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COMMUNICATION ABOUT VISUAL PATTERNS BY MEANS OF FUZZY CHARACTERIZATIONS. **

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INTRODUCTION.

Imagine the following situation: Two people, X and Y, look at an aquarium and get excited about the beautiful fish they see. They don't know their names but they want to point out particular fish individuals to one another. X asks Y, "do you see this medium-sized round fish which looks like a visiting professor?" "You mean the dark one?" "No, the one which is light blue."

Y is not able to identify this particular fish, but in many cases compact object characterizations of this kind are sufficient to enable another person to identify the reference object.

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<Fig. 1>

In this paper I will discuss some characteristics of descriptions of that sort. I will present a computer model for the interpretation of object descriptions which makes use of those characteristics.

CONTEXT SIMPLIFIES DESCRIPTIONS.

Observe that X does not specifically say that the fish he is referring to is in the aquarium which X and Y are looking at. But the context of the situation restricts the possibilities which Y is considering to the fishes in this particular aquarium. In the system which I will describe the communication between X and Y will be more efficient if the situation context restricts the set of possibly referenced objects more severely. This is, because X's object description does not have to convey so much information that it would be possible to distinguish the target object from all other objects in the universe, but only enough information to distinguish the object from the other objects in the given situation context.

This means that a smaller number of features or feature values would be sufficient for an object description in the restricted context, as compared to the unrestricted universe. In other words, only a comparatively small vocabulary would be required if we were willing to custom-tailor a vocabulary for each new context. How can we take advantage of the restricted context without giving up the idea of a general-purpose vocabulary?

CONTEXT-ADAPTIVE VOCABULARY.

Let us assume in the beginning that X and Y share a fixed vocabulary, i.e., they both use the same terms and the terms have the same meaning to both of them.

<Fig. 2>

Let the terms describe features that both, X and Y can perceive visually, for example color, height, length, shape, location, etc. If the meaning of the vocabulary was able to adapt to various contexts, the size of the required vocabulary would depend on the complexity of the context rather than on the complexity of the universe. This adaptation should follow general rules, such that X and Y do not have to agree explicitely in every new situation about how to adapt a given term to the particular context.

Consider, for example, the notion of 'tallness'. This concept is context-adaptive in two ways:

<Fig. 3>

First, 'tallness' describes drastically different scales of values, depending on the types of objects it refers to, for example the height of a cup, the height of a person, or the height of a building. I will call this type of adaptation 'global adaptation'.

Second, for any given type of object, a value on the tallness scale may refer to different height, depending on the height of other objects of the same type in the given context. This 'local adaptation' corresponds to the fuzziness of a concept.

REPRESENTATION OF ADAPTIVE CONCEPTS.

To model these two types of adaptation, I will introduce the concept of a fuzzy possibility distribution as developed by Zadeh*. The concept of 'tallness' can be represented by the possibility distribution shown on the figure.

<Fig. 4>

The curve indicates a degree of possibility π to which some object can be considered 'tall' given that it is perceived to have a certain height. It shows by how much a concept must be 'stretched' to apply to a particular situation. Global adaptation of 'tall' to some context corresponds to a

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* L.A. Zadeh, Fuzzy sets as a basis for a theory of possibility, Fuzzy Sets and Systems 1, 3-28, 1978.

change of scale on the abscissa.

Local adaptation corresponds to searching for an object whose height indicates a relatively high possibility for being referred to by 'tall'. A fuzzy tallness value imposes an elastic constraint on the height of an object. If there is no object with prototypical height for the given tallness value, this fuzzy value is taken to refer to a less typical value in the corresponding domain. The limits for this elasticity are given by the possibility distribution. For example, if X describes a person as 'tall', but in the given situation context Y cannot find a person to which the predicate 'tall' applies very well, Y will look for a person to whom the predicate 'tall' applies more or less.

CONCEPTUAL DECOUPLING.

