surveys. We will briefly consider panel rotation and survey mode errors.

Panel rotation error occurs when responses to a survey change depending on the length of time the panel has been included in the survey. Bailar (1975) described the effects of time-in-sample for the US Current Population Survey. In general, the longer a person has been in the sample, the less likely the person is to report being unemployed. A similar effect is found in the US National Crime Victimization Survey; persons in the survey for a longer time are less likely to report a victimization. Possible explanations for this phenomenon include that respondents learn to answer the survey so as to minimize the amount of time it takes to complete the survey or that differential dropout leads to a biased sample over time.

Survey modes include in-person, telephone, self-administered paper-and-pencil questionnaires and, most recently, self-administered Web questionnaires. The same questions asked using different survey modes can elicit different responses (see *Sample Surveys: Cognitive Aspects of Survey Design*). For example, respondents are more concerned about their self-images in personal interviews than on paper-and-pencil surveys. Thus, they may be more likely to report personal problems on a self-administered questionnaire than in a face-to-face interview. On the other hand, security and confidentiality concerns may make respondents less likely to respond truthfully to surveys on the Web. The accuracy of responses to Web surveys is an area of ongoing research.

Additional information on these other sources of nonsampling error can be found in references such as Groves (1989) and Biemer et al. (1991). An excellent example of a survey for which all sources of error, both sampling and nonsampling, are explored in detail is the US Current Population Survey (see US Department of Commerce 2000).

Bibliography

American Association for Public Opinion Research 1998 Standard definitions: Final dispositions of case codes and outcome rates for RDD telephone surveys and in-person household surveys. AAPOR, Ann Arbor, MI

Bailar B A 1975 The effects of rotation group bias on estimates from panel surveys. *Journal of the American Statistical Association* **70**: 23–30

Biemer P P, Groves R M, Lyberg L E, Mathiowetz N A, Sudman S 1991 *Measurement Errors in Surveys*. Wiley, New York

Bosecker R R, Ford B L 1976 Multiple frame estimation with stratified overlap domain. *Proceedings of the Social Statistics Section of the American Statistical Association*. 219–24

Brick J M, Kalton G 1996 Handling missing data in survey research. *Statistical Methods in Medical Research* **5**: 215–38

Cochran W G 1977 *Sampling Techniques*, 3rd edn. Wiley, New York

Groves R M 1989 *Survey Errors and Survey Costs*. Wiley, New York

Kish L 1949 A procedure for objective respondent selection within the household. *Journal of the American Statistical Association* **44**: 380–7

Kish L 1965 *Survey Sampling*. Wiley, New York

Krosnick J A, Alwin D F 1987 An evaluation of a cognitive theory of response-order effects in survey measurement. *Public Opinion Quarterly* **51**(2): 201–19

Lavrakas P J 1993 *Telephone Survey Methods*, 2nd edn. Sage, Newbury Park, CA

Lessler J T, Kalsbeek W D 1992 *Nonsampling Error in Surveys*. Wiley, New York

Little R J A, Rubin D B 1987 *Statistical Analysis with Missing Data*. Wiley, New York

Lohr S L 1999 *Sampling: Design and Analysis*. Duxbury Press, Pacific Grove, CA

Mosteller F 1978 Errors: Nonsampling errors. In: Kruskal W H, Tanur J M (eds.) *The International Encyclopedia of Statistics*. Free Press, New York, pp. 208–29

Nathan G 1988 *A Bibliography on Randomized Response: 1965–1987. Survey Methodology* **14**: 331–46

Rubin D B 1987 *Multiple Imputation for Nonresponse in Surveys*. Wiley, New York

US Department of Commerce, Census Bureau 2000 *Current Population Survey: Design and Methodology*. Government Printing Office, Washington, DC

Warner S L 1965 Randomized response: A survey technique for eliminating evasive answer bias. *Journal of the American Statistical Association* **60**: 63–9

E. A. Stasny

Nonstandard Reasoning

Logic since Antiquity has been concerned with 'the laws of thought,' immutable principles of reasoning from premises to conclusions. In the twentieth century, this monolithic view changed to one of different human *reasoning styles* and matching logical systems. With the emergence of information and cognition as central scientific themes, new items keep appearing on this broader agenda. These are often called 'nonstandard logics,' different from the established regime. This label is relative. The background to current studies of reasoning are the major approaches to valid inference in standard logic (semantic or proof-theoretic), reflecting philosophical argument and mathematical proof. Over time, these have acquired extended vocabularies and deviant notions of inference with linguistic and other scientific motivations. Nonstandard logics often originate in computer science and artificial intelligence (AI) (nonmonotonic logic, abduction). The resulting landscape is diverse, but there are unifying themes such as structural rules, preferences, resources, knowledge, or architectures for combining systems. These reflect cognitive trends in modern logic: reasoning about one's own information and that of others, update processes, games, communication, or heterogeneous information.

