Chapter

The Many Facets of the Cause-Effect Relation

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Abstract. This chapter presents a broad survey of the cause-effect relation, with particular emphasis on how the relation is expressed in text. Philosophers have been grappling with the concept of causation for centuries. Researchers in social psychology have found that the human mind has a very complex mechanism for identifying and attributing the cause for an event. Inferring cause-effect relations between events and statements has also been found to be an important part of reading and text comprehension, especially for narrative text. Though many of the cause-effect relations in text are implied and have to be inferred by the reader, there is also a wide variety of linguistic expressions for explicitly indicating cause and effect. In addition, it has been found that certain words have "causal valence"–they bias the reader to attribute cause in certain ways. Cause-effect relations can be divided into different types and, furthermore, a causal situation involves several participating subroles.

1. WHAT IS CAUSATION?

The cause-effect relation affects all aspects of our lives. It pervades our thinking and motivates our rational actions. Knowledge of cause and effect provides the basis for rational decision-making and problem-solving. It is important in all areas of science and technology. It can be argued that the ultimate goal of most research is to identify cause and effect.

Hume (1740/1965) called the association of ideas, which he said underlies the concept of causation, the *cement of the universe*. Hitchcock (1998) referred to causal knowledge as the great guide of human life. Keil (1989) suggested that cause-effect relations are essential and more useful than other sorts of relations in governing the structure of concepts and intuitive theories:

> "The tremendous cognitive efficiency gained by using causal connections as a kind of glue has been repeatedly demonstrated in other areas such as text comprehension and story understanding; but it is equally if not more evident with respect to single concepts. Causal relations make it vastly easier to remember the features that make up a concept as well as to make inductions about new instances." (Keil, 1989, p. 280)

The concept of causation is complex and multifaceted, and it is surprisingly difficult to define. Two philosophers who contributed a great deal to our understanding of causation are David Hume and John Stuart Mill.

For Hume (1740/1965), causation comprises the following three conditions:
1. *contiguity* in time and place
2. *priority* in time
3. *constant conjunction* between the cause and the effect.

When a person finds, from experience, that an event of the kind A is always followed by an event of the kind B, the person comes to conclude that event A causes event B. For Hume, causation is nothing more than the association in the mind of two ideas as a result of experiencing their regular conjunction.

Mill (1872/1973) argued that constant conjunction is not sufficient for inferring causation, unless the conjunction is also unconditional. Mill described four methods by which one can determine that A causes B:

1. *the method of agreement*: If two or more instances of a phenomenon B have only one circumstance A in common, then A is the cause or effect of B.
2. *the method of difference*: If we compare an instance X in which a phenomenon B occurs and an instance Y in which the phenomenon does not occur, and we find that the two instances have the same circumstances except that a circumstance A occurs in X but not in Y, then A is the cause or the effect of B.
3. *the method of residues*: Subtract from any phenomenon the part that is known to be the effect of certain antecedents, then the remaining part of the phenomenon is the effect of the remaining antecedents.
4. *the method of concomitant variations*: If a phenomenon B varies in a particular way whenever another phenomenon A varies in some particular way, then A is a cause or an effect of B.

Perhaps the most influential of these ideas is *the method of difference*. According to this method, we can conclude that event A causes event B if we find two instances which are similar in every respect except that in one instance event A is followed by event B, whereas in the other instance both A and B do not occur. Mackie (1980) argued that the layman uses this kind of reasoning to infer cause-effect relationships. In deciding whether a particular event A caused an event B, we engage in the counterfactual or contrary-to-fact reasoning that involves asking whether B would have occurred if A had not occurred. If B would not have occurred had A not occurred, we conclude that A caused B.

Mill's *method of difference* has been extended to distinguish between *necessary* and *sufficient* causes. An event of the kind A is a *sufficient* though not a *necessary* condition for an event of the kind B to occur if, when A occurs, B always follows, but when A does not occur, B sometimes occurs and sometimes not. On the other hand, if when A does not occur, B never occurs, but when A occurs, B sometimes occurs and sometimes not, then A is a *necessary* though not a *sufficient* condition for B to occur.

Mill (1872/1973) also pointed out that an effect is usually the result of a conjunction of several causes, even though in practice one of these causes is singled out as *the cause* and the rest are referred to as *conditions*. He said that "if we do not, when aiming at accuracy, enumerate all the conditions, it is only because some of them will in most cases be understood without being expressed, or because for the purpose in view they may without detriment be overlooked" (pp. 327-329). Mackie (1980) referred to the background conditions that are understood without being expressed as *the causal field*.

