The Cognitive Nature of Instantiation

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People are easily able to infer that a property true of everything must be true of a particular individual and, similarly, that a property true of an individual is also true of something or other. If everything is made of quarks, then George is made of them, and if George is made of quarks, then something is made of them. The three experiments reported here examine how people make inferences like these that require instantiation—from universal terms (e.g., *everything*) to particular terms (e.g., *George*), from particular terms to indefinite terms (e.g., *something*), or from universal terms to indefinite ones. Results from all three experiments show that it takes people longer to recognize the deductive correctness of arguments that depend on two types of instantiation (e.g., from a universal term to a particular term and from a particular term to an indefinite) than those that depend on two examples of the same type. Experiments 1–3 rule out overall abstractness of the premise or the conclusion as the cause of this difference. Experiments 2 and 3 rule out the possibility that the difference is due to repeated noun phrases. Experiment 3 rules out scope ambiguity as the source of the effect. These findings suggest that people use different cognitive operations to instantiate terms and that switching between them takes time and mental effort. @ 2000 Academic Press

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Every symbolic cognitive theory requires some way to match generalities with their instances. Production-rule theories (Anderson, 1993; Newell, 1990), for example, rely on a mechanism that binds variables in productions to the contents of working memory. Likewise, schema theories (Rumelhart, 1980; Rumelhart & Norman, 1988) posit a mechanism that matches variables in schemas to aspects of the individuals that fall under them. These theoretical devices reflect a shared need to hook general information about a class of entities to novel examples of that class. People know and remember information that applies to large or infinite numbers of cases-that all pentagons have five angles, that all vertebrates have hearts, that all Nepalese are Asians. In order for this

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Please address correspondence about this article and reprint requests to Lance Rips, Psychology Department, Northwestern University, 2029 Sheridan Road, Evanston, Illinois 60208. E-mail: rips@nwu.edu. information to be useful, people must be able to apply these generalities to new instances, for example, to use their knowledge that all pentagons have five angles together with the fact that Shape A is a pentagon to infer that A has five angles.

It is sometimes possible to bypass this instantiation process by generalizing directly from old instances to new ones. Suppose each vertebrate you've encountered happens to have a heart. Then you might predict that a new vertebrate will have a heart, provided that it is sufficiently similar to one or more old ones. Instance-to-instance inferences or analogies can't be the whole story, however. For one thing, you can sometimes deduce information about new examples even when you have encountered no previous instances. Although you may never have met a Nepalese, you would have no difficulty using the fact that all Nepalese are Asians to determine that a particular individual from Nepal is Asian. For another, instance-based reasoning-a form of inductive inference-fails to account for the certainty we sometimes experience in making such judgments (see Rips,



1995, for a discussion of the limitations of instance-based approaches).¹

Because of the crucial role that instantiation plays in cognitive theories, you might suppose that it would be the target of systematic research, but this is not the case. Instantiation occurs essentially in many deductive arguments, including the classroom chestnut All men are mortal; Socrates is a man; Therefore, Socrates is mortal, but astonishingly, it has not been a focus of research in the psychology of deduction. Research on reasoning with general expressions is usually confined to categorical syllogisms, whose form is more complex than that of the Socrates example, and these complexities have led researchers to emphasize processes other than instantiation. A categorical syllogism-for example, All daisies are flowers; All flowers are plants; Therefore, all daisies are plants-is an argument containing two premises, both of which include a quantifier (all, some, no, or some ... not), and a conclusion also containing a quantifier. It is sometimes possible to determine the correctness of categorical syllogisms without explicit instantiation. For example, you could reason that the syllogism about daisies is correct by considering the transitivity of the subset relation among the three named categories. Mental-model theories of syllogistic reasoning, in particular, do away with instantiation (Johnson-Laird & Byrne, 1991). By definition, mental models do not contain variables or other expressions of generality (Johnson-Laird, Byrne, & Tabossi, 1989, p. 672); hence, there is no opportunity to instantiate within the model. Any instantiation must therefore take place by means of the process that translates natural-language sentences into a model (or by means of some other external process). Because it is possible to sidestep instantiation in determining the correctness of some syllogisms, syllogisms are not the best venue for studying instantiation.

¹ Instantiation is also a crux for connectionist theories (see Marcus, 1998, for discussion). From this perspective, the issue is how to bind particular information to argument places in propositions without adopting localist representations of variables (e.g., Shastri & Ajjanagadde, 1993) or other departures from the connectionist program.

This article attempts to redress the current lack of psychological evidence about instantiation with experiments that focus directly on this form of inference. In these studies, participants read arguments containing general or particular expressions in their premise and conclusion, and they must then determine whether the argument is deductively correct. Because the present arguments are typically rather easy for adult participants, the experiments employ response time, in addition to the traditional measure of percentage of correct responses, in order to study the mental processes responsible for participants' decisions. Before examining the details of the experiments, though, we need to take a closer look at the nature of instantiation itself.

Three Kinds of Instantiation

The Socrates argument gives us an example of one type of instantiation. Realizing that the conclusion of this argument follows from its premises depends on understanding that what's universally true must be true of a particular individual; thus, we can reason from a premise containing a universal expression to a conclusion containing a proper name or definite description in place of that expression. To take a simpler example, we can reason from Everything is extended to Wrigley Field is extended, where *everything* is the universal expression (universally quantified noun phrase or a similar phrase) and Wrigley Field is the proper name. We can call this form of instantiation reasoning from universal-to-particular instances to distinguish it from other forms that we are about to meet.

Notice that what a premise claims to be universal can be not only a simple property (... *is extended*), but also a relation of a thing to other things or to itself. For example, sentence (1a) asserts that being self-related is true of everything:

- (1) a. Everything is related to itself.
 - b. Wrigley Field is related to itself (Wrigley Field).
 - c. *Wrigley Field is related to Comiskey Park.

When the relation is between each thing and

itself, as in (1a), we must be careful to substitute the same proper name (or a reflexive pronoun) at each of the corresponding positions in the premise. Although (1b) follows from (1a), it's obviously incorrect to conclude that (1c) is true on the basis of (1a). (The star in front of (1c) indicates the deductive incorrectness of the argument from (1a) to (1c).) By contrast, when two or more general expressions appear in the premise, it is possible to substitute different proper names in each position. For example, both (2b) and (2c) follow from (2a):

- (2) a. Everything is related to everything.
 - b. Wrigley Field is related to itself (Wrigley Field).
 - c. Wrigley Field is related to Comiskey Park.

We can also instantiate universals to singular terms other than proper names. It follows from (2a), for example, that the home of the Chicago Cubs is related to the home of the White Sox, where *the home of the Chicago Cubs* and *the home of the White Sox* are definite descriptions. This article, however, confines its attention to proper names for the sake of simplicity and uses *particular noun* and *proper name* interchangeably (see Rips, 1994, Chap. 6, for details on instantiation rules).

Although instantiation from universal-to-particular-instances may be the paradigm, it is not the only variety of instantiation. It is sometimes helpful to conclude that because a property or a relation holds of a particular individual that it also holds of some individual or other. For example, from Mark McGwire hit 70 home runs in a season, it follows that Someone hit 70 home runs in a season. Although there seems to be no standard term for this type of inference, let's label it reasoning from particular-to-indefinite instances. The phrase expressing the indefinite item is typically an existential quantifier phrase, such as something, or an indefinite noun phrase, such as a thing or an entity. As in the case of universal-to-particular reasoning, we will assume that the proper name in the argument succeeds in naming an actual individual.

There are also limits on the substitutions that are permissible in this type of inference, limits that differ from those of universal-to-particular instantiation. For example, when a particular noun is repeated in a premise, as in (3a), we're free to substitute either an indefinite and a reflexive pronoun or two different indefinites. Both (3b) and (3c) follow from (3a):

- (3) a. Wrigley Field is related to itself (Wrigley Field).
 - b. Something is related to itself.
 - c. Something is related to something.

However, if the premise contains two different proper names, the conclusion must contain a different indefinite for each. Thus, (4c) follows from (4a), but (4b) does not:

- (4) a. Wrigley Field is related to Comiskey Park.
 - b. *Something is related to itself.
 - c. Something is related to something.

(The fallacy of the argument from (4a) to (4b) is more apparent for concrete relations. *Fred Smith is the father of James Smith* clearly does not entail *Someone is the father of himself.*) In short, two universals in the same sentence allow substitution of either one or two different proper names, as the sentences in (2) illustrate; however, two proper names only allow substitution of two different indefinite phrases, as shown in (4).

Because indefinite instances instantiate particular ones and particular ones instantiate universals, it must be the case that indefinite instances also instantiate universals. It follows from Everything is related to everything that Wrigley Field is related to Comiskey Park, and it follows from Wrigley Field is related to Comiskey Park that Something is related to something. So Everything is related to everything entails Something is related to something. But although we can reason from universals-toindefinites by way of particular instances, it may be possible to arrive at the conclusion by a more direct route. Reasoners may appreciate that sentences with universals entail ones with indefinites without going through an intermediate step in which a particular instance comes to mind.

