertain to many animals or even humans. Most likely if I introduced my cat to you by the name Misty; there would be little reason to argue that point. If I changed the name after 2 minutes, one would probably question me, "I thought your cat's name was Misty".

These sentences can be formed into an argument. Sentences/statements will be called premises. Premises can be combined by different forms. Arguments have premises in a form.

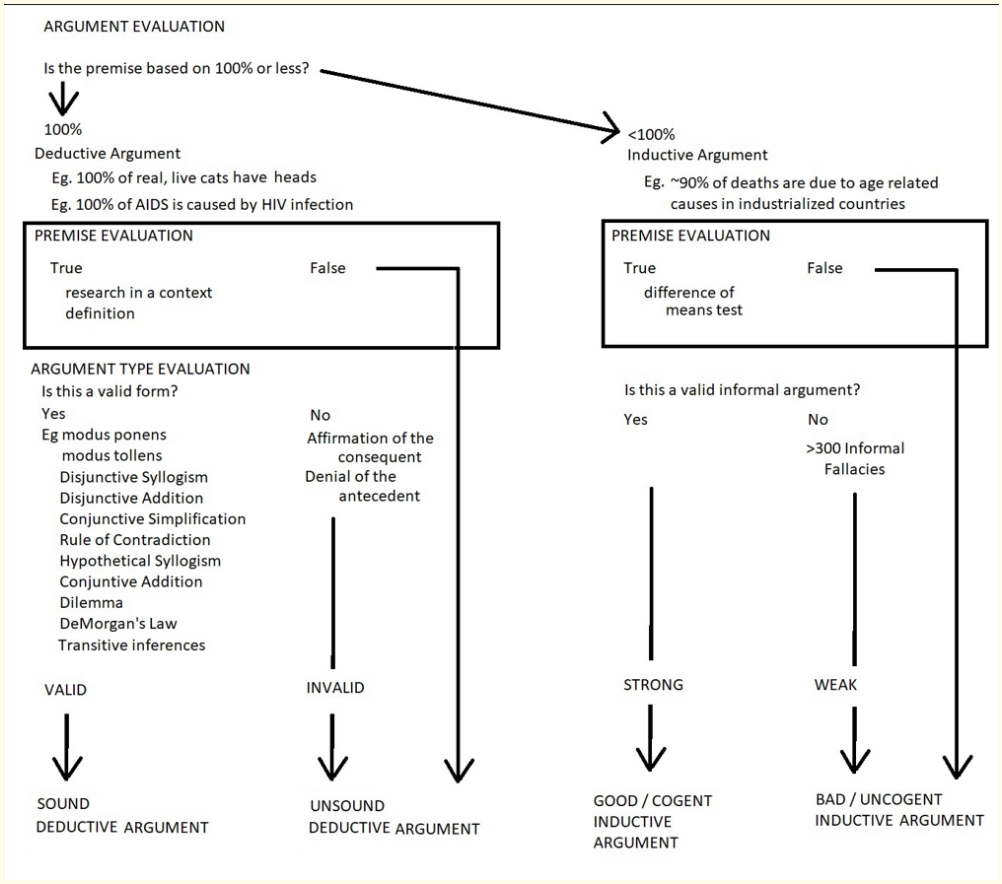


Figure 2: *Argument terminology with details.*

Premise evaluation

Premises are propositions that are attempting to support a conclusion. Propositions are statements that are declarative; they are not commands (imperative) or questions (interrogative). Premises can be true or false. Adequately supported premises are true; while falsified premises are false. Adequate support can be obtained by: equivalent substitution, inference from an experiment, reliable and valid tests, process of elimination. Falsification will be handled below.

Support

How are premises supported?

Equivalent substitution

In this technique, something that is equivalent (exactly the same) is substituted for that which it is equivalent to.

Eg.

Beginning premise: 5 is not even (true)

Equivalency: Not even = odd

Substitution: 5 is odd (still true).

Inference

Inference is a type of inductive logic that goes from a sample (specifics) to population (general); see example 1. This also depends upon the context. The association may be different depending on different contexts. Contexts include: socio-economic status, race, gender, ethnicity, location, etc.

Example 1:

Structure:

Definitions:

O1 = Organism type 1

O1i = Organism type 1, particular individual of that type

A1 = Attribute 1

Premise 1: If ALL Os in representative sample has A1

then O1i probably has A1

Premise 2: ALL Os in representative sample has A1

Premise 3: O1i exists

Conclusion: O1i probably has A1

Example

IF all real, live cats we checked like fish THEN most real, live cats like fish

if we checked a representative sample

If Bill is a real, live cat THEN Bill probably likes fish

Depends upon stats to make the inference to determine a difference or correlation.

Sensitive and specific tests

Some conditions have tests that help to determine their existence. Sensitive tests are used to rule out diagnoses and specific test to rule in diagnoses. Some tests like amylase and lipase are both sensitive and specific for pancreatitis based upon the stats called sensitivity (Sn, Se) an specificity (Sp). Modus ponens is a form used in this process.