Besides the ability for global and local adaptation, there is another advantage to using fuzzy concepts: if we view a fuzzy concept as a concept with elastic constraints we do not have to insist any longer that the communication partners X and Y agree completely on the definition of their concepts. This, of course, is very useful if communication between two partners is to occur only occasionally in the same context, because they do not have to determine a common interpretation for their terms first. They still will be able to understand one another as long as the meaning of the feature descriptors for both communication partners is close enough to have high compatibility with the target object compared to other objects in the context domain. In particular, there should be no "gap" between two features denoted by the same term in the sense that a feature value which can be considered in between two typical values for the two communication partners should comfortably be labeled by the same term by both partners.

In effect, this means that fuzzy terms describing values along the same feature dimension should have the same ordering along this dimension for both communication partners. For example, some values along the 'tallness' dimension could be ordered in the following way:

<Fig. 5>

not tall < more or less tall < tall < very tall.

TRANSMISSION OF FUZZY CONCEPTS.

I will now explain how fuzzy concepts are represented and communicated in my object identification system: the input to the system is a PRUF representation* which conveys the intended meaning of the corresponding natural-language object description.

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* L.A. Zadeh, PRUF - a meaning representation language for natural languages. Int. J. Man-Machine Studies (1978) 10, 395-460.

For example, the PRUF representation of the English object description

"The red fish which is quite small"

is:

<Fig. 6>

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(OBJECT (category = FISH)
        (π (color) = RED)
        (π (size) = QUITE SMALL)
        (determiner = definite))
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Ramón López de Mántaras demonstrated in this symposium* how meaning that is relevant for the object identification task can be translated from the English description into PRUF. In this PRUF description, the descriptor "(category = FISH)" is represented as a crisp, i.e. non-fuzzy, descriptor and "(π (color) = RED)" as a fuzzy descriptor. The meaning of the latter descriptor is characterized by a possibility distribution over perceived colors of fish. The possibility value for a particular color corresponds to the degree of compatibility of this color with the concept "red color". Only relative compatibility values are relevant here. I should note that these compatibility values are subjective

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* R. López de Mántaras, Translation of natural language descriptions of simple objects into PRUF, XXIInd Intern. Congr. of Psych., Leipzig, 1980.

measures which will vary from person to person.

The size descriptor in the PRUF expression contains the linguistic modifier 'quite' which modifies the possibility distribution associated with the fuzzy linguistic value 'small'.

The determiner 'definite' in the PRUF description indicates that the issuer of the object description implies that it refers to a particular object rather than to any of a set of objects.

INTERPRETATION OF DESCRIPTIONS.

How are these fuzzy descriptions interpreted? The context data base is searched first for objects whose features correspond to the highest possibility values associated with the description. The possibility distributions which are relevant here are the ones which the interpreter associates with the descriptors rather than the distributions of the describer. If no perfect match between description and object is found, objects with lower compatibility between the interpreter's meaning of the description and the actual features are searched for.

<Fig. 7>

This figure depicts two differing possibility distributions associated with the description "red fish which is quite small" for the two communication partners. Y is able to identify the target object as long as it has some compatibility with the description for the interpreter and there is no other object in the context which has a higher degree of compatibility.

To successfully distinguish the referenced object from other objects to which the characterization may apply, the description must contain at least one feature which does not apply comparably well to other candidate objects, according to the possibility distribution of the interpreter.

Thus, it easily can be seen that the precision required for an object description depends directly on the presence of similar objects in the context, and X and Y can determine independently, how much precision is required to avoid ambiguity. Furthermore, our definition of fuzzy feature values makes it unnecessary for X to tell Y the level of precision of the description. In fact, each descriptor in a description may have different precision in a given context.

FUZZY REFERENCE CONTEXT.

Up to this point we have assumed that X and Y refer to exactly the same context. This assumption may be acceptable if they communicate about objects that are within well-defined boundaries, for example in an aquarium. But if we want to admit that they communicate about what they see when they go diving at the sea, this requirement is too strong. As little as we want X and Y to have to agree on the precise meaning of their vocabulary we want them to have to agree on the precise context.