One purpose of the experiments in this article is to examine the possibility that the three types of instantiation just mentioned (universal-toparticular, particular-to-indefinite, and universal-to-indefinite) correspond to three distinct cognitive operations. This is suggested by the restrictions just discussed, but is by no means a foregone conclusion, even within deduction theories that include rules for instantiation. A system proposed by Braine, for example, contains a single instantiation rule rather than three (Braine, 1998, Table 11.3, Schema 8). To test the hypothesis of distinct instantiation processes, the experiments in this article examine the time it takes people to derive a conclusion that requires one or two different types of instantiation.

Issues of Representation

We can capture the facts about instantiation within a system that represents universal and indefinite noun phrases as distinct types of variables (Rips, 1994, 1999). This kind of representation is due to Skolem (1928) and provides an alternative to the more usual logic formalisms that employ both quantifiers (e.g., *for all* and *for some*) and variables. Similar quantifierless systems also appear in some reasoning programs in artificial intelligence (see Genesereth & Nilsson, 1987).

In this representation, universal noun phrases, such as *everything*, appear as *universal variables*, which I will write as u(u', u'', etc.). Indefinite noun phrases, such as *something*, appear as *indefinite variables*, shown as i(i', i'', etc.), possibly followed by subscripts. For example, *Everything is related to itself* (=(1a)) becomes u is related to u, whereas *Everything is related to is related to u'*. Similarly, *Something is related to itself* (=(3b)) is i is related to i, and *Something is related to i'*.

In some sentences, the meaning of an indefinite phrase depends on the presence of the universal phrases with which it appears. For example, one meaning of *Everything is related to something* is that there is a single object to which everything is related, but another possible meaning is that everything is related to some object or other (not necessarily the same one). In the second sense, for instance, Wrigley Field may be related to Comiskey Park, Shea Stadium to Yankee Stadium, and so on, but with no one thing related to everything. We can represent the first meaning as *u* is related to *i*. To represent the second meaning, however, we need to indicate that what the indefinite phrase picks out depends on what the universal stands for. We can do this by subscripting the indefinite variable with the universal it depends on—*u* is related to i_u , in this example. For the first meaning, the indefinite has wide scope relative to the universal; for the second meaning, the indefinite has narrow scope. (See Kurtzman & MacDonald, 1993, for a study of people's comprehension of scope relations in natural language.)

This representation has several advantages. In the first place, it simplifies the deduction process for instantiation. Traditional logic systems often require rules for eliminating quantifiers, manipulating the resulting expressions, and then reintroducing quantifiers. The present representation has no explicit quantifiers, making quantifier introduction and elimination unnecessary. However, unlike mental models, which also contain no quantifiers, this representation retains the distinction between universal and indefinite variables. Thus, it treats instantiation within the reasoning system instead of leaving this matter to ad hoc devices. Finally, the representation is consistent with current theories in linguistic semantics (e.g., Kratzer, 1998; Reinhart, 1997) that depict indefinites as functions depending on other terms with which they appear (similar to the dependence indicated by subscripts in our notation).

This quantifier-free representation highlights the issue of how people determine whether one such expression instantiates another. In these terms, the hypothesis that these experiments explore is that different combinations of variables and names require different rules of instantiation. For example, the inference from u is related to u' to Wrigley Field is related to Comiskey Park makes use of just one type of instantiation rule (that governing universal-toparticular instantiation), whereas the inference from u is related to u' to i is related to Comiskey Park makes use of two.

A Method for Studying Instantiation

In general, people take longer to accomplish a task that requires two distinct mental processes than a task that requires a single, repeated process (e.g., Allport, Styles, & Hsieh, 1994; Garavan, 1998; Spector & Biederman, 1976). Switching between processes is likely to take extra time, since the cognitive system needs additional resources to retrieve and coordinate the second operation. Moreover, priming between processes of the same type would give an advantage to repeating the same process relative to employing two distinct ones. Thus, if one task requires processes A and B, a second requires A and (a second application of) A, and a third B and B, we should expect the first task to take longer than the mean of the second and the third. For example, Spector and Biederman (1976) found that participants took longer to add three to the first number in a list, subtract three from the second number, add three to the third, and so on, in alternating sequence, than to add three to each number in the list or to subtract three from each number.

To see how this assumption about switching can help in studying instantiation, consider the arguments in (5):

- (5) a. Everyone dazzles everybody. Fred dazzles Ginger.
 - b. Fred dazzles Ginger. Someone dazzles somebody.c. Everyone dazzles Ginger.
 - Fred dazzles somebody.

Although all three arguments are deductively correct, they vary in the types of instantiation they embody. In argument (5a) both universals instantiate to particular nouns, and in argument (5b) both particular nouns instantiate to indefinites. In contrast, (5c) contains a universal that instantiates to a particular noun and a particular noun that instantiates to an indefinite. If the separate types of instantiation correspond to different cognitive operations, we should predict that response time to confirm (5c) should be longer than the average of the times for (5a) and (5b).²

In a preliminary test of this hypothesis, participants read arguments like those in (5) one at a time on a computer monitor (Rips, 1994, Chap. 7). In addition to the arguments in (5), the study included other deductively correct arguments in which universals, particulars, and indefinites appeared in the premises and conclusions. There were also an equal number of deductively incorrect arguments that reversed the position of the premise and the conclusion of the correct arguments (e.g., Fred dazzles somebody; therefore, everyone dazzles Ginger). Unlike the examples in (5), however, each argument contained a different transitive verb and (where applicable) a different set of proper names. Participants were to assume that the premise of each argument was true of a group of people, and they were to decide whether the conclusion was necessarily true of the same group. To indicate their response, they pressed a button marked "follows" or one marked "doesn't follow" on their keyboard.

Mean response time for arguments such as (5c) was 4190 ms, whereas the mean of arguments analogous to (5a) and (5b) was 3134 ms, in accord with the hypothesis. This result cannot be due to differences in difficulty of the types of instantiation, considered singly. Argument (5c) uses universal-to-particular and particular-to-indefinite instantiation, while (5a) and (5b) use

crease) if these tasks both draw on the same cognitive processes (see Pashler, 1994, for a review of dual-task experiments). In the present context, if people could carry out two different types of instantiation in parallel, but had to carry out two repetitions of the same type serially (e.g., because of competition for resources), then we might predict faster times to (5c) than to (5a) or (5b), above. There is little reason to suppose, however, that repetitions of the same type of instantiation are restricted in this way. (Intuition suggests that, if anything, parallel processing is more likely when the types of instantiation are the same.) More important, the alternative to the account proposed here is that the same mechanism handles all forms of instantiation. Under this alternative, there should be no difference in their competition for cognitive resources or in their serial/parallel processing characteristics. This yields a prediction of no difference between (5c) and the mean of (5a) and (5b), and this forms the null hypothesis for the experiments that follow. A finding that (5c) takes longer than the mean of (5a) and (5b) would then reject this hypothesis, whatever one's assumptions about dual-task interference.

² When people are encouraged to do two tasks at once, response times can sometimes increase (and accuracy de-

the same two types in separate arguments. The relevant difference is how the arguments divide up the instantiation types. Similarly, the individual types of noun phrases can't contribute to the difference. There are a universal noun phrase and a proper name in the premise of (5c), corresponding to two universals in (5a) and two proper names in (5b). Likewise, (5c) contains a proper name and an indefinite phrase in its conclusion, corresponding to two proper names in (5a) and two indefinites in (5b). Thus, the average frequency of types of noun phrases in (5a) and (5b) is the same as that in (5c).

It is possible to object, however, that the difference between the arguments could be due to uncontrolled aspects of the experiment. Within the group of stimulus arguments, for example, ones that had a premise of the form Everyone verbs everybody were always deductively correct, as were those with the conclusion Someone verbs somebody. The first sentence entailed all the others, and the second was entailed by all the others. Participants who noticed this pattern could have responded to items like (5a) and (5b) without fully processing the argument. This short-circuiting strategy is not possible for (5c), and this difference may account for the result just reported (see the General Discussion for further comments on this possibility). To eliminate this strategy, and others like it, it is helpful to examine arguments more complex than those of (5), and the experiments that follow develop this idea.

Overview of the Experiments

All experiments in this article rely on the method just described, but they alter the form of the stimulus arguments. Experiment 1 employs sentences with several noun phrases (e.g., X reminded Y to compare Z to W) so that it is possible to vary the number of instantiation rules that people need to confirm the argument, while, at the same time, equating the overall generality of the premises and conclusions. For this reason, participants cannot use the form of the premise or conclusion (considered separately) as a clue to the correct answer. Experiment 2 uses arguments of the same form, but varies the phrasing of the universal and indefi-

nite terms in order to avoid repetition. This maneuver eliminates the possibility that the faster response times for arguments like (5a) and (5b) are due to duplication of the quantifiers (every ... every, some ... some) rather than to duplication of the instantiation rule. Experiment 3 examines whether the pattern of results is due to ambiguities in the stimulus sentences. The arguments in this experiment had premises and conclusions that were conjunctions (X admired Y, and Z interviewed W). When universal and indefinite terms appear in separate conjuncts, these sentences eliminate ambiguities about the relative scope of these terms. In examining these issues, the experiments limit themselves to judgments of deductive correctness. When judging the inductive strength of arguments, people sometimes fail to give due weight to implicit information that could determine whether a property of a superset is true of a subset (Sloman, 1998).