1. *Standard Logic: Valid Consequence, Proof Calculi, Completeness*

Standard logic covers the achievements of the renaissance of logic, starting with Boole and Frege in the nineteenth century, and culminating in the work of Gödel, Tarski, Turing, and others in the 1930s. The resulting core of the field consists of propositional logic (codifying reasoning with the key operations 'not,' 'and,' 'or') and predicate logic of quantifiers ('for all,' 'there exists'). Both are based on the semantic conception of valid consequence, demanding 'transmission of truth' from premises P to a conclusion C:

every situation in which all the premises P are true also makes the conclusion C true.

To describe and produce valid inferences, one can sometimes use simple mechanical methods, such as the truth tables of propositional logic. More general, and more relevant to capturing actual reasoning, are proof-theoretic approaches (Hilbert), deriving conclusions from premises via rules. Proof systems of various sorts also drive mechanized reasoning in AI and computational logic. Crucially, the semantic approach based on truth and the syntactic one of proof coincide for quantificational logic: this is Gödel's celebrated Completeness Theorem, the first significant insight into logical systems *per se*. Another is Church's Theorem (based on Gödel's even more famous 'Incompleteness Theorem'), saying that no mechanical algorithm can decide validity in quantificational logic.

2. *Extending the Vocabulary: from Mathematics to Natural Language*

Logical systems use 'logical forms' with fixed operators for key notions (Booleans, quantifiers), plus variable parts for expressions that can be interpreted freely (a typical valid form is: 'from premises A-*or*-B, and *not*-A to conclusion B'). The above systems have been successful in analyzing mathematical proof, but gradually extensions had to be made to deal with the kind of argument found in philosophy, linguistics, and in the latter part of the twentieth century, computer science and cognitive science. For example, logical semantics of natural language deals with generalized quantifiers ('most,' 'few'), plus a spectrum of expressions for reasoning involving possibility, time, knowledge, action, etc.—for both single and multiple agents. The extra vocabulary is 'nonstandard,' the canons of validity remain classical.

3. *Alternative Views of Validity and Logical Operations*

There are also genuine deviations from the classical core. A recurrent historical example is the view that conclusions only follow validly from *consistent* premises. Then, nothing follows from a contradiction A-*and*-*not*-A, while on the 'standard' account, everything does.

3.1 *Deviations in Natural Language and Philosophy*

The idea that 'natural reasoning' in our ordinary language differs from standard logical calculi is a recurrent theme in the twentieth century—high-lighted in the 'paradoxes of material implication': natural 'if … then … ' does not behave like the truth-functional Boolean conditional. This has led to many deviant calculi for 'modal' or 'relevant' implication. Philosophical critiques of the standard account of valid consequence still appear today.

3.2 *Deviations in Scientific Reasoning*

Other deviations arise in the foundations of science. 'Constructivism' in mathematics views proofs as constructions of mental entities, whose properties must be established by computational means. *Intuitionistic logic* accepts only those inferences as valid which have a constructive proof. Thus, one cannot prove an assertion 'there exists an x such that $F(x)$' without producing an explicit example. This line is generalized in constructive 'type theories.' In physics, quantum mechanics has inspired *quantum logics* with failures of Boolean distributivity laws in reasoning about the location or momentum of particles. But most of all, reflecting the close analogies between 'reasoning and reckoning' (as Hobbs put it), computer science has inspired many new systems of reasoning. Examples from the 1970s are *dynamic logic* describing the effects of programs and actions generally, *logic programming* (using proofs as computation procedures) and perhaps most radically, *linear logic* in the 1980s, treating propositions as computational 'resources' that can be used only once. The result of all this is alternatives to classical logic, developed with equal rigor, but different in their valid principles, general philosophy, and mathematical properties.