Modus ponens (type of form)

If p → q

p

Thus q

Eg. If TG+ (high serum uric acid, synovial fluid analysis, x-rays of bone erosions) then person has gout

Tests for Gout are + (TG+)

Therefore, G (Gout).

Process of elimination

All possible options are listed in this method and evidence is used to throw out options. For example, if a person has pain in the knee the differential diagnoses may include the following: strain, sprain (meniscus, ACL, PCL, LCL, MCL), bursa, joint (lyme, gout, arthritis) and others (always want to have other). A doctor would ask many history questions to limit the possible diagnoses such as asking when and how it started to determine if it was traumatic or not. Other questions, exam procedures, x-rays and lab tests would help to rule in or rule out other possibilities. This is related to a complex form of "Disjunctive Syllogism".

Disjunctive Syllogism (aka "this or that") (type of form)

p v q

if ~q then p

if ~p then q

Eg. The Dx could be A,B,C,D,E,F or G

No other tests positive for A-F

Therefore, consider G (Gout).

Determining the cause of urinary pain is a process of elimination as well.

Premises can be eliminated as well by determining that they are the result of formal fallacies or informal logical fallacies. For an example of a formal fallacy, if a person says that "uncontrolled diabetes type II will cause high blood sugar" then that is true. However, it is NOT true that "all causes of high blood sugar is due to diabetes type II". It could be type I or any other condition listed in a diagnostic laboratory manual for example: acute stress or Cushing's.

Premises are true if they are derived from:

Inference from multiple experiments specific to the context it is being applied to

Reliable and valid tests

Sound arguments (true premises and valid forms).

Falsification

Falsification can occur by the following means: death by exception, self-defeating, logical fallacies.

Death by exception

This method is where the person says a claim and you show an example when the claim is incorrect.

Eg.

Claim: There is no evidence for God

Exception: Kalam cosmological, Deontological, Teleological, Ontological argument, Martyrdom without Motive (Paul, James the less, disciples), Historical, Prophesy, Events of Christ, Experience.

Eg.

Claim: When you drop something it will fall to the ground

Exception: Except if it is a helium balloon

Exception to the Exception: Unless the helium balloon has anvils attached to it.

It is important to determine if the exception matters in the context of the discussion.

Self-defeating

Self-defeating is where if a person believes a viewpoint then that viewpoint falsifies itself. If one believes that truth does NOT exist then is it that true? Denial of truth is a self-defeating claim. First principles are an example of principle that are true since denying them would be self-defeating.

Logical fallacies

There are lists of over 300 informal fallacies [11] and many formal fallacies. Informal fallacies include equivocation and ah hominem which shall be covered later. Formal fallacies include particular forms that are not sound such as:

If p then q

q

Thus p.

For example:

All real, live dogs have heads

x has a head

x is a real, live dogs.

This is wrong because the thing with a head may be a cat. Thus, logical fallacies are involved in falsification of premises.

Conclusion

Premises can be supported or falsified or unsupported. Just because something is unsupported it does not make it false. It is best to say "I do not know". If the premises are true and the form is valid, then "the conclusion logically follows from the premises" [10p541] That conclusion can be used as a premise for other arguments.

Forms

Introduction

Indeed, we have introduced many forms already; for example, modus ponens and disjunctive syllogism. "Modus ponens" is often used as an example of a form. Modus ponens shows one of the following:

A. Causation events: if p always causes q and p happened then q happened

B. Attribute association: if p always has attribute q and p exists then attribute q exists

C. Diagnostic test: if test p being positive always means the person has diagnosis q and p is positive then person has q.

Here is the basic structure of the argument form:

If p then q

p

therefore q.

Here is an example:

If x is a real, live cat then x has a head.

x is a real, live cat

therefore, x has a head.

If x is a live cat then x has a head

Misty is a live cat

Therefore, Misty has a head.

Here is a more complex form using fence building:

If the vertical fence pole meets criteria N, H, P, L then you can secure the pole (cement it in, back fill with dirt and tamp it tight)

Criteria N = Normal pole (4x4, 8ft, straight, not damaged, new, wood)

Criteria H = Height of pole top lower than previous panel and higher than its highest horizontal stud

Criteria P = Previous privacy fence panel level horizontally and centered to pole

Criteria L = Level on both vertical dimensions

Criteria N, H, P, L meet

Therefore, you can secure the pole.

Here is another complex example using Basic Life Support:

If a patient does NOT meet the criterion U, D and HAS Criterion P, C then do CPR

Criterion U: Unresuscitatable death signs: decapitation, levity, rigor mortis (with no potential of hypothermia)

Criterion D: "Do Not Resuscitate" order valid

Criterion P: Primary assessment has been done

Criterion C: Cardiac arrest = no pulse

Patient does NOT meet the criterion U, D and HAS P,C

Therefore, do CPR.

Here is another complex example with diagnosis.

Definitions:

A = high serum uric acid

B = synovial fluid analysis showing uric acid crystals

C = x-rays of bone erosions

If patient has criterion A, B, C then they have G

Joe has criterion A, B, C

Joe has Gout.

Form evaluation

How would you know if an argument is legit, true, good, valid, sound, cogent, etc.? Previously, I noted that the premises would have to be true according to premise evaluation methods. Another concern is whether the form of the argument is valid or strong.