But is *cause* a necessary condition, a sufficient condition, or both? Mackie (1980) suggested that a cause is an *Insufficient* but *Necessary* part of an *Unnecessary* but *Sufficient* condition for an event. This is often referred to as the *INUS condition*. Jaspars, Hewstone and Fincham (1983) and Jaspars (1983) found evidence that whether a cause is a necessary or sufficient, or necessary and sufficient condition varies with the type of entity being considered for causal status. Cause is likely to be attributed to a person if the person is a sufficient condition. Necessity does not appear to be important when a person is a candidate for causal status. On the other hand, cause is

likely to be attributed to the circumstances or situation if the situation is a necessary condition. Sufficiency is not so important for situational causes. Cause is ascribed to a stimulus when it is both a necessary and sufficient condition. So, "a personal cause is seen more as a sufficient condition, whereas situational causes are conceived primarily as necessary conditions" (Jaspars, Hewstone & Fincham, 1983, pp. 16-17).

Mackie (1980) also pointed out that our concept of causation includes some presumption of a continuity from the cause to the effect, a causal mechanism by which the cause generates the effect. We conceive of the effect as being "fixed" by the cause.

Some philosophers have distinguished between general causation and singular causation (e.g. Ehring, 1997; Mellor, 1995). Whereas *general causation* refers to the causal tendency or cause-effect relation between two *types* of events over time, *singular or local causation* refers to the cause-effect relation between two *particular* events. It has been argued that local causation need not be an instance of a general causal law, and indeed a unique and unrepeated event can be causal. Furthermore, an event may be considered causal in a particular instance even if, over time, it is not found to be a necessary or sufficient condition for the effect event.

In view of the problem that a cause need not be necessary or sufficient for its effect, the concept of probabilistic causation has gained popularity. In this probabilistic view, an event of the kind A causes an event of the kind B if the occurrence of A makes the occurrence of B more likely (Hitchcock, 1998). This view recognizes the possibility of indeterministic causation—that there are instances where the causal mechanism is inherently probablistic, as in the field of quantum mechanics. Treatments of this idea can be found in Eells (1991) and Salmon (1984).

But how do ordinary people in their daily lives decide that there is a cause-effect relation between two events. Social psychologists working in the area of attribution theory have found that the human mind has a very complex and sophisticated mechanism for inferring cause and effect. Humans use empirical information (in the form of covariation information) in combination with world knowledge to construct a theory of the causal mechanism that produced the effect. Social beliefs and probably also cultural factors influence the attribution of responsibility.

Researchers in social psychology have developed many models of how humans use various types of information to attribute cause. This includes the *inductive logic model* (Jaspars, Hewstone & Fincham, 1983), the *abnormal conditions focus model* (Hilton & Slugoski, 1986), the *analysis of variance model* (Kelley, 1973), the *likelihood ratio model* (Ajzen & Fishbein, 1975), the *linear combination model* (Downing, Sternberg & Ross, 1985; Schustack & Sternberg, 1981), the *probabilistic contrast model* (Cheng & Novick, 1990 and 1992), and the *joint model* (Van Overwalle, 1997; Van Overwalle & Heylighen, 1995).

People's theories and prior beliefs play an important role in causal attribution. Covariation of two events, however strong, does not lead one to infer a cause-effect relation if it is not plausible according to some theory (Shultz, 1982; Alloy and Tabachnik, 1984; White, 1995). Furthermore, people tend to seek out and prefer information about causal mechanisms rather than information about covariation when identifying causes of events (Ahn, Kalish, Medin & Gelman, 1995; Shultz, 1982; Shultz, Fisher, Pratt & Rulf, 1986). When making causal attributions, people seek to identify the underlying causal mechanisms that have "causal power" to generate the effect. Covariation information appears to be used only when information about causal mechanisms are not available.

Philosophers are still grappling with various aspects of the concept of causation. Recent books on the subject include Ehring (1997), Mellor (1995), Owens (1992), Sosa and Tooley

(1993), and Salmon (1998). A survey of the concept from the perspective of physics can be found in Jones (1996), Schlegel (1973) and Salmon (1984).

2. CAUSAL INFERENCE IN TEXT COMPREHENSION

The previous section examined the concept of causation. People perform causal inferencing automatically to make sense of events in the world and to guide their interaction with the world. Automatic causal inferencing has been found to be an important part of reading and text comprehension. Comprehension of text involves identifying relations between the various events, states and ideas expressed in the text. This allows the reader to construct a coherent, connected representation of the text in the reader's mind. There is a substantial body of research indicating that identifying and inferring cause-effect relations between events is central to the comprehension of narrative text, i.e. stories (Van den Broek, 1989; Van den Broek, Rohleder & Narvaez, 1996).

Keenan, Baillet and Brown (1984) found that when giving subjects two sentences to read, where the first sentence specifies a cause for the event in the second sentence, reading times for second sentences steadily increased as causal relatedness between the pair of sentences decreased. This suggests that establishing causal relatedness between sentences is an important part of text comprehension. The difficulty in establishing causal relatedness between pairs of sentences appears to increase the time it takes to comprehend the second sentence. Zwaan, Magliano and Graesser's (1995) study provided additional support for this conclusion.