EXPERIMENT 1: INSTANTIATION WITHOUT DIFFERENCES IN GENERALITY

This experiment examines the amount of time people take to decide whether one sentence instantiates another, and it attempts to determine whether people take longer to confirm two different types of instantiation than two repetitions of the same type. On each trial, participants saw an argument—a pair of sentences—with each sentence of the form *X* reminded *Y* to compare *Z* to *W*. Two of the terms (*X*, *Y*, *Z*, or *W*) were held constant in the two sentences, whereas the other two varied. The pairs in (6a–6c) are examples:

- (6) a. Everyone reminded Jill to compare everybody to Cathy.
 Someone reminded Jill to compare somebody to Cathy.
 b. Ann reminded everyone to compare Beth to everybody.
 Someone reminded everyone to compare somebody to everybody.
 - c. Everyone reminded everybody to compare Martha to Jane.
 Someone reminded everybody to compare somebody to Jane.

Participants decided on each trial whether the

second sentence of the argument must be true whenever the first sentence was true.

The stimulus arguments varied according to how many different types of instantiation they contained. To spell this out more precisely, let's say that two terms are a corresponding pair if they occupy the same relative position in the two sentences of an argument. Thus, the corresponding pairs in argument (6a) are (everyone, someone>, (everybody, somebody>, (Jill, Jill>, and (Cathy, Cathy). In one-type arguments, corresponding pairs are either constant (e.g., (Jill, Jill \rangle , (Cathy, Cathy \rangle) or they exemplify a single type of instantiation. Argument (6a) is a onetype argument, for example, since (everyone, someone) and (everybody, somebody) are both universal-to-indefinite instantiations. Similarly, (6b) is also one-type, since both (Ann, someone> and (Beth, somebody> are particular-toindefinite instantiations. By contrast, the corresponding terms exemplify two different types of instantiation in two-type arguments. In (6c), for example, (everyone, someone) is universal-toindefinite, but (Martha, somebody) is particularto-indefinite. The examples in (6) have their instantiated pairs as the first and third terms. In the stimulus arguments, however, the ordinal position of the instantiated pairs varied; so it was not possible for participants to anticipate their location in the sentence.

If different cognitive operations handle different types of instantiation, then we would expect two-type arguments to take participants longer to affirm than one-type arguments. This should be so even when the corresponding arguments share the same instantiation types. For example, argument (6c), which employs universal-to-indefinite particular-to-indefinite and types, should take longer than the average of (6a) (universal-to-indefinite) and (6b) (particular-to-indefinite). This prediction parallels the one for (5a)-(5c), discussed earlier. The advantage of the more complex sentences in this experiment is that they control the overall level of generality of the premises and conclusions. The premises of arguments (6a)–(6c) each have the same set of terms (two universal and two particular terms). Moreover, the conclusion of (6c) contains two indefinites (someone, some*body*), one universal (*everyone*), and one particular term (*Jane*), the same as the average number of indefinites, universals, and particular terms in the conclusions of (6a) and (6b). Over all the deductively correct arguments, the average frequency of the three kinds of terms is the same for the premises of the one-type problems, and, likewise, the average frequency for the conclusions of the one-type items is the same as that for the conclusions of the two-type items.

The instructions told participants that the stimulus sentences all concerned people who were members of the same group and that all named individuals were members of this group. We can assume that in this context participants will take the universal and indefinite terms to range over group members and will take the proper names to denote people in the same domain. Under these conditions, then, participants are likely to represent the sentences in a way that depends only on the variables and names. For example, the representation of the first sentence in (6a) might be u reminds Jill to compare u' to Cathy and the second sentence as i reminds Jill to compare i' to Cathy, using the conventions introduced earlier. In other words, participants are likely to exclude from the representation special conditions (e.g., ones that assure that the variables stand for humans or that Jill and Cathy are humans) and to attend directly to the relations among the terms in the two sentences.

Method

The participants in this experiment viewed a series of arguments one at a time on a monitor, and they judged each according to whether "the second sentence MUST be true whenever the first sentence is true." A participant began a trial by pressing the space bar of a keyboard with his or her thumb. This produced a ready signal (the word READY) at the left of the screen and a little above center. The ready signal lasted 2 s and was replaced automatically by an argument, such as (6a), (6b), or (6c). The two sentences of the argument were left-aligned, and the first one appeared at the same position on the screen that the ready signal had occupied. The participant

evaluated the argument, pressing the "F" key or the "J" key on the keyboard to indicate the response. The key press erased the argument, and it initiated feedback to the participant (either *Your response was correct* or *Your response was NOT correct*). The feedback message lasted 2 s, after which the screen became blank. At this point, the participant could begin the next trial by pressing the space bar. The computer recorded the participant's response time from presentation of the argument to the key press; it also recorded the participant's accuracy.

Instructions appeared on the monitor at the beginning of the session, and the participants were able to ask questions about the procedure before the trials began. To give them a feel for the pacing of the experiment, the computer presented eight practice trials before the main trials. The practice trials consisted of simple propositional arguments (e.g., Mary goes to the store and Fred goes to the beach/Fred goes to the beach), half deductively correct and half deductively incorrect. Instructions cautioned participants to make their responses as quickly as they could but without making any mistakes. The practice trials appeared in random order (a new permutation for each participant), as did the experimental trials.

In this experiment, 12 participants pressed the "F" key with their left forefinger to indicate a "must be true" response and pressed the "J" key with their right forefinger to indicate that the conclusion "need not be true." A second group of 12 participants pressed the "J" key for "must be true" and pressed the "F" key for "need not be true."

The arguments. There were 12 forms of deductively correct arguments in this experiment, and Table 1 lists them in symbolic form. In the table, *i*, *i'*, *i''*, ... stand for indefinite nouns (someone or somebody); *n*, *n'*, *n''*, ... stand for particular nouns (common first names, such as Jane or Bob), and *u*, *u'*, *u''*, ... stand for universal nouns (everyone or everybody). Thus, the 4th argument in the table is the symbolic form of (6c). The first 6 of these argument forms share the same set of terms in their premise; the last 6 share the same set of terms in their conclusion, and we can call them the *constant* premise and constant conclusion groups, respectively. Within each group of 6 forms, the first 3 are one-type arguments (i.e., depend on just one type of instantiation), whereas the last 3 are two-type. The very 1st argument form, for example, depends on (two instances of) universal-to-indefinite instantiation, because u in the premise becomes i in the conclusion and u' in the premise becomes i' in the conclusion. By contrast, the 4th argument depends on both universal-to-indefinite and particular-to-indefinite instantiation (u goes to i and n to i'). The Appendix lists examples for each of the 12 forms.

Within the constant-premise group, the frequency of the different types of terms is the same for one-type as for two-type arguments. Universals occur six times and particulars occur six times overall in the premises of the one-type arguments, and the same frequencies are maintained in the premises of the two-type arguments. Universals occur twice, particulars six times, and indefinites four times in the conclusions of the one-type arguments, and the same frequencies again occur in the conclusions of the two-type arguments. Frequency of the different types of terms is also equated in the premises and conclusions of the constant-conclusion group. Among the premises of the onetype arguments, universals occur four times, particulars six times, and indefinites twice, the same as the frequencies for two-type items. Among the conclusions, particulars occur six times and indefinites six times in both the onetype and two-type arguments. Thus, the average level of generality (defined in terms of the average number of universals, particular, and indefinite nouns) is equal for premises of the one-type and for the premises of the two-type problems; the same is true for the conclusions of the one-type and the conclusions of the twotype problems.