Context plays a two-fold role in this system: first, it corresponds to the set of objects which contains the object of communication; second, it serves to determine the scale by which features are measured. For example, the tallness scale for houses is normalized by the height of a small house and the height of a tall house in the given context. If X and Y now consider slightly different, but largely overlapping contexts, several things can happen:

<Fig. 8>

First, the features of the objects which belong to only one of the partner's context can be in the same range as in the common context; then the feature scales are not affected.

Second, some features may be slightly outside that range; this has the same effect as if X and Y associate slightly different possibility distributions with their feature labels.

Third, some features may be off drastically; then we can expect a communication problem. But there is a good chance that Y will detect this fact, because he may not find any object to which the description fits.

In case there is a relatively strong disagreement between some concepts or between the reference contexts of the issuer and the interpreter of a description, successful communication can be enhanced at the expense of a more elaborate description. Redundant descriptions help offset both, disagreement in use of vocabulary and uncertainty with respect to reference context.

COMPUTER IMPLEMENTATION.

The communication model I have described is being implemented in the AI-language L-FUZZY*, a dialect of the LISP-based language FUZZY. L-FUZZY can directly represent fuzzy sets with linguistic modifiers. Fuzzy sets are interpreted as possibility distributions and the linguistic modifiers are represented by procedures which modify these distributions.

CONCLUSION.

Let me conclude by summarizing features of my system:

1. the context of a situation allows a description to be relatively simple;

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* C. Freksa, L-FUZZY - an AI language with linguistic modification of patterns, ERL Memo M80/10, Berkeley, 1980.

2. only a small vocabulary is required to communicate in a multitude of situations taken from a large universe, because the same term may correspond to many different instances, if it is adaptive;

3. linguistic modifiers serve to augment the vocabulary;

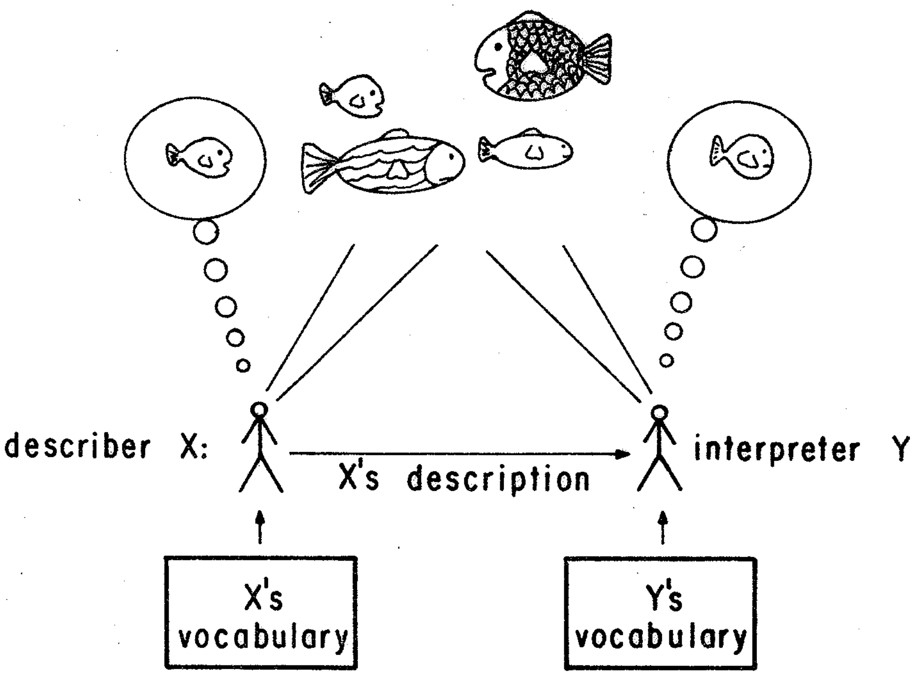
4. fuzziness is exploited to avoid the necessity for precise agreement on the language, to have context-adaptable degree of precision, and to be flexible with respect to the reference context;