Deductive logic cases, where the attributes have a 100% association, require valid forms and true premises to be considered "sound". These forms include the following: modus ponens, modus tollens and many others that I will list later. Here is the criterion for a deductive case:

A deductive argument is said to be sound if:

- Premises are true (versus false)
- Form is valid (versus invalid)

Equation/function:

- True premises are in a valid form → sound argument

A deductive argument is said to be unsound if:

- The premises are false OR the form is invalid
- Therefore: premise (false) OR form (invalid) = UNSOUND
- Also: premises (false) AND form (VALID) = UNSOUND
- Also: premises (TRUE) AND form (invalid) = UNSOUND.

Inductive logic cases, where the attributes are less than 100% associated between p and q, require strong argument styles that are not logical fallacies and true premises to be considered "good" aka "cogent".

An Inductive argument is said to be cogent if:

- Premises are true (versus false)
- Argument style is strong versus weak

An inductive argument is said to be unsound if:

- The premises are false OR the form is weak
- Therefore: premise (false) OR form (weak) = UNCOGENT
- Also: premises (false) AND form (STRONG) = UNCOGENT
- Also: premises (TRUE) AND form (weak) = UNCOGENT.

The "valid" (deductive, formal) and "cogent" (inductive, informal) forms will be listed below under the details of the types of logic.

Types of logic, list

Regarding types of logic, I will list the types [34], explain argumentation, explain forms and then give further details of the types. Here is a list of the different types:

Formal logic/classical logic/Aristotelian logic

- Arguments: premises and conclusions
- Zeroth-order logic (propositional logic)
- First order logic (aka predicate logic, quantification logic, first-order predicate calculus)
- Second order logic- quantifying predicates (aka attributes, adjectives)
- Higher-order logic (aka HOL, Third order logic, others)- form of predicate logic with quantification over sets
- Formal fallacies

Informal logic

- Language
- Classification
- Argumentation
- Notions of validity
- Logical fallacies
- Rhetoric
- Dialectic
- Cognitive bias
- Artificial intelligence

Not classical/modern logic

- Propositional- simple declarative statements OR combined
- Modal logic by C.I. Lewis
- Mathematical
- Trivalent

Other types of logic

- Symbolic
- Mathematical logic

- Predicate Logic
- Computational
- Bayesian logic
- Probability calculus.

Types of logic, details

Formal logic (aka classical logic, Aristotelian logic)

Details of forms of formal logic

Valid forms list

1. Propositional inferences
2. Modus ponens
3. Modus tollens
4. Logistic inferences [35p1]
5. Transitive inferences [35p1]
6. Disjunctive Syllogism (this or that)
7. Disjunctive Addition
8. Conjunctive simplification
9. Rule of Contradiction
10. Hypothetical Syllogism
11. Conjunctive Addition
12. Dilemma
13. DeMorgan's Laws 1 and 2
14. Distributive conjunction by disjunction [31p2]
15. Distributive disjunction by conjunction [31p2].

Valid forms details

1. Propositional inferences list [35p1][10p1]

a. Zeroth-order logic (propositional logic)

i. Includes modus ponens and modus tollens

b. First order logic (aka predicate logic, quantification logic, first-order predicate calculus)

i. Predicates = attributes

ii. Example

1. If you push the Green Start Button on the AED then it Starts

2. GS(B) → S

c. Second order logic- quantifying predicates (aka attributes, adjectives)

d. Higher-order logic (aka HOL, Third order logic, others)- form of predicate logic with quantification over sets

2. Modus ponens: If A then B, A therefore B

a. Basic Modus ponens (MP) [10]

i. Structure

1. Premise 1: If P then Q

2. Premise 2: P

3. Conclusion: Q

ii. Structure Abbreviated

1. p → q

2. p

3. C: q

iii. Example

1. "if I can speak" then "I am alive"

2. "I can speak"

3. Therefore, "I am alive"

iv. Example

1. Premise 1: If P(PtA has criterion for Dx A) then Q (PtA has DxA)

2. Premise 2: PtA has criterion for Dx A
3. Conclusion: PtA has DxA

b. Example 1:

i. If most of our customers are a particular age group x, we should put more advertising money to x

ii. Our main customers are 30-40 year olds

iii. We should put more advertising money to 30-40 year olds more

iv. Counters

1. Perhaps we have been marketing to the wrong group and we would get more money if we marketed younger
2. Perhaps we will reap the benefits in the future when the younger people have more money to buy out product

c. Suppression

i. Premise 1: If it rained, person A gets wet

ii. Premise 2: It rained

iii. Conclusion: person A gets wet

iv. If you add to premise 2 "and person A was in the house" then people will not follow Premise 1 to its logical conclusion

v. If the premise 2 addition is removed then it will suppress a person's conclusion "person A gets wet"

vi. This suppression is a difference between a logistician's way of thinking and the average person.