The fourth column of Table 1 lists the kinds of instantiation that each argument requires and indicates that the number of examples of each kind is the same for one-type as for two-type problems. In the constant-premise arguments, for example, universal-to-indefinite instantia-

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TABLE 1

Argument F	'orms, M	Iean Corre	ct Response	Time, and	Error	Rates,	Experimer	nt i
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Number of rule	Argument	Argument		Mean response time	Error rate ^a	
types	number	form	Types of instantiation	(ms)	(%)	
Constant-pr	remise					
One	1.	F(u, u', n, n')⊢ F(i, i', n, n')	Universal-indefinite	5271	8.3	
	2.	F(u, u', n, n')⊢ F(u, u', i, i')	Particular-indefinite	6510	6.2	
	3.	F(u, u', n, n')⊢ F(n", n"", n, n')	Universal-particular	5902	11.4	
Two	4.	F(u, u', n, n')⊢ F(i, u', i', n')	Universal-indefinite Particular-indefinite	6204	13.5	
	5.	F(u, u', n, n')⊦ F(n", u', i, n')	Universal-particular Particular-indefinite	7343	17.7	
	6.	F(u, u', n, n')⊢ F(i, n", n, n')	Universal-indefinite Universal-particular	6536	18.8	
Constant-co	onclusion					
One	7.	F(u, u', n, n')⊦ F(i, i', n, n')	Universal-indefinite	5675	10.4	
	8.	F(n", n"", n, n')⊢ F(i, i', n, n')	Particular-indefinite	6475	11.4	
	9.	F(i, i', u, u')⊢ F(i, i', n, n')	Universal-particular	6985	14.6	
Two	10.	F(u, n", n, n')⊢ F(i, i', n, n')	Universal-indefinite Particular-indefinite	6377	10.4	
	11.	F(n", i', u, n')⊦ F(i, i', n, n')	Particular-indefinite Universal-particular	6634	15.6	
	12.	F(u, i', u', n')⊦ F(i, i', n, n')	Universal-indefinite Universal-particular	6577	7.3	

 $^{a} n = 96.$

tion occurs twice in the one-type arguments (both times in argument 1) and twice in the two-type arguments (once in argument 4 and once in argument 6). This means that one-type and two-type arguments differ, not in the total number of times a particular sort of instantiation applies, but in the way these sorts are assigned to the arguments. Differences in difficulty of the individual kinds of instantiation, then, should not affect the contrast between one-type and two-type problems.

To produce the stimulus arguments from the forms in Table 1, I constructed four versions of each form by rearranging the corresponding terms. In the first argument, for example, the corresponding terms are $\langle u, i \rangle$, $\langle u', i' \rangle$, $\langle n, n \rangle$,

and $\langle n', n' \rangle$. A random Latin Square permuted these pairs in four different ways, so that each pair appeared once in each ordinal position within an argument. If (7a) was one such version of the first form, for example, (7b) might be another:

(7)	a.	u reminded u' to compare n to n'
		i reminded i' to compare n to n'
	b.	n reminded u to compare n' to u'
		n reminded i to compare n' to i'

Rearranging the order of corresponding pairs does not alter the deductive correctness of the argument. A different random Latin Square produced four argument versions in this way from each of the Table 1 forms. However, we will let the form in the table stand for all four versions.

Thus, there were 48 different deductively correct arguments in all (12 forms \times 4 versions per form). Within each version, everyone substituted for the first universal noun and everybody for the second (if there was more than one); someone substituted for the first indefinite and somebody for the second. Common first names were randomly assigned to the positions for particular nouns, with different first names for each argument. The stimulus ensemble also contained 48 deductively incorrect arguments, formed from the deductively correct ones by reversing the order of the premise and conclusion. Half the arguments in the ensemble were therefore deductively correct and half deductively incorrect. Individual sentences in the incorrect arguments were the same as in the correct ones.

Participants. The 24 participants in this experiment were introductory psychology students, who received course credit for their cooperation. None reported having taken a college-level course in logic.

Results and Discussion

The participants' response times in this experiment tend to confirm the idea that arguments requiring two different types of instantiation are more difficult than those requiring only one. Table 1 shows the mean correct response times for the individual argument forms and suggests that one-type arguments are typically, though not invariably, faster than two-type problems. Times for some trials were very long relative to other trials for the same argument form, and for this reason Table 1 reports mean times after removing these outliers. (For these purposes, outliers are times longer than Q_3 + $1.5(Q_3 - Q_1)$ or shorter than $Q_1 - 1.5(Q_3 - Q_1)$ Q_1), where Q_1 is the first quartile for a particular argument form and Q_3 is the third quartile; see Mosteller & Hoaglin, 1991.) This procedure eliminated 3% of the data, but did not change the overall pattern of results.

Main predictions. Mean response time for arguments requiring one type of instantiation is 6130 ms, whereas mean time for the arguments

requiring two is 6615 ms, F(1,23) = 16.56, $SE_m = 81$ ms, $p < .001.^3$ This confirms the experiment's basic prediction. Notice that the form of the arguments in this experiment would have allowed participants to make a correct response on the basis of the first successful or unsuccessful instantiation. Within each argument, both pairs of instantiated terms were correctly instantiated or both were incorrectly instantiated. In argument (6c), for example, the corresponding terms (everyone, someone) and (Martha, somebody) are correct. Thus, participants could have saved some work by evaluating just one of the mismatching pairs in each problem (e.g., (everyone, someone)) and responding on that basis. The obtained difference between one-type and two-type arguments, however, suggests that participants did not take advantage of this shortcut and, instead, processed the entire argument on most trials.

Table 1 shows some overlap in the distribution of times for one-type and two-type arguments. For example, the mean response time for argument 2 (a one-type problem) is longer than that for argument 4 (a two-type problem). This may be due, however, to the specific kinds of instantiation that figure in these problems. Argument 4 depends on both universal-to-indefinite and particular-to-indefinite instantiation, whereas argument 2 depends only on particularto-indefinite instantiation. If universal-to-indefinite instantiation is especially easy, then this could decrease the times for argument 4, offsetting the advantage of one-type argument 2. To check for violations of the predicted advantage for one-type arguments, we need to compare times for individual two-type arguments to both those one-type arguments containing the same kinds of instantiation. For example, we should compare times for argument 4 (universal-to-

³ I calculated the standard error of the mean (SE_m) in this article as

$$SE_m = \sqrt{\frac{MS_e}{n}},$$

where MS_e is the mean square error term that appears in the denominator of the relevant *F* ratio, and *n* is the number of observations in the means of the tested comparison. indefinite and particular-to-indefinite instantiations) to the mean times for argument 1 (universal-to-indefinite) and argument 2 (particularto-indefinite). This is the test outlined earlier (see *A Method for Studying Instantiation*).

To carry out these tests, we can put together related problems in the constant-premise and constant-conclusion groups. For example, arguments 4 and 10 in Table 1 each contain both universal-to-indefinite and particular-to-indefinite pairs, and so they can be compared to the means of arguments 1 and 7 (universal-to-indefinite) and 2 and 8 (particular-to-indefinite). This comparison shows a trend in the predicted direction of longer times for the former arguments (6290 ms) than for the latter (5983 ms), though this difference is not significant by a planned contrast, F(1,182) = 2.49, p > .10. Arguments 5 and 11 each contain universal-toparticular and particular-to-indefinite instantiations and can therefore be compared to arguments 2 and 8 (particular-to-indefinite) and 3 and 9 (universal-to-particular). The means are 6988 and 6468 ms, respectively, and are this time reliably different, F(1,182) = 7.13, p <.01. Finally, arguments 6 and 12 (universal-toindefinite and universal-to-particular) can be compared to arguments 1 and 7 (universal-toindefinite) and 3 and 9 (universal-to-particular). This contrast is again significant, with the mean for the two-type arguments (6558 ms) longer than the mean of the relevant one-type problems (5958 ms), F(1,182) = 9.42, p < .01. (The contrasts are based on a pooled error term drawn from an analysis of variance of the Table 1 data, $SE_m = 225$ ms. The pooled error has the advantage of using more of the data from the experiment. The same error term figures in the remaining contrasts in this section.) These comparisons are, of course, not independent, so caution is needed in interpreting them; however, they lend some further support to the idea that verifying two different types of instantiation is more difficult than verifying a single repeated type.

Some of the arguments in this experiment contain both a universal and an indefinite noun in the premise or conclusion. Participants might have seen the conclusion of argument 5, for example, as Joan reminded everybody to compare someone to Fran. The meaning of such a sentence is potentially ambiguous. On one interpretation, it means that Joan reminded each individual to compare someone or other (not necessarily the same person) to Fran. On the other, the sentence means that there's a certain individual (say, Fred) whom Joan reminded everyone to compare to Fran. Someone has narrow scope with respect to everybody on the first interpretation and has wide scope on the second. This ambiguity affects arguments 2, 4, 5, 9, 11, and 12 in Table 1. Inspection of these arguments shows that they remain deductively correct no matter which reading a participant gives to the sentence in question; thus, the ambiguity does not change the correct response to these items. (Figure 1 under General Discussion provides justification for this claim.) It may take the participant longer to comprehend ambiguous than unambiguous sentences, however, and this could in turn increase response times for the arguments that contain them. In line with this idea, the mean response time for unambiguous one-type arguments 1, 3, 7, and 8 is faster than that for ambiguous one-type arguments 2 and 9 (5831 vs. 6748 ms), F(1,182) = 22.11, p <.01. The response time for unambiguous twotype arguments 6 and 10 is also faster than that for ambiguous two-type items 4, 5, 11, and 12 (6456 vs. 6690 ms), although the difference is not significant in this case, F(1,182) = 1.43, p > .10. The ambiguous sentences may also be responsible for a significant effect of individual argument within the constant-premise versus constant-conclusion and the one-type versus two-type groups, F(8, 182) = 5.96, $SE_m =$ 225 ms, p < .001. (We consider other possible explanations for this asymmetry under General Discussion.)