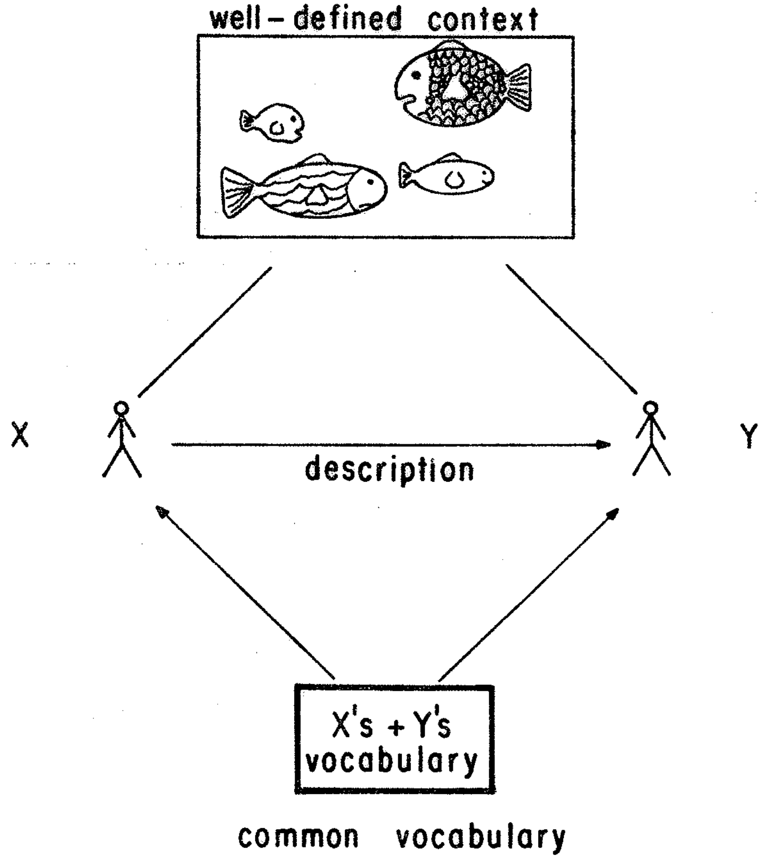
5. the message that is transmitted from the describer to the interpreter is a "skeleton" that is filled with meaning by the context and by the interpreter;

6. all these features taken together make it possible that descriptions of complex situations may be rather compact.

ACKNOWLEDGEMENT.

I wish to acknowledge exciting discussions with Susana Berestovoy, Klaus Haagen, Steve Palmer and Lotfi Zadeh and I like to thank them for helpful criticisms on previous drafts of this paper.