3. Modus tollens (MP)(aka rule of contraposition(CP) [31p2]: If not B then not A, not B therefore not A

a. Eg symbolic

i. Structure

- $p \rightarrow q$

1. $\sim q$
2. C: $\sim p$

ii. Structure Abbreviated

1. If not q then not p

- In symbolic logic: $\sim q \rightarrow \sim p$

b. Eg Speaking and Alive

   i. Eg. “if Mark can speak” then “Mark is alive”

   ii. Mark is not alive

   iii. Thus, Mark can not speak

c. Eg Rain

   i. If it rained last night, then the sidewalk is wet

   ii. Contrapositive: If the sidewalk is not wet, then it did not rain last night

d. Eg Diagnosis

   i. If dx D then signs S

   ii. MT/CP: If NO signs S then NO Dx D

   iii. Since diagnosis are determined by signs, the second premise is more pragmatic

e. Eg Diagnosis

   i. If signs S then dx D

   ii. MT/CP: If NOT dx D then NO signs S

f. If the initial premise is true then the converse is:

   i. TRUE

g. Notice that is it not true that if it rained last night, then the sidewalk is wet. The sidewalk might have a water resistant cover over it. The sidewalk might have dried by the time you saw it.

4. Logistic inferences [35p1]

   a. All A have attribute B, All attributes B have attribute C; therefore A has attribute C

      i. Eg. IF all cats have characteristics A, B, C and Bill is a cat THEN Bill has A,B,C

   b. Eg. All As are Bs, All Bs are Cs, therefore All As are Cs

      i. Eg. All spiders are insects, all insects are animals, therefore all spiders are animals

5. Transitive inferences [35p1]

   a. Eg. A is taller than B; B is taller than C; therefore A is taller than C

6. Disjunctive Syllogism (this or that)

a. p v q

b. if ~q then p

c. if ~p then q

d. Eg. If you draw out a sock out of my drawer then you will get a “white” OR “black” sock

e. If NOT “white” then it will be “black”

f. If NOT “black” then if will be “white”

g. Extra thoughts:

i. If you pull out 3 socks then you are guaranteed a match AND an extra sock.

ii. Always consider for more options when someone says there is only x many options.

7. Disjunctive Addition

a. p q

b. thus p v q

c. Eg. There are balls labeled p in the bag. Same with q

d. Thus you will get a p or q labeled ball

8. Conjunctive simplification

a. p ^ q p^q

b. thus p thus q

c. Eg. If a person went to the store AND the library

d. Then they did go to the store (p)

e. Then they did go to the library (q)

9. Rule of Contradiction

a. Definition

i. ~p = absence of p

ii. c = contradiction

b. Structure

i. ~p → c

ii. Therefore p

c. Translation: If not p is a contradiction then p

d. Example 1

i. Eg. "I can't type in English"(~p) is a contradiction

ii. Therefore, I can type in English (p)

e. Example 2

i. Eg. "I don't exist" is a contradiction

ii. Therefore, I do exist

10. Hypothetical Syllogism

a. p → q

b. q → n

c. Thus p → n

d. Eg. If "I can speak" implies "I am alive"

e. And If "I am alive" I have a pulse"

f. Then If "I can speak" implies "I have a pulse"

11. Conjunctive Addition

a. p

b. q

c. Thus p AND q

d. Eg. If "I can speak"

e. If "I have a pulse"

f. Then "I can speak and I have a pulse"

12. Dilemma

a. Structure

i. p v q … p OR q

ii. p → r

iii. q → r

iv. r

b. Example

i. "I lie and say the speech was good" OR "I tell the truth and say the speech was bad"

ii. If I lie then I feel bad

iii. If I say the speech was bad then I feel bad

iv. Either way "I feel bad"

c. Assessment

i. Think of other options than p or q … how about n or m?

13. DeMorgan's Laws

a. 1st DeMorgan's Law: [31p2]

i. Not (p ^ q) → not p v not q ….

ii. The Red area of the Venn diagram

iii. Example:

1. Do not mulch the garden in area blue and yellow;

2. thus, do not mulch the blue or yellow area

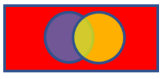
b. 2nd DeMorgan's Law: [31p2]

i. Not (p v q) → not p ^ not q ….

ii. Example:

1. Do not mulch the garden in area blue or yellow;

2. Thus, do not mulch the garden in blue and do not mulch in yellow



14. Distributive conjunction by disjunction [31p2]

a. (a^(bVc)) = ((a^b)V(a^c))

b. p AND (b or y)=(p AND b) OR (p AND y))

c. purple AND (blue or yellow) = (purple AND blue) OR (purple AND yellow)

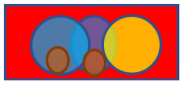
d. Venn Diagram

e. Example:

i. I have 2 trees

ii. Put them in the purple area AND (blue or yellow)

iii. Put them in the purple AND blue area OR the purple AND yellow area




15. Distributive disjunction by conjunction [31p2]

a. (aV(b^c)) = ((aVb)^(aVc))

b. a OR (b AND c) = (a OR b) AND (a OR c)

Invalid forms (aka formal fallacies)

Invalid Forms, Formal Fallacies (based on the structure of the argument; as opposed to the content)

1. All D have attribute L, C has attribute L therefore D is C

a. Eg. All running dogs have legs, All running cats have legs; therefore dogs are cats

2. p → q, q, therefore p

a. If x is a live dog then x has a head, y has a head therefore y is a dog

b. Critique: y could be a cat or many other things that have a head

3. Expecting a different result from the same thing

a. If p →q

b. p

c. Expecting r.