But although scope ambiguity may have slowed responses in this experiment, it cannot fully explain the difference between two-type and one-type arguments. Considering just the unambiguous arguments, we find that times remain faster for the one-type problems (5831 vs. 6456 ms), F(1,182) = 10.30, p < .01. As in the case of the earlier comparisons, this one balances the specific types of instantiation that appear in the two argument groups. The difference can therefore not be blamed on either the ambiguity of the individual sentences or the degree of difficulty of the specific types of instantiation. Still, it would be interesting to know the outcome for unambiguous versions of all 12 arguments. Experiment 3 addresses this issue.

Error rates. Error rates for the deductively correct arguments appear in the last column of Table 1. For one-type arguments the overall error rate was 10.4%, whereas for two-type arguments the error rate is 13.9%. Although the difference significant in errors is not $(F(1,23) = 2.71, SE_m = 1.5\%, p > .10)$, the trend agrees with the response-time data in suggesting that participants found two-type arguments more difficult than one-type arguments. The positive correlation between response times and errors indicates that the participants were not sacrificing accuracy for speed in making their responses.

Summary. Participants in this experiment took about 0.5 s longer to verify an argument that contained two types of instantiation than to verify an argument containing two tokens of the same type. This difference obtained when the overall level of generality in the premise and in the conclusion was constant, when the frequency of the instantiation types was constant across arguments, and when any ambiguous sentences were discarded. It is nevertheless possible to object that other peculiarities of the one-type arguments are responsible for their response-time advantage. For example, onetype arguments contained more sentences with both everyone and everybody than two-type arguments, and, likewise, one-type arguments contained more sentences with both someone and somebody than two-type arguments (see Appendix). Perhaps mere repetition of these similar-sounding terms within the same sentence makes it easier for participants to process them. This is the possibility that Experiment 2 examines.

EXPERIMENT 2: INSTANTIATION WITHOUT REPEATED QUANTIFIERS

If separate cognitive operations handle different kinds of instantiation, then people should take longer to verify arguments that depend on two kinds than arguments that depend on one. Experiment 1 provided support for this hypothesis, but the prediction should hold no matter how the arguments express their critical universal and indefinite noun phrases. The present experiment varies these phrases in order to provide more general backing for the hypothesis: Universals appear as *everybody* (*everyone*) or as *each person* and indefinites as *someone* (*somebody*) or as *a person*. Varying the phrases within a premise or a conclusion helps eliminate the possibility that the results of Experiment 1 are due simply to faster reading of repeated words or morphemes.

Method

In this experiment, participants again judged whether each of a sequence of arguments was deductively correct. The procedure duplicated that of Experiment 1. The arguments were also the same as those of the previous experiment, with two exceptions. First, and most important, when the premise or conclusion of an argument contained two universals, the first of these appeared as everyone or everybody and the second as each person. Similarly, when a premise or conclusion contained two indefinites, the first appeared as someone or somebody and the second as a person. Within a given argument, however, universals (indefinites) that occur in corresponding positions in the premise and conclusion always had identical wording. The examples in (8) give one version each of arguments 1, 2, and 4 (see Table 1), corresponding to the examples in (6) for Experiment 1:

(8) a. Everyone reminded Jill to compare each person to Cathy. Someone reminded Jill to compare a person to Cathy.b. Ann reminded everyone to compare Beth to each person.

Someone reminded everyone to compare a person to each person.

 c. Everyone reminded each person to compare Marsha to Jane.
 Someone reminded each person to compare a person to Jane.

Two universals appear in the premise of (8c) (i.e., *everyone* and *each person*); because the

second of these is in the same position as a universal in the conclusion, the same phrase occurs there. (Repetition of phrases in corresponding positions of the premise and conclusion is not a factor in this experiment, since there are exactly two such repetitions in each argument; see Table 1.) The second, and more minor, difference between the stimulus arguments of Experiments 1 and 2 is that separate sets of proper names appeared in the deductively correct and the deductively incorrect arguments of the latter study.

Thirty undergraduates participated in this experiment in exchange for course credit. None had been in Experiment 1, and none had taken a college logic course.

Results and Discussion

We can assume that people take less time to perform two examples of the same operation than two different cognitive operations. This implies that if different cognitive operations handle different forms of instantiation, then response times should be faster for arguments with two examples of the same type of instantiation than for arguments with two different types. Response times for this study support this prediction. Mean correct time for the one-type arguments is 5469 ms, compared to 6257 ms for two-type arguments, F(1,28) = 35.59, $SE_m =$ 97 ms, p < .0001. In this experiment, the premises (conclusions) of the arguments expressed repeated universals with distinct wording (each vs. every) and, similarly, for repeated indefinites (some vs. a). Thus, the differences between argument forms that Experiment 1 uncovered are not due to the more similar wording that experiment employed.

Table 2 reports the response times for the individual arguments, trimmed according to the same procedure as that in Experiment 1. (Trimming eliminated 5% of the data in this study but did not change the pattern of differences discussed here.) Comparisons between individual arguments that share the same kinds of instantiation again support the one-type versus two-type difference. Arguments 4 and 10 involve both universal-to-indefinite and particular-to-indefinite instantiations and took longer for par-

ticipants to confirm than the mean of arguments 1, 2, 7, and 8, which contain two tokens of universal-to-indefinite or two tokens of particular-to-indefinite instantiation (6090 vs. 5406 ms). This comparison was not significant in the previous experiment, but does achieve significance here. Likewise, arguments 5 and 11 each use both universal-to-particular and particularto-indefinite types and took significantly longer for participants than arguments 2, 3, 8, and 9, which contain just the component inferences (6670 vs. 5692 ms). Finally, arguments 6 and 12, with both universal-to-indefinite and universal-to-particular instantiation, also took longer than arguments 1, 3, 7, and 9, with the relevant component instantiations (6028 vs. 5278 ms). In each case, F(1,214) > 10, $SE_m = 241$ ms, p < .01, by planned comparisons.

Response times in this study are somewhat faster than those of Experiment 1, but there is a strong correlation between times for comparable arguments in the two experiments, r(10) = .86, p < .001. This suggests that argument difficulty is robust over different ways of expressing the universal and the indefinite terms.

Error rates.By contrast with the response times, error rates are slightly larger in Experiment 2 than Experiment 1. The errors, however, are consistent with the times in showing the one-type arguments (13.5% errors) significantly easier than the two-type problems (18.6%), F(1,29) = 12.56, $SE_m = 1.0\%$, p < .01.

Two additional explanations. We noticed earlier that the premises of one- and two-type arguments contain the same number of universals, the same number of indefinites, and the same number of particular nouns. The arguments' conclusions are also balanced for the frequency of the different kinds of terms. Pairs of universals and *pairs* of indefinites, however, are more common within the premises or conclusions of one-type than of two-type problems. These pairs had similar wording in Experiment 1 and could have led to the advantage that the onetype arguments exhibited; however, the present study found no evidence that this was so. The difference between argument forms did not decrease when the members of the pair had distinct phrasing. It remains possible that universal

THE NATURE OF INSTANTIATION

		TABLE 2					
Argument Forms,	Mean Correct	Response Time	, and Error	Rates,	Experiment	2	

Number of rule types	Argument number	Argument form	Types of instantiation	Mean response time (ms)	Error rate ^a (%)
Constant-p	remise				
One	1.	F(u, u', n, n')⊦ F(i, i', n, n')	Universal-indefinite	4518	10.0
	2.	F(u, u', n, n')⊦ F(u, u', i, i')	Particular-indefinite	6041	10.8
	3.	F(u, u', n, n')⊢ F(n", n"", n, n')	Universal-particular	4923	18.3
Two	4.	F(u, u', n, n')⊦ F(i, u', i', n')	Universal-indefinite Particular-indefinite	6348	15.8
5.	5.	F(u, u', n, n')⊢ F(n", u', i, n')	Universal-particular Particular-indefinite	6742	25.0
	6.	F(u, u', n, n')⊢ F(i, n", n, n')	Universal-indefinite Universal-particular	5999	18.3
Constant-co	onclusion				
One	7.	F(u, u', n, n')⊦ F(i, i', n, n')	Universal-indefinite	5465	14.2
	8.	F(n", n"", n, n')⊢ F(i, i', n, n')	Particular-indefinite	5600	12.5
	9.	F(i, i', u, u')⊦ F(i, i', n, n')	Universal-particular	6204	15.0
Two	10.	F(u, n", n, n')⊢ F(i, i', n, n')	Universal-indefinite Particular-indefinite	5833	18.3
	11.	F(n", i', u, n')⊢ F(i, i', n, n')	Particular-indefinite Universal-particular	6599	14.1
	12.	F(u, i', u', n')⊦ F(i, i', n, n')	Universal-indefinite Universal-particular	6056	20.0

a n = 120.

or indefinite pairs speed processing no matter how the sentences express them, but even this more abstract possibility seems inconsistent with the data. One-type arguments 3 and 8 each contain a single pair, as do two-type arguments 5, 6, 10, and 11. Mean time for the former (5262 ms), however, is significantly faster than mean time for the latter arguments $(6293 \text{ ms}), F(1,214) = 24.52, SE_m = 241$ ms, p < .01.