Cause-effect relations between events and statements in a story affect how well the events and statements are recalled. The greater the number of causal connections an event or statement has to the rest of the text, the better it is recalled by the reader (Trabasso, Secco, & van den Broek, 1984; Trabasso & van den Broek, 1985; Fletcher & Bloom, 1988; Van den Broek, Rohleder & Narvaez, 1996). Furthermore, events and statements that lie along a causal chain connecting a text's opening to its final outcome are recalled better than those not on the chain (Black & Bower, 1980; Trabasso, Secco, & van den Broek, 1984; Trabasso & van den Broek, 1985; Fletcher & Bloom, 1988). Black and Bower (1980) and Trabasso and van den Broek (1985) found that proximity to the causal chain was a strong predictor of recall for story events.

Cause-effect relations also affect the perceived importance of story events. Events with more causal connections and that occur in the causal chain from the beginning to the end of the story are judged more important by readers and are also more likely to be used in a summary of the story (Omanson, 1982; Trabasso & Sperry, 1985; Trabasso & van den Broek, 1985). Van den Broek (1988) found that the judged importance of a goal statement increased strongly as its number of cause-effect relations increased, independent of its hierarchical level. The more causal connections the goals had, the more important they were judged to be.

Clearly, the causal structure of a text determines how statements in the text will be understood and remembered. Many of the cause-effect relations in text have to be inferred using information in the reader's short-term memory, long-term memory and background knowledge (Van den Broek, Rohleder & Narvaez, 1996). Fletcher and Bloom (1988) and other researchers have suggested that that the goal of narrative comprehension is to discover a sequence of causal links that connect a text's opening to its final outcome.

3.   EXPLICIT EXPRESSIONS OF CAUSE-EFFECT IN TEXT

Though many of the cause-effect relations in text are implicit and have to be inferred by the reader, the English language actually possesses a wide range of linguistic expressions for explicitly indicating cause and effect. Darian (1996), Khoo (1995), and Xuelan and Kennedy (1992) have analyzed how cause and effect is explicitly expressed in science textbooks, newspaper text, and a text collection of British English respectively.

Linguists have identified the following ways of explicitly expressing cause and effect:
1. using *causal links* to link two phrases, clauses or sentences
2. using *causative verbs*
3. using *resultative* constructions
4. using *conditionals*, i.e. "if ... then ..." constructions
5. using *causative adverbs, adjectives* and *prepositions.*

3.1   Causal Links

Altenberg (1984) classified causal links into four main types:
1. the adverbial link, e.g. *so, hence, therefore*
2. the prepositional link, e.g. *because of, on account of*
3. subordination, e.g. *because, as, since*
4. the clause-integrated link, e.g. *that's why, the result was.*

He presented a detailed typology of causal links and an extensive list of such linking words compiled from many sources, including Greenbaum (1969), Halliday and Hasan (1976), and Quirk, Greenbaum, Leech and Svartvik (1972).

An *adverbial link* is an adverbial which provides a cohesive link between two clauses, which may be two sentences. An *adverbial link* can be:
1. *an anaphoric adverbial*, which has an anaphoric reference to the preceding clause, e.g. "There was a lot of snow on the ground. *For this reason* the car failed to brake in time."
2. *a cataphoric adverbial*, which has a cataphoric reference to the following clause, e.g. "There was a lot of snow on the ground *with the result that* the car failed to brake in time."

Whereas an *adverbial link* links two clauses, a *prepositional link* connects cause and effect in the same clause. The prepositional phrase formed usually has an adverbial function, i.e. the preposition links a noun phrase to the clause, for example,

The car failed to brake in time because of the slippery road.

The words "because of" function as a phrasal preposition. Occasionally, the prepositional phrase modifies a noun phrase, e.g.,

The car crash, due to slippery road conditions, could have been avoided had the road been cleared of snow.

A link by *subordination* can be:
1. *a subordinator*, e.g. *because, as, since, for, so*
2. *a structural link* marked by a non-finite *ing*-clause, e.g. "*Being* wet, the road was slippery."
3. *a correlative comparative construction,* e.g. "There was *so* much snow on the road *that* the car couldn't brake in time."

Lastly, *clause-integrated links* form part of the *subject* or the *predicative complement* of a clause. When the linking words are the *subject* of a clause, Altenberg called it a *thematic link*, e.g.

The car didn't brake in time. The reason was that there was a lot of snow on the road.
The linking words "the reason" function as the subject of the sentence. When the linking words form part of the *predicative complement* of a clause, it is called a *rhematic link*, e.g.
The car accident was due to the slippery road.
The linking words "due to" form the first part of the phrase that functions as the complement of the verb "to be."

3.2   Causative Verbs

Causative verbs (also called *lexical causatives*) are verbs the meanings of which include a causal element. Examples include the transitive form of *break* and *kill*. The transitive *break* can be paraphrased as *to cause to break*, and the transitive *kill* can be paraphrased as *to cause to die*.

   Thompson (1987) divided causative verbs into three groups:
1. Transitive causative verbs that also have an intransitive usage. For example, "x *breaks* y" is paraphrased as "x causes y to *break*."
2. Causative verbs that do not have an intransitive usage. The transitive *kill* is paraphrased using the intransitive *die*, a different word: "x *kills* y" is paraphrased as "x causes y to *die*."
3. Causative verbs that do not have any intransitive verb that can be used in the paraphrase. The past participle form of the causal verb is used instead. "X *butters* y" is paraphrased as "x causes y to be *buttered*."