4. *Varieties of Inference*

That 'natural reasoning' comes in different styles, with possibly different logical features, was already observed by Bolzano in the early nineteenth century. Scientific reasoning employs stricter standards than common sense. Variety also occurs in AI with problem solving or planning (deductive or heuristic), where systems are more 'optimistic' than standard logic.

4.1 *Nonmonotonic Logics*

Practical reasoning uses defaults going beyond standard logical conclusions. Thus, we use some rule

('Dutch trains run on time') unless counter-examples are explicitly indicated, e.g., when planning our escape from Amsterdam's futuristic Science City. Or we take an answer 'John, Mary' to the question 'Who were skating?' as conveying not just that John and Mary skated, but that *no others did*, assuming a maximally informative respondent. Such additional inferences may be withdrawn later, because of further information: the train may be carrying soccer fans, the respondent may be a government employee. Reasoning in which C may follow from P, but no longer from P + Q is called 'nonmonotonic'—while classical consequence is monotonic: once drawn, conclusions persist. A general pattern behind nonmonotonic reasoning is 'circumscription,' which, in its most abstract form, assumes that situations come ordered by some preference, and then makes C follow from P if

C holds in all most preferred situations where P holds.

In the escapist example, one 'prefers' the more likely situations where trains run according to schedule to those containing a disturbing factor. Preferences may reflect plausibility, utility, or simplicity, depending on circumstances. A classical consequence is the special case when no models are preferred to others. Thus, classical inferences are also valid in circumscription. This is a general phenomenon in AI: most logics that diverge from classical logic are richer, whereas the deviant logics of Sect. 3 were poorer, putting greater demands on inference.

4.2 Directions and Purposes in Reasoning

The preceding systems all view reasoning as a forward-oriented process of accumulating conclusions from given premises. But in addition to this forward deductive mode, there is also 'backward' *abduction* (Peirce) seeking plausible premises to support already given observations. Moreover, there is *induction* (Mill, Carnap), looking for plausible generalizations beyond the immediate content of the premises. These different directions and purposes all occur when analyzing activities such as 'refutation,' 'explanation,' or 'confirmation' in the philosophy of science. Abduction is studied also in connection with logic programming, and induction in the foundations of probability and uncertainty.

4.3 Reasoning with Uncertainty and Probability

Probabilistic reasoning seems a major mode of cognition in its own right. Its standard formalism is not logic, but probability theory. However, there is an increasing literature on nonstandard, often qualitative probabilistic reasoning, including 'fuzzy logic' and 'possibility theory,' while key probabilistic notions such as randomness and independence of events are migrating into logic. In particular, new versions of predicate logic have been proposed that admit dependencies between variables. Interestingly, these often become *decidable*, unlike the standard system.

5. Logical Dynamics: Reasoning as an Activity

Under the influence of computer science and cognitive science, many logicians view semantic interpretation or reasoning as cognitive processes. This is closer to actual argumentation, where dynamic timing and procedural conventions are crucial to outcomes. Within this trend, *dynamic semantics* views the meaning of a proposition as the update of a hearer's information state produced by it. Thus, propositions become cognitive procedures, and natural language a programming language modifying information states of other agents. One major dynamic notion of valid consequence is

in final information states reached by processing the successive premises, updating with the conclusion will not have any further effect.

A broader perspective arises in *belief revision theory*, which has updates adding information to the current state, contractions (removing information), and revisions (doing both)—doing justice to the 'zigzag character' of much of our reasoning. Information states can be those of individual agents, but interactive communication updates collective information states of groups of agents, often pictured as 'Kripke models.' Perhaps the most 'activist' perspective on reasoning is that of *game theory*. Logic games have existed since the fifties (Lorenzen, Hintikka), suggesting dialogical alternatives to proof and semantics, in terms of winning and losing argumentation games. Their take on valid consequence employs the typical game-theoretic notion of a *strategy*, a response pattern to any sequence of moves by one's opponents:

in fair rational debate, the proponent of the conclusion C has a winning strategy for upholding C against any play by an opponent granting the premises.

Logic games tie up the study of reasoning with that of rational behavior in general.

6. Systematic Theory of Reasoning

With the rapid growth of nonstandard logics, the unity of the meta-theory for classical logic gets lost. It is too early for a new synthesis, but some unifying themes are noticeable.