describer X:
X's description
interpreter Y
X's vocabulary
Y's vocabulary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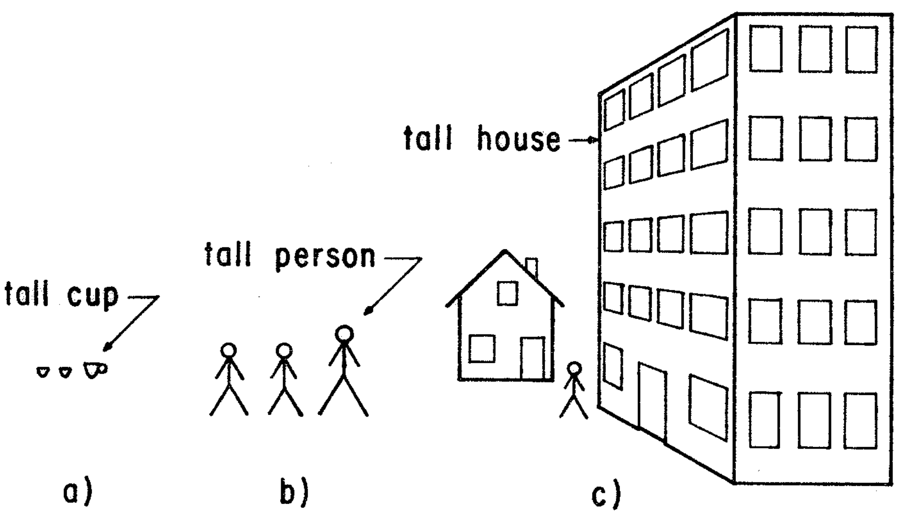
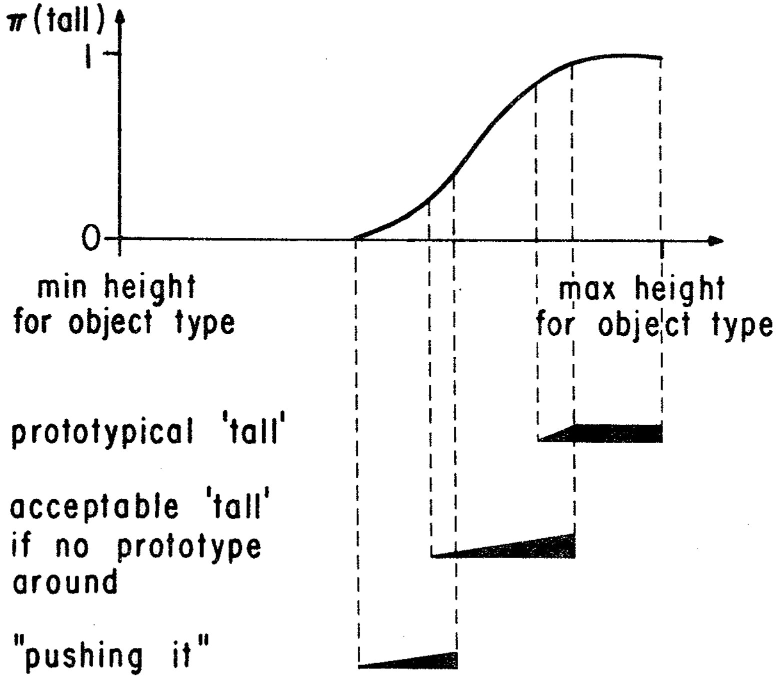
X
description
Y
X's + Y's vocabulary
common vocabulary