   How can causative verbs be distinguished from other transitive words that are not causative, e.g. *hit*, *kick*, *slap* and *bite*. It may be argued that all transitive action verbs are causative since an action verb such as *hit* can be paraphrased as *to cause to be hit*. Indeed, Lyons (1977, p. 490) said that there is a natural tendency to identify causality with agency and that causativity involves both causality and agency. Wojcik (1973, p. 21-22) said that "all agentive verbs involve the semantic prime CAUSE at some level." Agents may be said to "cause" themselves to do things. The sentence "John intentionally broke the window" seems to entail "John caused himself to break the window." Wojcik considered all action verbs to be causative verbs in this sense.

   However, most writers do not equate action verbs with causative verbs. Thompson (1987) argued that verbs like *hit*, *kick*, *slap*, and *bite* are not causative. She said that whereas causative verbs accept events and states of affairs as subjects, verbs like *hit* do not. Consider the following sentences:
   (1a)   Oswald killed Kennedy by shooting at him.
   (1b)   Oswald's accurate shooting killed Kennedy.
   (2a)   John broke the vase by shooting at it.
   (2b)   John's accurate shooting broke the vase.
   (3a)   Tom hit the can by shooting at it.
   (3b)   * Tom's accurate shooting hit the can.
Examples (1b) and (2b) show that the subject of the verbs *kill* and *break* can be an event. Examples (3a) and (3b) show that the subject of the verb *hit* can only be a person or an object. Thompson said that this is because for action verbs like *hit* the subject is, in a sense, not separable from the result of the action.

   The following criteria have been proposed for distinguishing causative verbs from other transitive action verbs:

1. Causative verbs accept events and states of affairs as subjects, whereas other action verbs accept only agents as subjects (Thompson, 1987).
2. Causative verbs are transitive verbs which also have an intransitive usage where the subject of the verb has the patient role (Szeto, 1988).
3. Causative verbs specify the result of the action, whereas other action verbs specify the action but not the result of the action (Szeto, 1988).

Khoo, Kornfilt, Oddy and Myaeng (1999) adopted the third criterion as a working definition of a causative verb in their analysis of verb entries in the *Longman Dictionary of Contemporary English* (1987) to develop a comprehensive list of causative verbs. They included not only action verbs like *kill*, but also transitive verbs like *amaze* which are not action verbs but nevertheless specify the impact of some object or event. Another guideline they used was that the subject of a causative verb must be separable from the result. This excludes words like *mar*, *surround* and *marry*, for which the subject of the verb is an integral part of the effect specified by the verb, e.g.:

The new power station mars the beauty of the countryside.
A high wall surrounds the prison amp.
Will you marry me?

Khoo (1995) identified a total of 2082 causatives verbs which he categorized into 47 types of results.

Levin (1993) provided a systematic and extensive classification of verbs based on their syntactic behavior. The verbs in each class share a semantic component, i.e. their meanings have something in common. Though the focus of her work was not on identifying causative verbs, nevertheless many of the verb classes do have a causal component in their meanings.

3.3 Resultative Constructions

A resultative construction is a sentence in which the object of a verb is followed by a phrase describing the state of the object as a result of the action denoted by the verb. The following examples are from Simpson (1983):

(4a)   I painted the car *yellow*.
(4b)   I painted the car *a pale shade of yellow*.
(4c)   I cooked the meat *to a cinder*.
(4d)   The boxer knocked John *out*.

In example (4a), the adjective *yellow* describes the color of the car as the result of the action of painting the car. In each of the four examples, the phrase in italics is the resultative phrase describing the result of the action denoted by the verb. The examples show that a resultative phrase can be an adjective, a noun phrase, a prepositional phrase or a particle. Simpson (1983) said that the most common kind of resultative is where the resultative phrase is an adjective.

Simpson (1983) showed that some verbs that are normally intransitive can take an object if followed by a resultative phrase:

(5a)   I cried.
(5b)   * I cried myself.
(5c)   I cried myself *to sleep*.
(5a)   * I cried my eyes.
(5b)   I cried my eyes *blind*.

The objects in these three sentences have been called *fake objects* (Goldberg, 1991).

Some transitive verbs will take as object a noun phrase that they don't normally accept as object, if the noun phrase is followed by an appropriate resultative phrase as in the following examples:

(6a)   John drank the beer.
(6b)   * John drank himself.
(6c)   John drank himself *into the grave*.
(6d)   * John drank me.
(6e)   John drank me *under the table*.

In examples (6c) and (6e), the object of the verb *drink* is not the "patient" of the verb, i.e. it does not denote the thing that John drank.