Transformations

Transformations, some of which are valid forms or can be used in a valid manner (negation of a falsehood) [36]

1. Negation
    a. Insertion of the word NOT or ~ or
    b. Symbolic
        i. Initial premise: p is q
        ii. Negated premise: p is ~q
    c. Eg. Right Triangle and equilaterality
        i. Right Triangle = has a 90 degree angle
        ii. Equilateral = has all angles 60 degrees and equal sides
        iii. The right triangle is equilateral (false)
        iv. Negation: The right triangle is NOT equilateral (true)
    d. Eg Even and Odd
        i. Starting conditional phrase
            1. 10 is an even number
            2. If you have a 10 then the number is even
        ii. Negation: 10 is NOT an even number (false)
    e. Statement
        i. If it rained last night, then the sidewalk is wet. (slight possibly that it is false; if a plastic cover is over the sidewalk)
        ii. Negation: If it rained last night, then the sidewalk is NOT wet (probably false since most sidewalks are not covered)
    f. Negation can be used to change a false statement to a true then feed it into an argument form
        i. Only 2 possibilities
            1. The number 4 is odd (false)
            2. The number 4 is NOT odd (true)
        ii. Feeding true premise into the valid argument form “modus ponens” to form sound conclusion

1. If a number is NOT odd then it is even
2. The number 4 is NOT odd
3. Therefore, 4 is even

g. Rule of double negation: ~(~a) = a [31p2]

2. Converse

a. Eg symbolic

i. If p then q

ii. Converse: If q then p

b. Eg Rain

i. If it rained last night, then the sidewalk is wet (most likely true, unless covered by plastic, car, etc.)

ii. Converse: If the sidewalk is wet, then it rained last night (most likely true unless sprinkler, spilled water, etc.)

c. If the initial premise is true then the converse is:

i. Could be FALSE or TRUE

d. Converse and Inverse are logically equivalent to each other

i. If the converse if true then the inverse is true

ii. Eg. Subset of Even

1. If p then q: If the number is even then it is 10 … false premise
    a. The number could be 2,4,6,8,12 etc.
2. Converse: If the number is 10 then it is even … true
3. Inverse: If the number is not even then it is not 10 … true

iii. Eg. Subset of Even AND Multiple of 5

1. If p then q: If the number is even AND a multiple of 5 then it is 10 … false premise
    a. The number could be 20,30,40 etc.
2. Converse: If the number is 10 then it is even and a multiple of 5 … true
3. Inverse: If the number is not even and not a multiple of 5 then it is not 10 … true

iv. Eg. Incorrect attribute of subject

1. If the creature is a butterfly then it will eat lava … false premise
2. Converse: If a creature eats lava then it is a butterfly … false premise
3. Inverse: If the creature is not a butterfly then it will not eat lava … false premise
    a. Is there bacteria that eat lava? What does it mean to eat?

3. Inverse
    a. Eg symbolic
        i. If p then q
        ii. Inverse:
            1. If not p then not q
            2. ~p → ~q
    b. Eg Rain
        i. If it rained last night, then the sidewalk is wet
        ii. Inverse: If it did not rain last night, then the sidewalk is not wet.
    c. If the initial premise is true then the inverse:
        i. Could be FALSE or TRUE
    d. Converse and Inverse are logically equivalent to each other.

Causation terminology and revisiting of forms

Conditional Reasoning (aka if-then statements) [37] [10p7].

Types of Causes:

Necessary AND sufficient cause: p1ns → q1

- Eg.
    - p1 = God decides to create universe
    - q1 = God created universe
- Eg.
    - Kalam Cosmological Argument
    - Define universe = all EMS/energy (“Let there be light”), matter, space, time

- Something that is not part of the universe … unembodied mind from which all originated
- If universe began to exist then something made it that is not material
- Universe began to exist
- Therefore, something made it that is not material (unembodied mind)

Necessary, NOT sufficient cause: (p1n + p2)s → q1 OR (p1n +p3)s → q1

Sufficient, NOT necessary cause: p1s, p2s or p3s can cause q1

Eg.

- p1 = cue stick hits cue ball
- p2 = anything else hits cue ball
- p3 = table tilts enough, earthquake is enough
- q1 = cue ball moves

Additive sufficient causes: (p1 + p2)s → q1

Eg.

- p1 = car going down road with tire at point a
- p2 = squirrel going across street to point a
- q1 = squirrel is hit by car tire

Assessment: p1 or p2 by themselves do not cause q1

It has to be both at the same time and location

NOT sufficient, NOT Necessary cause: (p1 + p2)s → q1 OR (p3 + p4)s → q1

Assessment: the sets are sufficient yet individually they are NOT sufficient, NOT necessary.