6.1 Structural Rules

Nonmonotonicity is a hallmark of nonstandard reasoning systems—though a symptom, not a diagnosis. However, it has turned out useful to classify styles of reasoning by their *structural rules*, such as monotonicity, transitivity ('if P implies Q, and Q implies R, then P implies R'), and others, which move premises around, or duplicate them when needed. The structural rules of classical logic treat premises as an unordered set, whose presentation is irrelevant. By contrast, nonstandard reasoning tends to be more sensitive to the formulation of data, which shows in failures of classical structural rules. Thus, in dynamic consequence, permuting two premises may change the update achieved—reflecting the order-dependence of natural language.

6.2 New Vocabulary

Nonstandard consequence may reinterpret traditional logical operations. Thus, in logic games, a negation signals a 'role switch' between two players. Nonstandard reasoning may also involve new operations, outside the classical core. In particular, with games, there is not one conjunction, as in Boolean logic, but *three*: choosing which game to play at the start, playing one game after the other, or playing two games concurrently. The resulting calculi are much richer in vocabulary than classical ones.

6.3 Mechanisms and Structures

More important than individual 'logical laws' are general mechanisms behind nonstandard reasoning systems. Striking new notions are *preference*, *dynamics*, and *resources*, mentioned before. These provide a much richer picture of actual reasoning, and 'parameters' that can be set for different purposes. Other important trends go beyond the single-sentence habitat of standard logic—addressing larger-scale, longer-term data structures and processes. These include *cooperative architecture* (how do different styles of reasoning cooperate to achieve useful effects?), *heterogeneous information* (how do symbolic and non-symbolic, e.g., visual data cooperate in reasoning?), and *meso-structure* (which higher-level discourse and theory structures drive reasoning?). Most strikingly, reasoning is a *social activity* involving agents that communicate, cogitate and act—and *multiagent logics* of knowledge and collective information update are conspicuous in contemporary research.

7. Conclusion

Modern logic arose out of reflection on proof in mathematics and argumentation in philosophy, and created the standard systems of the twenty-first century. Modern studies of reasoning, while retaining the modus operandi of this phase, deal with a much broader spectrum of laws, structures, and processes, and in doing so, merge with disciplines such as methodology of science, argumentation theory, linguistics, computer science, or cognitive psychology. In this perspective, 'nonstandard reasoning' signals nothing specific, except this broad horizon.

See also: Artificial Intelligence: Uncertainty; Axiomatic Theories; Deductive Reasoning Systems; Game Theory; Knowledge Representation; Logics for Knowledge Representation; Mathematical Models in Philosophy of Science; Scientific Discovery, Computational Models of

Bibliography

Abramsky S, Gabbay D, Maibaum T (eds.) 1992–2000 *Handbook of Logic in Theoretical Computer Science*. Oxford University Press, Oxford, UK

Barwise J (ed.) 1977 *Handbook of Mathematical Logic*. North-Holland, Amsterdam

Gabbay D, Guenthner F (eds.) 1983–8 *Handbook of Philosophical Logic*. Reidel, Dordrecht, The Netherlands; Revised and expanded edition to appear 2001, Kluwer, Dordrecht, The Netherlands

Gabbay D, Hogger C, Robinson J (eds.) 1993–8 *Handbook of Logic in Artificial Intelligence and Logic Programming*. Oxford University Press, Oxford, UK

Gabbay D, Woods J (eds.) in press *Handbook of Argumentation Theory*. Kluwer, Dordrecht, The Netherlands

Van Benthem J, ter Meulen A (eds.) 1997 *Handbook of Logic and Language*. Elsevier, Amsterdam

J. van Benthem

Nontraditional Families and Child Development

The process of development among children and adolescents growing up in different kinds of family environments has long been a topic of interest to social scientists. For many years, most researchers have assumed that conditions for child development are most favorable in families that include two heterosexual parents, one of each sex, who are married to one another, and who are biologically related to the child. Fathers in such families are assumed to be employed fulltime outside the home, and mothers are assumed to work only in the home, where they are responsible for childcare and upkeep of the household, but do not earn money. Even though the existence of such so-called 'traditional families' has not characterized much of human history, and even though many families today—even in Westernized countries—do not fit this pattern, it has nevertheless been widely assumed as the norm against which other family rearing environments should be measured (Lamb 1999).

ISBN: 0-08-043076-7