

STRUCTURE AND USE OF VERBS OF MOTION

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I Introduction

This article outlines in a summary fashion aims, present status, and further plans of a research programme¹ on the structure and use of motion verbs.

One of the ultimate aims of a semantic theory is the specification and explanation of the relations between semantic representations and cognitive structures. In linguistic theory semantic representations are formal characterizations of the information conveyed by sentences. But linguistic theory is not self-contained: a theory of what we understand should be part and parcel of a theory of how we understand.

Verbs of motion form an attractive domain for the study of such relations between structure and use. Situations in which verbs of motion are used have been widely studied in the psychology of perception (Michotte, 1946, Heider, 1944, Johansson, 1973). Especially Michotte's work is highly relevant for our semantic purpose. Coming from a neo-Kantian tradition Michotte proposed that our innate notions of space and time, such as substance, permanence, causality have their genetic origin in the innate structure of perception. Study of the perception of motion and locomotion could therefore lead to the roots of these concepts. Michotte's experimental method consisted of systematically varying the visual motion patterns, and analysing the subjects' description thereof. These analyses centered around the

use of certain verbs or classes of verbs, a major instance being the class of causal verbs. In spite of the fact that Michotte was fully conscious of his experimental dependence upon the verbal reactions of his subjects (Michotte, 1962), he never undertook a truly linguistic analysis of his subjects' verbs of motion. That part of his work remained intuitive.

Such analyses, however, are available in the linguistic literature. Though there are several older sources (e.g. Collitz, 1931), it seems to have been Gruber's (1965) work which has reopened the interest in the structure of verbs of motion. Like Michotte, Gruber was not interested in motion per se, but in more general notions which resemble, and are probably derived from, concrete concepts of physical motion. A recent extension of Gruber's work is to be found in Jackendoff (1976). Other important linguistic analyses are Miller's (1972), and Schank's (1972).

It is not surprising to find that Michotte's perceptual categories, such as causality, direction, velocity, return as semantic components in linguistic analyses, in spite of the fact that these latter are not based on perceptual arguments. Our research programme is an effort to bridge the gap: it is on the one hand concerned with a more systematic analysis of linguistic intuitions about verbs of motion, whereas, on the other hand, it tries to link these intuitions to the actual use of such verbs in perceptual situations, as well as situations in which inference is required. Again, it is hoped that some of the main results of this study apply more widely than to the field of verbs of motion alone.

II Linguistic intuitions

II.1 A coincidental classification of verbs of motion

If one is interested in the use of motion verbs, one would like to know the conditions under which such verbs can be used. The semantic representation of a particular verb should in some way or another express the information which, if present in the interpretation domain of the use, makes the verb, or better the sentence containing it, a true statement. This interpretation domain can be a perceptual situation, but also a conceptual structure which is less directly related to the real world.

Gruber (1965) has proposed that some of the essential information expressed by verbs of motion is about the moving theme, the source it comes from and the goal it goes to. For a subset of these verbs there is further information about the agent which causes or permits the theme to move. Verkuyl (1976) elaborates these notions in much more detail. Here we will limit ourselves to making a gross classification of motion verbs, which will be mainly based on relations of co-reference between the just-mentioned entities figuring in Gruber's system of thematic relations. But before we go into this, it should be noticed that not all verbs of motion involve the change of location which is expressed in Gruber's schema.

Verbs like tremble, shrink, mix do not have Miller's (1972) travel-component, or Schank's (1973) PTRANS, but it would be counter-intuitive to exclude them as verbs of motion. Therefore the following preliminary distinction is made:

(i) Transposition vs. non-transposition verbs

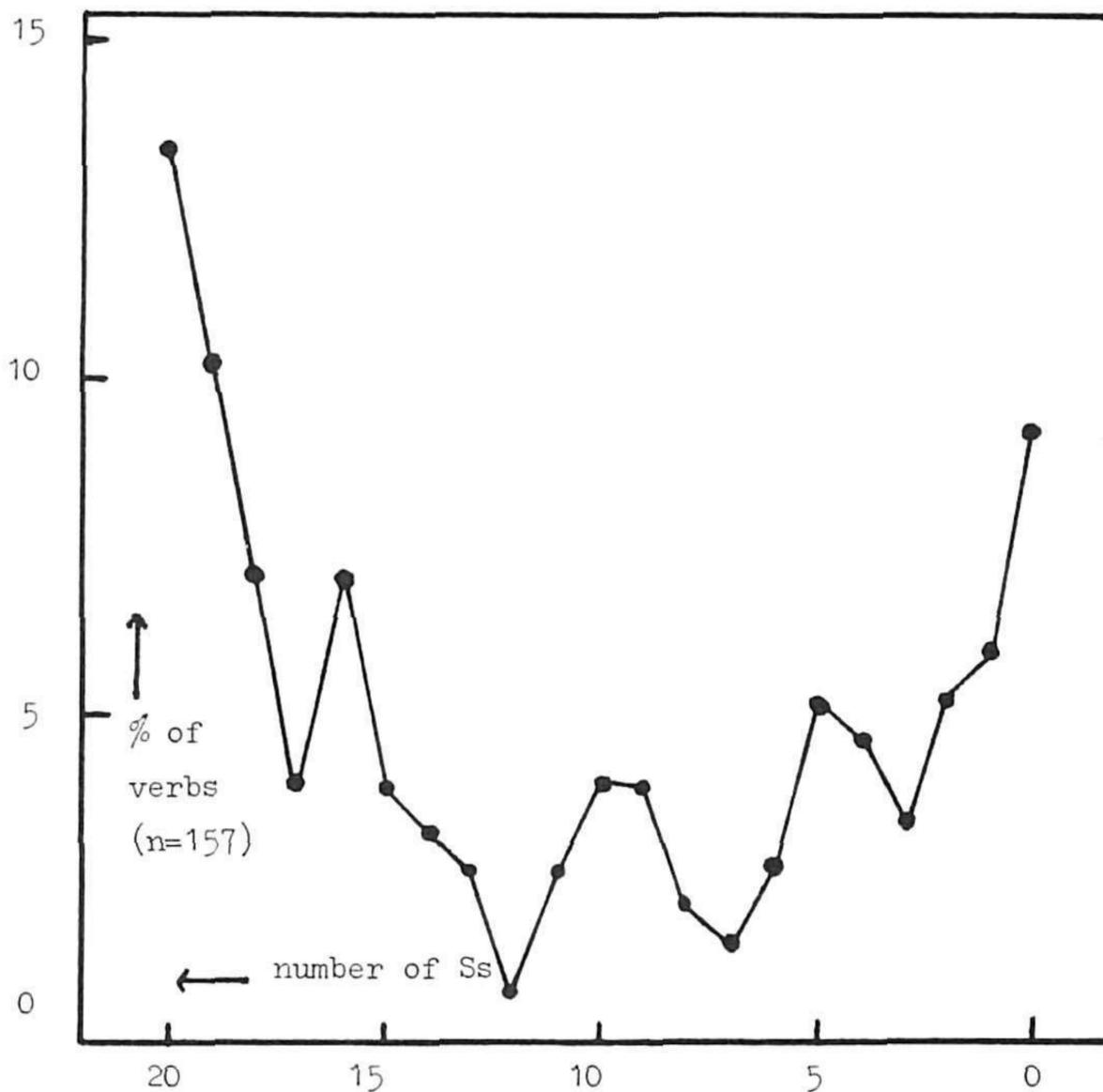
Non-transposition verbs express that the theme is in motion at a certain fixed location. This is, of course, not a mathematical point, but a region which is conceptually not further partitioned. This latter criterion is sufficiently vague to allow for some doubtful cases. An instance is the airplane circles over the town, where one might consider such a region as unpartitioned, making circle a non-transposition verb, or a differentiated area marked by towers, high buildings, or clouds. If under this latter conceptualization the verb could still be used, circle would (also) be a transposition verb.

We decided to devise a linguistic test to determine whether a verb is a transposition verb. Since transposition verbs involve the change of one location to another, it should be possible to conceive of a third location where the theme can be in the mean time. The test can, therefore, be the following simple completion task: "They verbed (X) via ...", where the subject has to invent a location at the place of the dots. There is an optional X for transitive verbs.

This so-called via-test was applied in an experiment, where twenty subjects were asked to find completions for 157 Dutch verbs of motion. They were told that this would not always be possible, but they were invited to try.

Figure 1 summarizes the results. For most verbs (nearly) all, or (nearly) none of the subjects were able to find an appropriate completion. That is, the test rather neatly dichotomizes the set of verbs into a transposition and a non-transposition class. Some typical examples of both classes are given in the figure. It should be noted that these are translations from Dutch, and it is more the rule than the exception that no straight one-to-one translation is possible.

TEST OF TRANSPOSITION (PTRANS) :



+PTRANS:
 approach, bring, climb,
 creep, escape, fly, go,
 lead, proceed, push, reach,
 roll, row, run, rush, sail,
 shuffle, travel, trudge,
 walk.