Conditional logic and revisiting of forms

Syntax for conditionals

- Conditional logic syntax [37]
  - Major premise … If p, then q [37]
- p = antecedent [37] cause, p can have many qualifiers

- If person A walks in the rain then their skin gets wet
- Qualifiers: AND they are not using an umbrella, raincoat, cover, etc. …
- If person A drops something then it will fall to the ground
- Qualifiers: AND the something is heavier than air, nothing is between the something and the ground, there is not
    - anything else that will restrict the something (fan, tether string, etc.)

- q = consequent [37] caused

"Logical forms" [37] of argumentation

- Modus ponens (MP) [37] (If P then Q; P//Therefore, Q)
- Modus tollens (MT) [37]
- Affirmation of the consequent (AC) [37](P than Q; Q therefore P) [35] [29p4]
- Denial of Antecedent (DA) [37]
- Inferences including negation
    - Or-elimination: P or Q; Not-P; Therefore Q [35] aka "Process of Elimination"
- Reductio absurdum.

Name of form (Abbrev.) "aka"→ Aspect	Modus ponens (MP), "assertion of the antecedent"?	Modus tollens (MT) "Contrapositive", "Denying the consequent"	Affirmation of the consequent (AC) "Assertion of the consequent"	Denial of the antecedent (DA)	Reductio ad absurdum (RA) "Apagogical arguments"	Counterfactual assertion
Type of Logic	Deductive	Deductive	Inductive	Inductive	Inductive	Inductive
Starter statement	If p then q	If p then q	If p then q	If p then q	If p then q P(x), x has attribute P, Improbable x has P thus Not P(x)	If p then q when p did not happen
Starter = True?	True	True	True	True	True	False since p did not actually happen
Form	If p then q	If ~q then ~p	If q then p	If ~p then ~q	If ~q then ~p P(x) < P(x*)	
Minor premise	"p is true" If p exists If p happened	"q is false"	"q is true"	"p is false"		

Normatively correct conclusion	"so q is true" So q exists So q happened	"so p is false"	"so p or not q"	"so q or not q"		
Minor premise wording	Positive	Negative	Positive	Negative		
Conclusion type	Definite	Definite	Indefinite	Indefinite	More probable	
Minimally required models to make a correct inference	"p and q"	"p and q", "not-p and not-q"	"p and q", "not-p and q"	"not-p and not-q", "not-p and q"		
Example (Eg.)	P1. All live snakes have a head P2. Jimmy is a live snake C: Jimmy has a head	P1. If x does not have a head then it is not a live snake P2. x does not have a head C: It is not a live snake	P1. If it rains then the game is cancelled P2. The game is cancelled C: It rained	P1. If you work as doctor, then you have a job. P2. If you do NOT work as a doctor C: you do NOT have a job	P1. If x said he could run 10 miles in 30 P2: The fasted recorded is 44:24 C: x could not run that fast	P1. If I would have walked down road B I would have not gotten hit by a car "c" P2 I walked down road A C: Don't know if B → ~c
Correction	N/A	N/A	Could have been cancelled due to earthquake	You might have a job as a senator.		
Deduction or Induction	Deduction	Deduction	Deduction	Deduction	Induction	Induction
Valid or Invalid	VALID	VALID	Invalid	Invalid	Probably, depends on strength of inference and assumptions	Possibly, depending on strength of inference and assumptions
Notes					Modus tollen working with probabilities	What would have happened if B was the case instead of A

Table 6: *Logical forms in conditional reasoning for the major premise "if p, then q". Adapted from Datsogianni., et al [37p3].*

Informal logic

Informal logic includes: Informal fallacies, Rhetoric and Dialectic which are described below. In general, informal logic is meant to handle the arguments that are used in regular conversation. It serves to classify the way people use language (verbal and body language) to communicate statements. This classification often deals with incorrect forms of persuasion that are not in the formal system.

Informal fallacies

There are over 300 informal fallacies. A few examples include equivocation and ad hominin.

An example of equivocation is as follows:

P1: My body is made of cells.

P2: Cells are where prisoners are placed

C: I am a prisoner in my own body.

Evaluation: Notice that the person equivocates on the word "cells" between premise 1 and 2. P1 uses the definition of "cells" being the basic building block of life with nucleoli, mitochondria and other cell parts. P2 uses the definition of "cells" being the room that prisoners live in. Indeed this could have an emotional meaning that is implied by the source. The charge of equivocation would be missing the point of the person who is expressing an intense feeling of feeling trapped.

Ad hominin informal fallacy is expressed as follows:

Person A: God exists

Person B: You did not go to college and therefore you are too uneducated to understand that God does not exist.

Evaluation: Notice that Person B did not ask for the evidence why Person A believes in God. They changed the subject to a personal attack on the individual. Perhaps they could offer positive evidence against the concept of God or counters to typical positive evidences for God. Perhaps both Persons could look at the evidence together when professional debaters and experts handle these topics.

Rhetoric

Use of rhetoric includes all of the following: A. appreciating the audience, sponsor, family and your opposition; B. smiling at audience; C. frowning or shaking head to say "no" during opponent's rebuttal; D. style over substance; E. following up on opponents missed rebuttals; F. supporting a weaker than your real position; G. interruption; H. setting audience to heckle; I. Other.

Dialectic

System of debating with tables and symbolic logic.