An important question is whether all verbs will take an appropriate resultative phrase. In other words, for each verb, is there some resultative phrase (possibly one that nobody has thought of yet) that the verb will accept? And if it is true that some verbs can take a resultative phrase and other verbs can't, then how can these two classes of verbs be differentiated? Is there a systematic explanation for these two classes of verbs? These questions have not been satisfactorily answered.

3.4   Conditionals

"If ... then ..." conditionals assert that the occurrence of an event is contingent upon the occurrence of another event. Since the contingency of one event on another suggests a cause-effect relation between the two events, *if-then* constructions often indicate that the antecedent (i.e. the *if* part) causes the consequent (the *then* part).

It has been found that people sometimes interpret an *if-then* construction as a conditional and sometimes as a biconditional (i.e. "if and only if"), depending on the context. A conditional specifies that the antecedent is *sufficient* for the consequent to happen. A biconditional (i.e. "if and only if") specifies that the antecedent is both *necessary and sufficient* for the consequent to happen.

Whether *if-then* is interpreted as a conditional or biconditional depends on the background information available to the subject (Cummins, Lubart, Alksnis, & Rist, 1991; Hilton, Jaspars & Clarke, 1990; Rumelhart, 1979). If the subject can think of other antecedents that can lead to the consequent, then the subject will interpret *if-then* as a conditional, otherwise the subject will interpret it as a biconditional. Here are two examples from Rumelhart (1979):

If you mow the lawn then I will give you $5. (biconditional)
If you are a U.S. senator then you are over 35 years old. (conditional)

We tend to interpret the first statement as expressing a biconditional relation ("if and only if"), whereas it seems more natural to interpret the second as asserting a simple conditional relation ("if, but not only if . . .").

Another factor that influences the interpretation of *if-then* constructions is the extremity or rarity of the consequent event. The more extreme or unusual the consequent, the more likely it is that the antecedent is judged by subjects to be necessary but not sufficient (Hilton, Jaspars & Clarke, 1990). Kun and Weiner (1973) and Cunningham and Kelley (1975) found that extreme or unusual events such as passing a difficult exam or being aggressive to a social superior seem to require an explanation in terms of multiple necessary conditions (e.g. working hard and being

clever, and being drunk and provoked). On the other hand, non-extreme and frequent events (e.g. passing an easy exam) could have been produced by many sufficient causes on their own (e.g. working hard or being clever).

If-then constructions do not always indicate a cause-effect relation. In the following example there is no cause-effect relation between the "if" and the "then" part of the sentence:

If you see a lightning, you will soon hear thunder.

Though hearing thunder is contingent on seeing a lightning, one does not cause the other. Seeing a lightning and hearing thunder are caused by the same atmospheric event. An analysis of the different conditional constructions and their semantics can be found in Dancygier (1993).

3.5 Causative Adverbs, Adjectives and Prepositions

Some adverbs and adjectives have a causal element in their meanings (Cresswell, 1981). One example is the adverb *fatally*:

Brutus fatally wounded Caesar.
Catherine fatally slipped.

These can be paraphrased as:

In wounding Caesar, Brutus caused Caesar to die.
Catherine slipped, and that caused her to die.

The adjective *fatal* also has a causal meaning:

Caesar's wound was fatal.
Guinevere's fatal walk ...

Other examples of causal adverbs cited by Cresswell are

- the adverbs of perception, e.g. *audibly*, *visibly*.
- adverbs that are marginally perceptual, e.g. *manifestly*, *patently*, *publicly*, *conspicuously*.
- adverbs that involve the notion of a result whose properties are context dependent, e.g. *successfully*, *plausibly*, *conveniently*, *amusingly*, *pleasantly*.
- adverbs that suggest tendencies, liabilities, disposition or potencies, e.g. *irrevocably*, *tenuously*, *precariously*, *rudely*.
- adverbs that refer not to causes but to effects, e.g. *obediently*, *gratefully*, *consequently*, *painfully*.
- adverbs of means, e.g. *mechanically*, *magically*.

Causal adverbs and adjectives are not well studied, and a comprehensive list of such adverbs and adjectives has not been identified.

Prepositions are also sometimes used in text to indicate cause-effect relations. Dirven (1995) classified causative prepositions into the following categories:

- Cause as proximity
  - as accompaniment: *with*, e.g. "tremble with fear", "irritated with her"
  - as target: *at*, e.g. "bridle at a remark", "angry at him"
  - as connection and path: *by*, e.g. "impressed by", "excited by"
- Cause as source
  - as separation from contact: *of*, e.g. "die of thirst", "die of boredom"
  - as separation from a point: *from*, e.g. "die from drugs", "shiver from the cold", "suffer from migrane"

- as separation from a volume: *out of*, e.g. "got a kick out of", "drink too much out of nervousness"
- Cause as volume
  - as enveloping volume: *in*, e.g. "find pleasure in," "revel in"
  - as dispersion path: *about*, e.g. "delighted about", "apprehensive about"
  - as back-and-forth motion: *over*, e.g. "fell in disgrace over debts", "weep over"

Dirven (1997) also analyzed how prepositions are used to indicate emotions as cause and as effect.