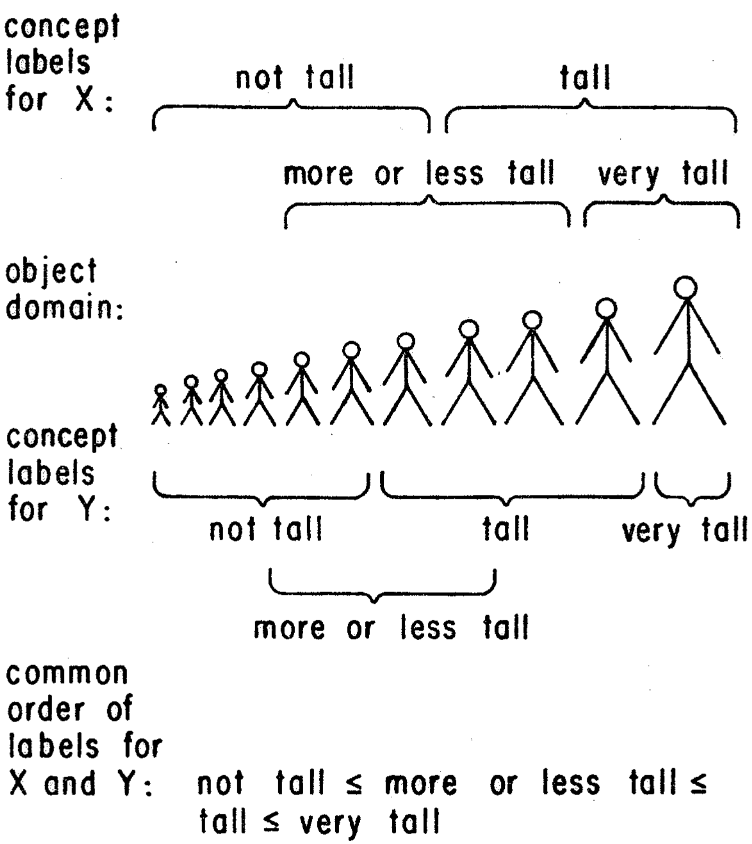


Context adaptability of the fuzzy concept 'tall'

Compatibility of 'tall' with height (object)



interpretation of the compatibility function



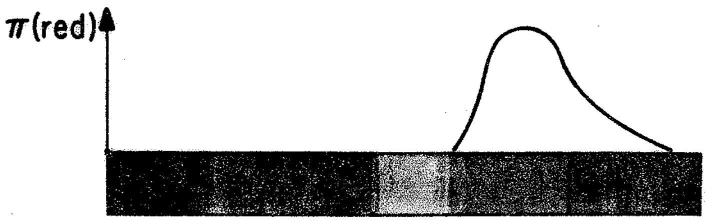
English description:

"The red fish which is quite small"

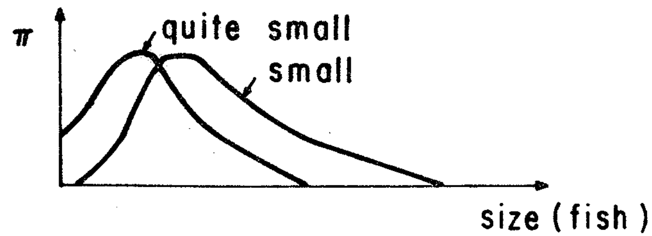
PRUF translation:

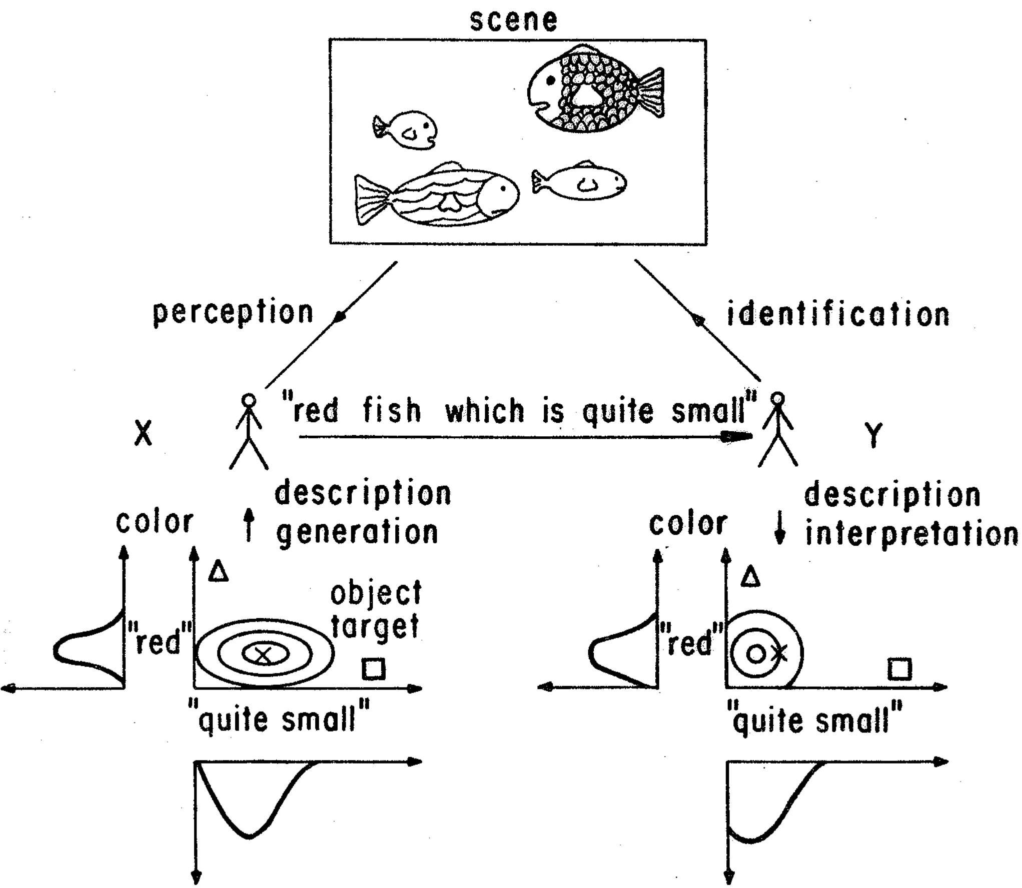
(OBJECT (catagory = FISH)
(π (color) = RED)
(π (size) = QUITE SMALL)
(determiner = definite))