Non-classical/modern

Non-classical (aka Modern logic) includes modal logic and propositional logic (PL). This system of logic is a formal deductive system with elements of induction (< 100%). This system was not part of classic methods formulated by Aristotle and contemporaries.

Modal logic handles propositions regarding different modes which include existence, knowing, morality, temporality/time, belief and others. Depending upon the mode, qualifiers are added to the propositions such as "necessary", "possible" regarding existence (the Alethic mode). The mode of modal logic depends on the qualifier used. See table 7 for some details of the "modes" of modal logic and the respective qualifiers. For example, if the qualifier "It ought to be the case that" is used in a proposition then the proposition is deontic. Modal

problem solving [20p904] by simulated clinical training [38p968] and debate [25p1]. The side effects of "high-fidelity simulation" include intense stress. The student body should be surveyed regarding the level of stress to avoid suicide, negative consequences on their families

	Expressions	Operators	Square meaning	Diamond meaning "possible"	Axioms applicability
Alethic	Existence		It is Necessarily	It is possible that	K, Nr, D, T 4, 4.2, 4.3, Q
Epistemic	Knowing		It is known that, it is known to person p that, it is common knowledge that	For all x knows, it may be true that	D, T, Q
Deontic	Morality	O=It is obligatory that	It ought to be the case that, it is obligatory/ forbidden/ permitted/ unlawful that	It may be the case that	K, D
Temporal (tense logic)	Time	Future G Past H	It is always the case that	It is sometimes the case that	K, Nr, 4
Doxastic	Belief		It is believed by s that, it is believed that, it is highly probable that, the probability is greater than r that, it is commonly believed that	It is possibly believed by s that	

Table 7: *Modal logic.*

sentences of the same mode can be combined in many ways called axioms. Some axioms do not apply to some modes. For example the deontic mode can be transformed with axiom K or D. Some of the axioms are similar to the forms used in classical formal logic.

Propositional logic (PL) is meant to take the statements from classical logic and combine them to make more complex deductions.

Barriers, solutions

Barriers that exist for logic are voluminous. Each barrier is specific to the type of logic: formal, informal, or modern. The details of these types seem to be too complex for most individuals to progress significantly though higher levels of learning. Many people exhibit a common understanding of basic logic; yet most members of society applying advanced logic does not seem attainable. Significant learner problems in students are about 5.8% - 9.1% [24p2]. These students most likely would have difficulty with these concepts while some would excel. Ahmady lists many barriers for critical thinking while difficulties with the subset of logic seem as vast as the topic itself.

Some solutions may involve governing bodies using artificial intelligence that can do the calculations; however, the AI may be limited by their programming of what the software considers the ultimate good (knowledge, thriving of humans, thriving of AI, thriving of self). Regarding governing bodies, they are often too entrenched in maintaining their own power through politics. Nevertheless, it is imperative for the populace to learn logic as part of critical thinking to avoid becoming compliant to the point of losing freedoms. Politicians often give stuff to get control; then when they get control they take more than was given. Healthcare providers have the obligation to their patients to reach a higher yet realistic threshold of achievement [18p260] in the realm of logic. They need to be able to perform individual based

and other side effects. Nevertheless, past studies have shown that intense learning helps to form "the student who had the self-evaluation capacity [that] seemed to reflect on their responsibility to learn and the need to acquire the required skills for patient care" [38p973] [24p7].

Discussion

Since logic has not been systematized to handle all situations and all bias eliminated, logical forms are sure to be used in computer algorithms to make decisions in the future with artificial intelligence (AI) for diagnosis. With 50 or more sub-dimensions, comprehensive critical thinking is unbearable for humans. Standardization may lead to cookbook type practice [18p261]; however, the AI programs need to have human override capability. Recent events have shown the importance of being able to question lock box outputs since they may be controlled by bureaucracy (national organizations, government, big corporations).

Utilization of logic in healthcare

The utilization of logic in healthcare can be implemented by the following stakeholders: patient, doctor, insurance company, community, community organizers and community leaders. Community organizers use logic as part of critical thinking to determine for whom communities act [39]. Genuine empowerment of these levels can be obtained by strengthening what they have, do and for whom they act [39]. Teaching logic might help in this empowerment to help these levels form reasons for what they believe, avoid fallacious conclusions and make level comparisons. Many diagnostic and treatment protocols have been questioned through systematic review and meta-analysis such as cranial osteopathy [40p2] and visceral osteopathy [41p1-2]. This list was from a very limited search and should be expanded into established protocols. Reviews of established treatments has been performed on chiropractic for acute low back pain [42], ice for acute low back pain [43] and R.I.C.E. for ankle sprain [44]. My point is not to say that these treatments are bad. An appraisal of the meta-analysis might reveal questionable study content such as high heterogeneity. This is not to say that the studies are bad. Often the study's content is limited by the research available. Indeed, all diagnostic and treatment protocols should be questioned and placed on an equitable playing field to provide the best healthcare for the community. Unfortunately, reasoned debate can be thwarted by political pressures that may silence questioning. These political pressures can be due to the following aspects: 1. not creating free, platforms for formal debates; 2. Lack of people trying to handle the material in as neutral of a fashion as possible to the population; 3. inequitable research infrastructure and 4. inequitable funding.