4. IMPLICIT CAUSAL ATTRIBUTION OF VERBS

We have seen that cause-effect relations are expressed both implicitly and explicitly in text. Implicit cause-effect relations are inferred by the reader using information expressed in the text as well as background knowledge. However, implicit causality in text can also take the form of a subtle bias. Some linguistic expressions do not have a causal meaning that readers are consciously aware of, but nevertheless bias the reader towards assigning responsibility or blame to a participant referred to in the text.

In particular, some verbs have "causal valence"—they tend to assign causal status to their subject or object. Some verbs give the reader the impression that the cause of the event is the participant occupying the syntactic subject position of the sentence. Other verbs suggest that the cause of the event is the participant in the object position. This phenomenon has been referred to as the *implicit* or *inherent causality* property of verbs (Brown & Fish, 1983; Caramazza, Grober, Garvey & Yates, 1977).

This implicit causal attribution can be made explicit by requiring the reader to determine whether an ambiguous anaphoric pronoun refers to the subject or object of the verb. Garvey and Caramazza (1974) had subjects complete sentences such as the following:

   The mother punished her daughter because she ___

In completing the sentence, the subject automatically makes a choice as to whether "she" refers to mother or daughter. Garvey and Caramazza also asked subjects to supply responses to questions of the form

   Why did the director criticize the actor?

In constructing a response to this question the subject decides whether the reason lies with the director or with the actor.

Garvey and Caramazza (1974) found that for the verbs *confess, join, sell, telephone, chase,* and *approach*, subjects tended to assign the pronoun and the reason for the event to the subject of the verb, for example,

   The prisoner confessed to the guard because he wanted to be released.

For the verbs *kill, fear, criticize, blame, punish, scold, praise, congratulate,* and *admire*, subjects tended to assign the pronoun and the reason for the event to the object of the verb, for example,

   The mother punished her daughter because she broke an antique vase.

Researchers have attempted to identify classes of verbs that tend to attribute causality in one direction or the other. Corrigan (1993) and Corrigan and Stevenson (1994) identified the following groups of verbs that have causal valence:

1. Experiential verbs
    1.1.   Experiencer-stimulus verbs

1.2.   Stimulus-experiencer verbs
2. Action verbs
    2.1.   Actor verbs
    2.2.   Non-actor verbs

Experiential verbs describe someone having a particular psychological or mental experience. For some experiential verbs, such as *like* and *fear,* the subject of the verb takes the semantic role of *experiencer* whereas the object of the verb has the *stimulus* role, e.g.:

John (experiencer) fears Bill (stimulus). (Cause is attributed to Bill)

These are termed *experiencer-stimulus verbs*. For other experiential verbs, such as *charm* and *frighten,* the subject of the verb takes the stimulus role whereas the object of the verb has the experiencer role, e.g.:

John (stimulus) frightens Bill (experiencer). (Cause is attributed to John.)

These are termed *stimulus-experiencer verbs*. Several studies have found that most experiential verbs tend to attribute cause to the *stimulus* regardless of whether the stimulus occupies the subject or object position, whether the sentence is active or passive, and whether the participants are animate or inanimate (Au, 1986; Brown & Fish, 1983; Caramazza, Grober, Garvey & Yates, 1977; Corrigan, 1988 & 1992).

Action verbs describe events in which the participant in the subject position of the verb acts on the participant in the object position. The subject and object can be animate or inanimate. The subject of the verb takes the semantic role of *agent* or *actor*, and the object of the verb takes the role of *patient*. Brown and Fish (1983) presented data indicating that action verbs give greater causal weight to the subject of the verb. However, several other studies (Au, 1986; Caramazza, Grober, Garvey & Yates, 1977; Garvey, Caramazza & Yates, 1974/1975) found many action verbs that gave greater causal weight to the object.

Corrigan (1988 & 1992) distinguished between two types of action verbs which she called *actor verbs* and *non-actor verbs*. Actor verbs, e.g. *harm* and *help*, tend to attribute the cause to the actor (i.e. subject) of the verb, regardless of whether the subject and/or object are animate. She found that many of these verbs have derived adjectives referring to the subject (i.e. actor):

Actor verbs	Derived adjectives referring to the actor
defy	defiant
help	helpful
dominate	domineering

For the sentence "John defies Bill," the derived adjective *defiant* refers to the subject *John*.

Non-actor verbs, that either have no derived adjectives, or have derived adjectives that refer to the object, tend to attribute cause to the object when the subject and object are both animate but have different social status. Non-actor verbs tend to attribute cause to the subject when the subject and object are both same-sexed humans named by proper nouns, when the subject and object are both inanimate, or when the subject is inanimate but the object is animate.

Garvey, Caramazza and Yates (1974/1975) found that the implicit causal attribution of a verb can be modified or reversed by the following:

- negating the verb. The sentence "the doctor *did not* blame the intern . . ." produced a smaller attribution bias towards the object than when the verb is not negated.
- converting the sentence to passive voice. When sentences are passivized, there is a shift in the direction of causal attribution towards the surface subject of the verb.