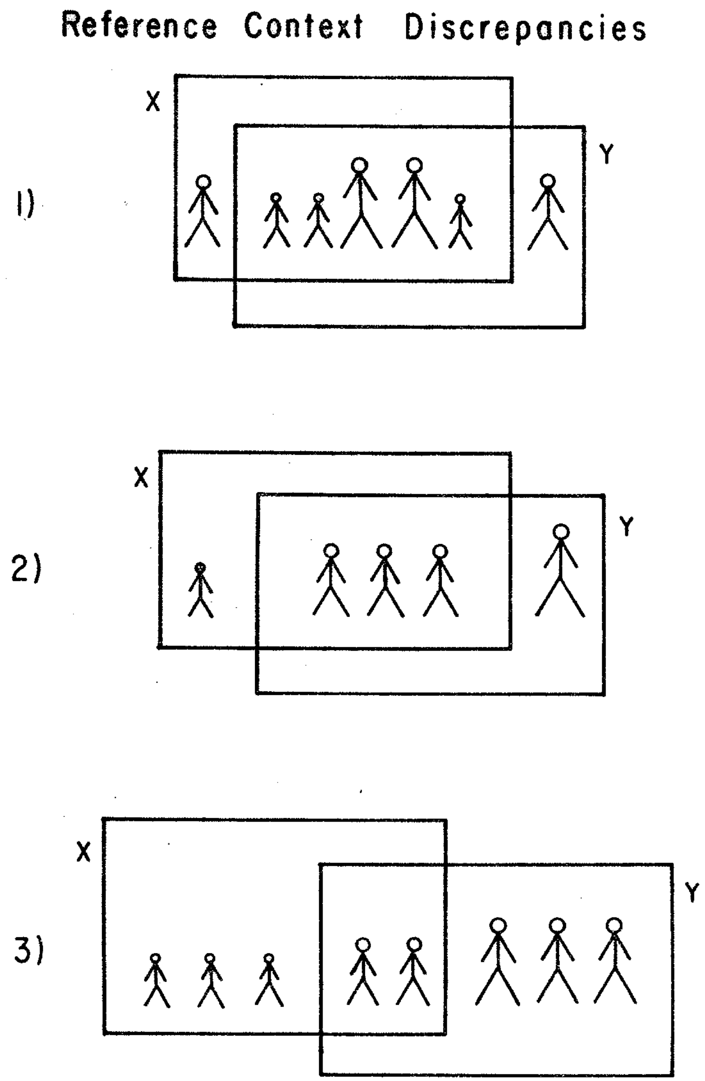
subjective possibility distribution for "red":



effect of the linguistic modifier "quite" on the possibility distribution for "small":




scene
perception
identification
X
"red fish which is quite small"
Y
description generation
description interpretation
color
"red"
object target
"quite small"
color
"red"
"quite small"


Reference Context Discrepancies
1)
2)
3)
X
Y