Training

Philosophy for children (P4C) is an example of an educational program meant to promote cognitive abilities including logic in the community with "promising" results [45p11]. Certainly the level of training should be structured by starting at lower levels of Bloom's taxonomy and slowly increasing complexity throughout K-graduate level curricula while adding new topics. This was accomplished in a chiropractic curriculum regarding EBCP topics [46]. This paper could be used as a sketch for the progression of topics.

Logical arguments are essential in debate and considered effective in learning healthcare; although further study is necessary [47p1]. Debates should provide depth (keep subject narrow) and avoid logical fallacies and rhetoric that promotes falsehoods.

Regarding debating healthcare subjects, the proponent of a procedure should provide positive evidence for:

1. Effect size compared to placebo and MCID: Treatment helps more than MCID verses placebo (not compared to acute phase). MCID is the minimally clinically important difference.

2. Treatment should not be associated with significant side effects including time (transport, treatment time, home instructions), adverse health effects, inconvenience, and cost. This might be difficult to determine if the treatment was provided free of charge by the researchers. Also the patient might overestimate the value of the procedure since they will compare to their discomfort during the acute phase instead of the natural history or placebo.

Application to healthcare

After exploring different aspects of logic, the following will be an exploration of the relationship between logical forms and the routine functions of a health professionals.

The function of physician includes:

- Having a database (mind, program, file system) to pull this information
- Determine which symptoms imply what diagnoses
    - Logical Form: "Modus ponens"
        - If person x has criterion A then they have Dx A
            - STATS: this is true if the test has a specificity >90 and the condition is not rare OR the positive likelihood ratio (+LR is >10)
        - Person x has Criterion A
        - Therefore person x has Dx A
        - If criterion for Dx A is met; then person x has Dx A
    - Forming list for "Process of Elimination"

Have post history diagnosis list by percentages and links to how to tests needed to rule in or out from least cost and invasiveness.

- Perform tests (physical examination, orthopedic/neurological physical tests)
    - Perform sensitive/screening tests for ruling out and specific/confirmatory tests for ruling in
    - Perform "Process of Elimination"
    - Determine post-physical test diagnosis list and links to how to special test from least cost and invasiveness.
    - Perform or order neuro-diagnostic (NCV, EMG, etc.), imaging (x-ray, MRI, CT, PET, bone scan) and laboratory special tests (urine, saliva, blood, feces, biopsy)
    - Determine post-special test diagnosis list and links to how to rule in or rule out each diagnosis
    - Working diagnosis determined

- Treatment best for diagnosis in context of patient, physician's experience and research
- Reevaluate if not better then it could be the treatment, adherence or the diagnosis:
    - I will play with the idea that the diagnosis was wrong.
        - What it the healthcare worker did not care about stats.
        - Notice the STATS said this:
            - STATS: this is true if the test has a specificity >90 and the condition is not rare OR the positive likelihood ratio (+LR is >10)
        - I will rewrite it in symbolism: (>90Sp(test) AND ~rare(Dx)) OR >10(LR) = (p AND ~q) OR L = DxA
        - Modus tollens shows that ~DxA → ~(p AND ~q) OR ~L
        - 1st DeMorgan's law shows that ~(p AND ~q) = ~p OR ~~q
        - Double negation rule shows that ~p OR ~~q = ~p OR q
        - Substitution back with DxA gives: ~DxA → (~p OR q) OR ~L
        - So if the test was positive and the person really did not have DxA then either: 1. the sp was bad OR rare condition OR 2. +LR was bad
- Determine rehabilitation status and lifestyle changes

I look forward to playing with this information to determine what routines are underpinned by named logically constructs. In addition, I wounder if some routines could be improved by logic and decrease common mistakes in practice.

Future research

Future research endeavors could include: 1. Elementary terms; 2. Exploration of 1st Principles; 3. Systems of determining premise truthfulness; 4. Application of logic to specific healthcare issues; 5. Logical fallacy exploration; 6. Exploration of the other sub-dimensions of critical thinking; 7. Explore types of logic such as modal logic; 8. Spirit/Mind/body concepts; 9. Training healthcare professionals; 10. Application of logic to healthcare; 11. Creating an AI healthcare diagnostic program.

To handle the storage and analysis of massive amounts of data, advances such as DNA computing [31] or quantum/qubit [48] computing may be more available in the future [31]. Furthermore, artificial intelligence (AI) could be used in the future to analyze information for humans. Computers have been able to beat humans at chess and a more complex game called "go"; perhaps it will be able to diagnose better than humans in the future.

Conclusion

This narrative review was used to explore the sub-dimension of logic within critical thinking. Perhaps this information will serve to foster a deeper level of critical thinking. Hopefully, our culture will not abandon reason for an elite few that uses canceling, marginalizing,

using logical fallacies (esp. ad hominem) or name calling. Instead of a bully culture, perhaps we can create a respectful atmosphere to freely vet ideas. Unfortunately, the bully playground has been around since human's began and even at the highest levels. At least those who know logic will see the truth; which will be internally freeing and perhaps allow for future progress.

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