- changing the nouns occupying the subject and object position. Garvey *et al.* (1974/1975) suggested that the relative social status of the participants occupying the subject and object position influence the causal attribution. For the sentence,

  The father praised his son . . .

  causality tends to be imputed more to the object than for the sentence

  The son praised his father . . .

5. TYPES OF CAUSATION AND ROLES IN CAUSAL SITUATIONS

From the forgoing discussion, it is apparent that there are different types of causation and different types of causes. It may be important to distinguish between them in some situations and applications. The cause-effect relation is important in knowledge-based and expert systems, and researchers have attempted to model human causal knowledge and causal reasoning (e.g. Kamerbeek, 1993; Konolige, 1994; Ligeza & Parra, 1997; Nayak & Joskowicz, 1996). To model causal knowledge, we need to know which types of causation are important for the intended application and to distinguish between them in the knowledge base. Causal situations are complex, and we may need to know what aspects or roles in causal situations need to be represented in the knowledge base.

We have not come across an exhaustive typology of causation and causal situations, although different researchers have highlighted different types of causation and causes. Besides physical events and states, cause can refer to a wide range of phenomena including mental cause (human thinking and reasoning), psychological cause, teleological cause (purpose), and statistical laws.

Aristotle (1996) distinguished between four kinds of cause:

- *material cause*. The material that an object is composed of can be seen as causing its existence.
- *formal cause*. The form, pattern or structure of an object can be said to cause its existence.
- *efficient cause*. This is mechanical cause and refers to whatever causes an object to change, move or come to rest.
- *final cause*. This is teleological cause, and refers to that for the sake of which the change occurs. For example, we walk for the sake of health, and so health can be seen as the final cause of the walking.

In a particular causal situation, all these causes can occur at the same time.

Teleological cause or *final cause* refers to a special type of causation where the cause, in a sense, occurs after the effect—a kind of backward causation. In human decision-making, a teleological cause is the intended effect of an action. For example, when a doctor prescribes a drug to treat a disease, it is because of the doctor's belief that the drug will cure the disease. An intended effect in the future is thus the cause of an event in the present. This is related to *mental causation*, since the cause is related to thought processes in the doctor's mind. Teleological cause is also seen as occurring in nature, and can be understood in terms of natural selection. For example, the wing of a bird can be said to exist in order that the bird may fly. A recent analysis of teleology can be found in Koons (1998).

Terenziani and Torasso (1995) provided a taxonomy of what a cause or an effect can be. In their taxonomy, a cause or event can be one of the following:

- A *state* that persists and do not change over a period of time
- An *occurrence*, which can be subcategorized into

◊ An *event*—an occurrence with a culmination or climax
◊ A *process*—an occurrence that is homogenous and does not have a climax or an anticipated result (e.g. snowing)

Events and *processes* can be further categorized into those that have duration (occur over a period of time) or are momentary. Thus, an *event* can be

- A *punctual occurrence* or *achievement*, i.e. the climax of an act (e.g. "John reaches the top")
- A *development* or *accomplishment*, i.e. an event that occurs over a period of time, ending with a climax (e.g. "John wrote the letter in an hour")

A *process* can be

- A *punctual or momentary process* (e.g. "John coughed")
- A *durative process or activity* that endures over a period of time (e.g. "John walked").

The taxonomy thus makes use of the following dimensions:

- *durativity*: punctuality (occurs momentarily) versus temporal extension (occurs over a period of time).
- *telicity*: whether the situation has a climax or not. This distinguishes *events* (having a climax) and *processes* (no climax).
- *stativity*: states of affairs versus actions. This distinguishes *states* from *occurrences* (actions).

Cause and effect can also be categorized according to temporal considerations. In some applications it may be necessary, for example, to distinguish between causal situations where the effect persists after the end of the cause versus situations where the effect ends when the cause ends. Terenziani and Torasso (1995) listed the following special types of cause-effect relations:

1. *one-shot causation*: the presence of the cause is required only momentarily to allow the action to begin (Rieger & Grinberg, 1977)
2. *continuous causation*: the continued presence of the cause is required to sustain the effect (Rieger & Grinberg, 1977)
3. *mutually sustaining causation*: each bit of cause causes a slightly later bit of the effect, and vice versa (Guha & Lenat, 1990, p. 241)
4. *culminated event causation*: the effect comes about only by achieving the culmination of the causal event (e.g. "run a mile in less than 4 minutes" causes "receive a prize")
5. *causal connection with a threshold*: there is a delay between the beginning of the cause and the beginning of the effect, and the effect is triggered only when some kind of threshold is reached.

Warren, Nicholas and Trabasso (1979) identified four types of cause-effect relations in narrative texts:

1. *motivation*: the relation between a goal or intention of a person to an action taken to accomplish or further this goal/intention
2. *psychological causation*: how an event brings about a person's emotion, goal, desire or some other internal state
3. *physical causation*: the mechanical causation in the physical world between objects and/or people
4. *enablement*: the conditions that are necessary but not sufficient for an event to happen.