Yet another possibility is that the response time difference is due to the total number of different kinds of terms within a sentence. The premise of argument 7, for example, has terms of two different kinds (universal and particular), whereas the premise of 11 has all three kinds (universal, particular, and indefinite). In general, one-type arguments have fewer kinds of terms per sentence (M = 1.8) than do two-type arguments (M = 2.3), and it is possible to argue that participants have more difficulty comprehending sentences with a greater variety of kinds. To check the possibility that this difference explains the one-type versus two-type response times, we can compare one-type arguments 1, 2, 7, and 9 to two-type arguments 6 and 10, since each of these arguments contain exactly two kinds of terms in both premise and conclusion. Mean times for the one-type arguments, however, is 5557 ms versus 5916 ms for the two-type items. This difference is marginally significant (F(1,214) = 2.87, .05

.10) and echoes the results from the full data set.

We can conclude that neither the frequency of individual terms nor the frequency of pairs of terms nor the frequency of kinds of terms in the sentences accounts for the one-type/two-type difference.

EXPERIMENT 3: INSTANTIATION WITHOUT SCOPE AMBIGUITIES

Sentences containing both universal and indefinite terms are semantically ambiguous, since the indefinite term can refer to just one entity or several different ones. The *Results* section of Experiment 1 shows that these scope ambiguities cannot explain the differences between arguments containing just one type of instantiation and arguments containing two. But it would nevertheless be useful to know what the times for individual arguments are like when the sentences clearly favor one interpretation over the other. The ambiguities in the arguments of Experiments 1 and 2 may be responsible for some of the variation within one-type and two-type arguments.

One way to reduce the ambiguity of these items is to reword the indefinite someone as someone or other, since the latter phrase selects narrow scope. As mentioned earlier, Joan reminded everybody to compare someone to Fran is ambiguous between the reading in which there is just one (unnamed) person whom everyone is to compare to Fran and a second reading in which everyone compares someone (but not necessarily the same person) to Fran. Joan reminded everybody to compare someone or other to Fran, however, seems to favor the second interpretation over the first. A pilot study, similar to that of Experiment 2, suggests that this rephrasing does not eliminate the onetype versus two-type difference. In this study, the phrase some person or other replaced a person, and someone or other replaced someone in the arguments of Experiment 2. This change in wording increased response times overall, but the mean time for one-type arguments (7338 ms) was significantly faster than that for twotype arguments (7817 ms), F(1,29) = 5.79, $SE_m = 162$ ms, p < .05. Error rates in this experiment were consistent with the response times. Participants made fewer errors (14.4%) when dealing with one-type problems than they did for two-type problems (21.0%), F(1,29) = 8.77, $SE_m = 1.6\%$, p < .01. This replicates the pattern found in Experiments 1 and 2.

Unfortunately, however, the use of someone or other does not completely eliminate the scope ambiguities in these problems. The premise of argument 9 (see Appendix), for example, appeared to participants in the pilot study as Someone or other reminded some person or other to compare everyone to everybody. Each of the two indefinite phrases could have narrow scope with respect to both of the universals or with respect to only one of them. The differences in these interpretations are easier to comprehend if we draw the terms in the sentence from different domains. For example, compare (9a), in which the indefinite phrases have narrow scope with respect to each actress, to (9b), in which these phrases have narrow scope with respect to every actor.

- (9) a. Each actress reminded one of her directors to compare one of her make-up artists to every actor.
 - b. Each actress reminded one of his directors to compare one of his make-up artists to every actor.

It is uncertain how many interpretations people discriminate in sentences with indefinites and multiple universals, but the possibility of these alternative readings suggests that we should take a different path to disambiguating these arguments.

The tack we take in the present experiment is to divide each of the original sentences into two conjuncts. Each argument form appeared in this experiment in six different versions, at least two of which were unambiguous. Example (10) shows one of the unambiguous versions for arguments 1, 2, and 4, and these examples can be compared to those in (6) and (8) for the comparable arguments in Experiments 1 and 2:

 (10) a. Everyone admired each person, and Jan interviewed Pam.
 Someone admired a person, and Jan interviewed Pam.

- b. Jan admired Pam, and everyone interviewed each person.
 Someone admired a person, and everyone interviewed each person.
- c. Everyone admired Jan, and each person interviewed Pam.
 Someone admired a person, and each person interviewed Pam.

In (10) universal and indefinite terms always appear in separate conjuncts. Because the scope of these terms doesn't extend across the conjunction, the sentences are unambiguous: No indefinite is within the scope of a universal, and no universal within the scope of an indefinite. Some of the other versions of the arguments remained ambiguous in this experiment; they were retained to prevent participants from predicting where in the sentences the instantiated terms would appear. However, because two or more versions of each argument form were unambiguous, we can test the difference between one-type and two-type arguments in a context free of ambiguities by confining ourselves to these versions. The different sentence types in this experiment also provide an opportunity to generalize the results beyond those of Experiments 1 and 2.

Method

The arguments in this experiment had the same abstract form as those in 1–12 of Tables 1 and 2. However, all premises and conclusions appeared in the sentence frame *X* admired *Y*, and *Z* interviewed *W*, as in (10).

As we observed earlier, two of the terms in each argument are instantiated, and the other two terms are constant. I created six different versions for each of the arguments 1–12 by assigning the instantiated and the constant terms to different positions in the sentence frame. In version 1 the two instantiated terms appeared in the first conjunct of the frame, as in (10), and in version 2 the two instantiated terms appeared in the second conjunct. These two versions always produced unambiguous sentences because an individual conjunct never contained both a universions, one instantiated term and one constant term appeared in each conjunct. There are four possible assignments of this sort, creating versions 3–6. For some of the arguments, all four of these remaining versions are ambiguous in that at least one conjunct contains both a universal and an indefinite. Arguments 2, 4, 9, and 12 conform to this pattern. For arguments 5 and 11, two of the remaining versions are ambiguous and the other two unambiguous. For the remaining arguments 1, 3, 6, 7, 8, and 10, all versions are unambiguous (as were the comparable arguments in Experiments 1 and 2). In sum, all 12 argument forms had two unambiguous versions—versions 1 and 2. Some arguments had four additional unambiguous versions, others two, and still others none.

The terms in each argument version could appear in one of four different orders (e.g., either of the corresponding terms (everyone, someone) or (each person, a person) could appear first in the first conjunct of (10a), and either (Jan, Jan) or (Pam, Pam) could appear first in the second conjunct). One of these four orders was chosen at random to represent each version. Four one-syllable, three-letter proper names appeared in the arguments—Kim, Jan, Pam, and Flo—and these were randomly assigned to the positions of the particular terms in the arguments. *Someone* or *a person* appeared as the indefinite terms and *everyone* and *each person* as the universal terms, as in Experiment 2.

The entire set of stimulus arguments consisted of 72 deductively correct items (12 argument forms by 6 versions) and 72 incorrect items (formed by reversing the position of the premise and conclusion in the correct items). Participants received these 144 arguments in random order—a different random sequence for each participant.

The procedure in this experiment followed that of Experiments 1 and 2, but with one small addition: Participants saw a summary of the instructions for the main experiment repeated after the practice trials. The entire session took 50 min or less to complete. The 30 participants were from the same population as those of Experiments 1 and 2 but had not taken part in the earlier studies. Two participants were apparently unable to understand the instructions, and

TABLE 3

Number of rule	Argument	Argument		Mean response time	Error rate
types	number	form	Types of instantiation	(ms)	(%)
Constant-pr	remise				
One	1.	F(u, u', n, n')⊦ F(i, i', n, n')	Universal-indefinite	4833	3.3
	2.	F(u, u', n, n')⊦ F(u, u', i, i')	Particular-indefinite	5928	1.7
	3.	F(u, u', n, n')⊢ F(n", n"", n, n')	Universal-particular	5071	2.8
Two	4.	F(u, u', n, n')⊢ F(i, u', i', n')	Universal-indefinite Particular-indefinite	5318	6.7
	5.	F(u, u', n, n')⊢ F(n", u', i, n')	Universal-particular Particular-indefinite	6275	17.5
	6.	F(u, u', n, n')⊢ F(i, n", n, n')	Universal-indefinite Universal-particular	5395	5.5
Constant-co	onclusion				
One	7.	F(u, u', n, n')⊦ F(i, i', n, n')	Universal-indefinite	5083	2.7
	8.	F(n", n"", n, n')⊢ F(i, i', n, n')	Particular-indefinite	4605	9.4
	9.	F(i, i', u, u')⊢ F(i, i', n, n')	Universal-particular	5184	0.0
Two	10.	F(u, n", n, n')⊢ F(i, i', n, n')	Universal-indefinite Particular-indefinite	4875	7.8
	11.	F(n", i', u, n')⊢ F(i, i', n, n')	Particular-indefinite Universal-particular	5851	15.0
	12.	F(u, i', u', n')⊢ F(i, i', n, n')	Universal-indefinite Universal-particular	4944	6.7

Argument Forms, Mean Correct Response Time, and Error Rates, Experiment 3 (Unambiguous Arguments Only)

two additional participants from the same population replaced them.

Results and Discussion

Response times. Interest in this experiment centers on those versions of the arguments that are free of scope ambiguities. For all unambiguous items, mean correct response time was faster for arguments containing just one type of instantiation (5117 ms) than for arguments containing two (5442 ms), F(1,29) = 14.69, $SE_m = 61$ ms, p < .001. The relevant means for the individual arguments appear in Table 3. (Table 3 reports trimmed response times, following the procedure of Experiments 1 and 2.) The same result holds if we restrict the analysis

to just versions 1 and 2, which were unambiguous for each of the 12 arguments in Table 3. For these versions, mean times were 5105 ms for arguments involving one type of instantiation and 5299 for arguments involving two, $F(1,29) = 4.51, SE_m = 88 \text{ ms}, p < .05$. This finding strengthens the idea that the one-type versus two-type difference does not depend on a confounding with premise or conclusion ambiguity. We found in Experiment 1 that this difference remained if we discarded those argument forms in Table 1 that contain both a universal and an indefinite term in their premise or conclusion. The present findings show that the difference also remains for unambiguous versions of all 12 argument forms.

The results also align with those of Experiment 1 in showing that participants are faster in dealing with unambiguous than ambiguous sentences. Looking at those argument forms that had both unambiguous and ambiguous versions (arguments 2, 4, 5, 9, 11, and 12 in Table 3), we find mean times of 5653 ms for the former and 5949 ms for the latter. This difference is significant by a planned comparison, F(1,430) = 7.13, $SE_m = 234$ ms, p < .01.

A more fine-grained analysis of the unambiguous items also shows that participants were typically slower to confirm two-type arguments than those one-type arguments that depended on the same forms of instantiation. One exception to this trend occurred for two-type arguments 4 and 10 (each requiring universal-to-indefinite and particular-to-indefinite instantiation). Times for these arguments were approximately the same as those of one-type arguments 1 and 7 (universal-to-indefinite) and 2 and 8 (particularto-indefinite). Mean response time for arguments 4 and 10 was 5096 ms versus 5112 ms for arguments 1, 2, 7, and 8. The remaining comparisons, however, follow the more usual pattern.

Error rates. As in the previous experiments, error rates correlated positively with the response times. Considering all unambiguous arguments, we find fewer errors (3.3%) for the one-type than the two-type items (9.9%), F(1,29) = 20.66, $SE_m = 1.02\%$, p < .0001. Likewise, for versions 1 and 2 only, participants made fewer errors for one-type arguments (3.0%) than for two-type arguments (10.8%), F(1,29) = 16.52, $SE_m = 1.4\%$, p < .001. These differences for errors in Table 3 are, if anything, more clear-cut than those of the response times, so there is no hint that participants were sacrificing accuracy for speed.

GENERAL DISCUSSION

Natural language provides us with terms of different inherent generality: Universal terms, such as *everything*, apply to all individuals within a domain; particular terms, such as names and definite descriptions, denote individual instances; and indefinite terms, such as *something*, apply to unspecified individuals.

Deductive inference allows us to descend the same ladder of generality. For once we know that a property or relation is true of everyone, we can conclude that it is true of Margaret, and once we know it is true of Margaret, we can conclude it is true of someone. The experiments in this paper suggest that people carry out these inferences by means of separate cognitive operations. Separate operations imply that people should find it more difficult to judge the deductive correctness of an argument if that argument depends on two different types of instantiation (e.g., universal-to-particular and particular-toindefinite) than if it depends on two examples of the same type (e.g., two examples of universalto-particular instantiation). This is because it is harder to switch between different cognitive operations than to perform the same operation twice over. In fact, all three experiments in this paper support this prediction: Response times are longer and errors more numerous when an argument contains two types of instantiation than when it contains one repeated type.

Of course, the idea that different types of instantiation correspond to different cognitive processes does not imply that there are no relations among them. The findings here are consistent with the possibilities that the types of instantiation employ some of the same subcomponents, that they can be used jointly in more complex cognitive activities, and that they are subject to some of the same restrictions from higher order processes. Interrelations like these are what we would expect from operations that have the common purpose of dealing with generality and abstraction. What the results suggest, however, is that the operations are not identical, so that completing one and beginning another requires effort.

These experiments also rule out several alternative explanations of the difference between one-type and two-type arguments. By equating the frequency with which universal, particular, and indefinite terms appear in the premises and conclusions, Experiments 1–3 demonstrate that the difference between one-type and two-type arguments is not the result of special strategies based on the overall generality of the sentences. Nor can it be due to the total number of times each type of instantiation appears in the onetype versus two-type items. In the same vein, Experiment 2 varied the wording of repeated universal and indefinite terms in order to show that the one-type/two-type difference is not simply a matter of faster comprehension of repeated phrases. Experiment 3 modified the syntactic form of the premises and conclusions in a way that eliminated scope ambiguities. The difference between one-type and two-type arguments persisted in these unambiguous contexts. These findings increase the likelihood that switching between types of instantiation poses difficulties in reasoning, but of course they don't eliminate all conceivable alternative explanations. The remainder of the paper considers two additional possibilities, one based on the notion of inferential distance between the premise and conclusion and the other a modification of the generality idea.

Instantiation and Inferential Distance

The response times in these experiments suggest that some forms of instantiation are easier than others. The data from Tables 1–3 show that arguments 1 and 7, which embody universal-toindefinite instantiation, are faster on average than either arguments 2 and 8 (particular-toindefinite) or arguments 3 and 9 (universal-toparticular instantiation). The unweighted means across experiments are 5141 ms for the universal-to-indefinite arguments, 5860 ms for particular-to-indefinite arguments, and 5712 ms for universal-to-particular arguments. The same relationship-faster times for the universal-to-indefinite arguments-also holds within each of the three experiments. This inequality would presumably not obtain if participants had to instantiate a universal to a particular term and then the particular term to an indefinite each time they judged the universal-to-indefinite problems. The finding that inferencing is faster when the terms are at the extreme ends of the scale of generality accords with results from experiments on linearly ordered relations (e.g., larger than). In these studies, response times are usually faster and errors less frequent when participants judge which of two distant items is larger (e.g., a horse or a rabbit) than which of two close items is larger (e.g., a dog or a rabbit)—see Banks (1977) for a review of these findings.

Can a similar concept of "inferential distance" explain the remaining results of the present experiments? We have seen that overall generality of the premises and conclusions cannot account for the data, since the experiments equated this variable across argument forms. Still, it is possible to look at differences in generality in another way, by ordering the individual premises and conclusions in terms of which ones entail others. Figure 1 shows the entailment relations that hold among the arguments of Tables 1-3. Figure 1a depicts the premise of the constant-premise arguments at the top of the diagram with the conclusions of arguments 1-6 arrayed beneath it. The downward arrows represent the entailment relations among these sentences. Numbers at the nodes of the diagram correspond to the argument number of the corresponding conclusion in the tables. The notation for the premise and the conclusions is also the same as in the tables; however, the figure distinguishes narrow-scope and widescope readings of the ambiguous conclusions. Narrow-scope interpretations have subscripts on the indefinite terms (e.g., i_u) to indicate that these terms are within the scope of the universals in the subscript (e.g., i_u is within the scope of u). Wide-scope interpretations have no subscripts. Figure 1b shows in a similar manner the conclusion of the constant-conclusion arguments at the bottom and the premises of arguments 7-12 above it. Note that narrow-scope sentences are always beneath the corresponding wide-scope sentence, since the wide-scope reading entails the narrow-scope reading.⁴

If response time depends on inferential distance, then the mean time for an argument should decrease with the number of links be-

⁴ Figure 1 also shows that the premise of the constantpremise arguments entails both the wide- and narrow-scope interpretations of the conclusions and that the conclusion of the constant-conclusion arguments is entailed by both the wide- and narrow-scope readings of the premises. This justifies the earlier claim that scope ambiguities do not affect the validity of these arguments.



FIG. 1. Entailment relations among (a) constant-premise and (b) constant-conclusion sentences. Arrows indicate that sentence at the top entail the sentence at the bottom. In the formulas, i denotes indefinite terms, n particular terms, and u universals. Subscripted indefinites have scope narrower than the corresponding universals.

tween its premise and conclusion in Fig. 1. This relation gives rise to four independent predictions that we can check against the results of Experiments 1-3: (a) argument 4 should be faster than argument 5; (b) argument 1 should be faster than 6 should be faster than 3; (c) argument 7 should be faster than 10 should be faster than 8; and (d) argument 12 should be faster than 11. (Inspection of Fig. 1 shows that these inequalities do not depend on whether participants adopt the wide- or narrow-scope interpretation of the indefinite terms.) A comparison with Tables 1-3 shows that although predictions (a) and (d) hold in all three experiments, (b) holds in none, and (c) in only one

(Experiment 1). Notice that inequalities (a) and (d) are both comparisons within the set of twotype arguments, whereas (b) and (c) relate onetype and two-type items. In particular, (b) predicts faster times for argument 6 (a two-type argument) than 3 (a one-type argument), and (c) predicts faster times for 10 (a two-type argument) than 8 (a one-type argument). These predictions are the opposite of what we would expect on the view that arguments employing different types of instantiation should take longer than arguments employing just one. And contrary to the inferential-distance idea, these predictions fail in five of six instances in Tables 1–3. We can conclude that although inferential distance may play a role in the decision times, we need some further factor to explain the onetype/two-type difference that turns up in these experiments.