Dick (1997), in attempting to model the causal situation in a legal case, found it necessary to distinguish between the following types of cause and effect:

- *Distant* versus *proximate* (direct) cause
- *Animate* versus *inanimate* agent
- *Animate agent* versus *instrument* (the direct mechanical cause, or the tool used by the agent)

- *Volitive* versus *non-volitive* cause, i.e. intentional versus accidental cause (for animate agents only)
- *Active* versus *passive* cause
- *Central* versus *peripheral* (or abstract) cause. Peripheral cause includes purpose and reason for an action
- *Explicit* versus *implicit* cause
- *Aims* (intended but unrealized goals) versus *actual effect*.

To model causal situations described in natural language text, it is necessary to distinguish not only the different types of causation, but also the various participants or roles relevant to the causal situation. Khoo, Chan, Niu & Ang (1999) analyzed medical abstracts from the MEDLINE database and identified the following roles and sub-roles in medical causal situations:

- Cause
  - Entity
  - State/Event
  - Size
    - Sufficient condition
    - Minimum condition
    - Maximum condition
- Effect
  - Entity
  - State/Event
  - Size
    - Strength
    - Percentage/Number
    - Comparison (e.g. *greater than*, *less than*, and *same as*)
    - Equation
  - Polarity (e.g. *increase, decrease, improve, worsen*, etc.)
- Condition
  - Entity
  - State/Event
  - Size
    - Sufficient condition
    - Minimum condition
    - Maximum condition
  - Duration
  - Degree of necessity
- Modality (e.g. *true, false, probable, possible*, etc.)
- Evidence
  - Research method
  - Sample size
  - Significance level
  - Source of information
  - Location (where the study was done or the place the evidence was obtained)
- Type of cause-effect relation

6. CONCLUSION

We have presented a broad survey of the cause-effect relation from the perspectives of philosophy, psychology and linguistics, with emphasis on cause-effect relations in text. The concept of causation is clearly multifaceted and complex. The definition of causation varies from situation to situation, and from one application to another. There are also many types of causation, and a causal situation has many aspects or roles that may be relevant to a particular application. Researchers in diverse research areas have investigated the use of cause-effect relations in their particular fields.

Researchers studying how people categorize things have found that cause-effect relations are important in determining the structure of natural categories and how people categorize things (e.g. Keil, 1989; Wattenmaker, Nakamura, and Medin, 1988). People make use of the cause-effect relation to infer attributes and the relative importance of attributes during the categorization process. Said Wattenmaker, Nakamura and Medin (1988), categories derive their coherence not from overlapping characteristic properties but from the complex web of causal and theoretical relationships in which these properties participate.

Researchers have developed many kinds of formalisms and techniques to represent causal knowledge in expert systems and to simulate causal reasoning (e.g. Bree, Hogeveen, Schakenraad, Schreinemakers & Tepp, 1995; Castillo, Cobo, Gutierrez, Iglesias & Sagastegui, 1994; Kamerbeek, 1993; Konolige, 1994; Ligeza & Parra, 1997; Nayak & Joskowicz, 1996). Model-based expert systems that use a causal model of a domain for diagnosing and solving problems are more robust than systems that use heuristics (e.g. Artioli, Avanzolini, Martelli & Ursino, 1996; Gonzalez & Chang, 1997). Researchers have also developed computerized knowledge-acquisition aids for eliciting causal knowledge from human domain experts (e.g. Charlet, Reynaud & Krivine, 1996; Grundspenkis, 1998; Lee & Kim, 1998; Mussi, 1995) as well as for mining causal knowledge from data (e.g. Glymour & Cooper, 1999).

Some researchers have attempted to develop computer programs to extract cause-effect information automatically from various kinds of text: narrative text (e.g. Bozsahin & Findler, 1992; Mooney, 1990; Schubert & Hwang, 1989), expository text found in text books and journal articles (e.g. Kontos & Sidiropoulou, 1991; Kaplan & Berry-Rogghe, 1991; Garcia, 1997), newspaper text (e.g. Khoo, Kornfilt, Myaeng & Oddy, 1998), and short messages and explanations (e.g. Selfridge, Daniell & Simmons, 1985; Joskowsicz, Ksiezyk & Grishman, 1989).

Most of the studies have made use of knowledge-based inferencing to identify cause-effect relations in the text. The knowledge bases used were typically hand-coded, and it was difficult to scale them up for realistic applications or apply them in another domain. Some researchers (e.g. Garcia, 1997; Khoo, Kornfilt, Myaeng & Oddy, 1998; Khoo, Chan & Niu, 2000) have attempted to make use of linguistic clues to identify explicitly expressed cause-effect relations in text without knowledge-based inferencing.

With the increasing amount of text accessible on the Internet and the World Wide Web, we expect to see an increasing number of studies focusing on extracting causal knowledge from the Web for knowledge discovery, text summarization and the development of knowledge-bases.

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