Generality, Revisited

By design, the total number of universal terms in the premise is independent of the onetype/two-type difference in these experiments. Nevertheless, it is clear that if both the instantiated terms of the premise are universal, then the argument must be deductively correct. The same is true if both the instantiated terms of the conclusion are indefinite. We considered a simple strategy based on these facts in discussing the results of the preliminary experiment, in which premises and conclusions each contained just two terms (see A Method for Studying Instantiation). In the present experiments, an analogous strategy would be more difficult, since it would require participants first to isolate the instantiated terms-perhaps by noting mismatching phrases in the premise and conclusion. Thus, participants would at least have to consider the corresponding terms of the argument, but they could then stop with a quick "valid" response if both instantiated terms of the premise or of the conclusion met the above requirements. (Participants would still have to engage in more elaborate processing if instantiated particular terms appeared in both the premise and conclusion.)

This strategy possess both advantages and disadvantages in accounting for the data of these experiments. On the positive side, a look at the arguments in Tables 1-3 shows that this strategy would produce the correct decision for all but arguments 5 and 11. The strategy therefore predicts that average time for these two arguments should be longer than that for the remaining items, and this relation holds in all three experiments (7004 vs. 6251 ms in Experiment 1, 6670 vs. 5699 ms in Experiment 2, and 6062 vs. 5123 ms in Experiment 3). On the negative side, the strategy is powerless in accounting for the differences among the remaining arguments. This includes the differences among the one-type arguments that we observed earlier under General Discussion, as well as the one-type/two-type difference involving arguments 6 and 12 and their component arguments (1, 3, 7, and 9) in Experiments 1 and 2. Notice that the relatively fast instantiation of universal to indefinite terms, which we discussed in the last subsection, can also explain why arguments 5 and 11 are slow. These are the only two-type arguments that do not depend on universal-to-indefinite instantiation (see Tables 1-3); thus, participants are forced to rely on slower processes in verifying them. This difference in instantiation speed is also consistent with the relatively fast response times for arguments 1 and 7; thus it appears to provide a better overall account than the generality-based strategy.

A related shortcutting strategy might rest on the fact that any stimulus argument whose premise contains no indefinite terms and whose conclusion contains no universal terms is always valid (see Table 1). The converse of this relationship is not true-arguments 2, 4, 5, 9, 11, and 12 all contain either an indefinite in the premise or a universal in the conclusion-so participants who use this decision rule would have to supplement it by some further processing for the latter arguments. Nevertheless, response times for the arguments to which this decision rule applies are consistently faster than those to which it doesn't (6039 vs. 6709 ms in Experiment 1, 5390 vs. 6332 ms in Experiment 2, and 4977 vs. 5583 ms in Experiment 3). Moreover, this strategy has the potential to explain some puzzling asymmetries in the data. For example, argument 9 is consistently the most difficult of the one-type constant-conclusion arguments; however, argument 3, which relies on exactly the same type of instantiation is never the most difficult one-type constantpremise argument (see Tables 1-3). The decision rule just described predicts this difference, since argument 3 meets the rule's provisions, whereas argument 9 does not. In general, because the rule depends on all the terms in the argument, uninstantiated as well as instantiated, the strategy can explain differences between the constant-premise arguments and the corresponding constant-conclusion items.

Participants in these experiments could not

have used this second strategy as their sole method, even for those arguments for which it yields a correct "valid" decision. For example, although arguments 1, 3, and 6 all meet the requirements of this decision rule for a fast "valid" response, argument 6 (a two-type argument requiring universal-to-indefinite and universal-to-particular instantiation) has response times significantly slower than the mean times for arguments 1 (universal-to-indefinite) and 3 (universal-to-particular). The difference ranges from 443 ms in Experiment 3 to 1278 ms in Experiment 1, F > 4.55, p < .05 in all experiments. It is possible, of course, that some participants were applying the strategy, whereas others were not (or that participants were applying the strategy on some trials but not others). Such a mixture of processes, however, should reduce the one-type versus two-type difference for those arguments to which the decision rule applies, and this is not the case for the data from these experiments. In addition, a cluster analysis of individual response profiles in Experiment 1 failed to reveal a group of participants who consistently applied this strategy. Specialpurpose strategies like the two we have just considered may well have played some role in these results, but the evidence for them is unclear.

Implications

These experiments support the notion that different types of instantiation require different cognitive mechanisms and that switching among these mechanisms takes time. If we measure switching time by the difference between two-type and one-type arguments, then the present results suggest a figure in the neighborhood of 0.5 s. As already noted, the evidence for different mechanisms does not necessarily mean that universal-to-particular, universal-toindefinite, and particular-to-indefinite instantiation are entirely independent processes. But the results do suggest that instantiation is not a homogeneous process that operates in the same way whenever we infer a more specific statement from a more general one.

The results are consistent with a theory (Rips, 1994, 1999) in which distinct rules govern the different forms of instantiation. The restrictions we noticed at the beginning of the article (see Three Kinds of Instantiation) suggest that these forms have different requirements, making it natural to formulate them as separate rules. The consistently faster response times for one-type than two-type arguments further reinforces the idea that separate mental rules oversee the three instantiation forms. It is possible, of course, that cognitive theories could handle instantiation and account for the present data without recourse to mental rules. At present, however, there are no alternative explanations for the kinds of inferences studied here.

The details of these instantiation processes are important, not only because of the part instantiation plays in reasoning, but also because of its more general role in symbol manipulation. Instantiation is what binds mental procedures to information in memory, and it is therefore responsible for all forms of retrieval in symbolic cognitive theories. The present results suggest by analogy that methods of retrieval might vary as a function of both the kind of information to be retrieved and the kind of process that retrieves it. It may prove useful, for example, to view retrieval of information about particular individuals as differing from retrieval of information about arbitrary ones: Remembering whether Calvin has climbed Mt. Formidable may differ from remember whether anyone has. Issues like these indicate potential benefits for taking inference as a base-level cognitive process rather than a specialized form of problem solving.

APPENDIX: SAMPLE ARGUMENTS FOR EXPERIMENT 1

Each of the 12 argument forms below appeared in Experiment 1 in four versions, generated by permuting the ordinal positions of the corresponding pairs of terms in the premise and conclusion (see *Method*, Experiment 1). In one version, for example, argument 1 might have appeared as *Jill reminded everyone to compare Cathy to everybody/Jill reminded someone to compare Cathy to somebody*. All examples are shown before permutation.

Number of rule types	Argument number	Argument form	Example
Constant-pr	emise arguments		
One	1.	F(u, u', n, n')⊦ F(i, i', n, n')	Everyone reminded everybody to compare Jill to Cathy Someone reminded somebody to compare Jill to Cathy
	2.	$F(u, u', n, n') \vdash F(u, u', i, i')$	Everyone reminded everybody to compare Beth to Ann Everyone reminded everybody to compare someone to somebody
	3.	F(u, u', n, n')⊢ F(n", n"', n, n')	Everyone reminded everybody to compare Martha to Jane Sarah reminded June to compare Martha to Jane
Two	4.	F(u, u', n, n')⊢ F(i, u', i', n')	Everyone reminded everybody to compare Lisa to Emily Someone reminded everybody to compare somebody to Emily
	5.	F(u, u', n, n')⊦ F(n", u', i, n')	Everyone reminded everybody to compare Hope to Fran Joan reminded everybody to compare someone to Fran
	6.	F(u, u', n, n')⊢ F(i, n", n, n')	Everyone reminded everybody to compare Miriam to Kristin Someone reminded Erin to compare Miriam to Kristin
Constant-co	onclusion argume	nts	
One	7.	F(u, u', n, n')⊦ F(i, i', n, n')	Everyone reminded everybody to compare Christie to Mary Someone reminded somebody to compare Christie to Mary
	8.	F(n", n"", n, n')⊢ F(i, i', n, n')	Jane reminded Ellen to compare Paula to Jean Someone reminded somebody to compare Paula to Jean
	9.	F(i, i', u, u')⊦ F(i, i', n, n')	Someone reminded somebody to compare everyone to everybody Someone reminded somebody to compare Betty to Marge
Two	10.	F(u, n", n, n')⊢ F(i, i', n, n')	Everyone reminded Trish to compare Julie to Nicole Someone reminded somebody to compare Julie to Nicole
	11.	$F(n'', i', u, n') \vdash$ F(i, i', n, n')	Rachel reminded somebody to compare everyone to Melissa Someone reminded somebody to compare Pam to Melissa
	12.	$F(u, i', u', n') \vdash F(i, i', n, n')$	Everyone reminded somebody to compare everybody to Susan Somebody reminded somebody to compare Rochel to Susan

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