-PTRANS:
 brake, kneel, separate,
 shiver, shudder, shock,
 shrink, split, stoop,
 stretch, swell, tremble,
 wrap, yawn.

Figure 1 : Percentage of verbs judged as transposition verbs as a function of number of subjects.

(ii) Agentive vs. non-agentive verbs

Transposition verbs can be agentive or not. In John threw the ball, John is the agent causing the theme's (ball)motion. In the ball fell in the water there is no such agent. In most linguistic studies two forms of agentive action are distinguished. One is always called causation, the other is denoted by permission, allowance, or the like. In John threw the ball, John is taken to be a causative agent: John by some action generates the motion of the ball. In John released the bird, however, John stops preventing the bird's own motion. Release is a permissive verb, like drop. Jackendoff (1976) introduces a function LET in the semantic representation of permissive verbs. (In Dutch drop has to be translated by laten vallen, i.e. let fall).

At this point it should be noticed that Michotte (1947), on convincing experimental grounds, makes a distinction between moving objects which are perceived as "being displaced", and objects which seem to have "proper motion". Only the first perceptual structure allows for a causative agent, i.e. for perceived causality. Michotte's classical case is entraining (i.e. pushing), where object A moves towards a stationary object B; at reaching it A continues moving, "pushing" B along. Here B is not seen to have proper motion: it is simply displaced, participating in A's pre-existing motion. Here, according to Michotte, there is genuine perception of causality. But if an object has "proper motion" all the time, i.e. does not participate in another object's motion at any time, causality is not perceived. A case is the perception of braking (Levelt, 1962) where a speedy moving object gets "stuck" in a certain differently coloured region of the field. Here subjects do report braking of the object by the coloured area, but Michotte (1963) gives arguments to suppose that in these and similar cases like releasing, and triggering, there is only immediate perception of dependence, not of causality. If subjects use causal verbs in these cases it can be the language itself which is to blame: "We should bear in mind that ordinary language totally lacks precision in this point, and that in ordinary discourse we continually confuse cause and condition." (p. 367). Whatever the truth in this statement, Michotte's distinction between perceptual causation and mere perceptual dependence seems to parallel the linguistic distinction between causative and permissive agents.

Only agentive verbs allow for instruments. It is the

agent which uses an instrument in bringing about the theme's motion. Non-agentive verbs like fall will never carry an instrument in their semantic representations. It is less clear whether both causative and permissive verbs allow for instruments. Jackendoff (1976) gives an apparently positive example for the permissive verb release: David released the bird from the cage with a coat hanger. However, Jackendoff gives arguments for the supposition that the coat hanger is not an instrument for releasing, but for an unexpressed causative action, namely opening the cage. This causative action is the means (not the instrument) by which the bird is released.

We now turn to a further classification of agentive verbs of motion. If source and goal are different locations, and if the theme is going from the one to the other, it is excluded that any two of theme, source and goal can coincide. However, there is no a priori reason why agent could not coincide with theme, with source, or with goal. Of course, there is the final possibility that none of these coincidences hold. Together, these four possibilities make a fourfold subclassification of agentive verbs:

(iii) Agent \equiv theme verbs.³

A major subclass here is formed by the intransitive verbs of locomotion such as run, walk, skate, swim, etc.

There are also transitive verbs in this class, but the agent/theme will never be in the direct object position. Examples are leave, enter, and pass. For these examples at least, it should be obvious that the agent is optional. In the ball passed my head, there is no agent. This cannot happen with verbs of auto-locomotion. In order to prevent confusion in a later section (III.1) we must make a further remark on pass. If pass is used in the agent \equiv theme sense, it is certainly causative. Michotte, however, would never call pass a causative verb. The good reason is that there is no causal relation between the activity of the agent and the motion of the object being passed. It is in this sense that we will use pass as a non-causative verb in III.1. Finally, it is our impression that all verbs in the present class are causative, and allow for genuine instruments. The subclass apparently excludes permissive verbs.

(iv) Agent \equiv source verbs

Here the moving theme displaces away from the agent.

Examples are throw, fling, kick, drop. This subclass contains both causative and permissive verbs.

(v) Agent \equiv target verbs

For these verbs the theme should move in the direction of the agent. It is hard to find examples in this subclass; Attract is one, fetch may be another. Causing motions "from a distance" so to say seems to be conceptually hard, as will also appear in the next subclass. Agent \equiv target verbs are more natural in the related semantic field of ingest-verbs, analyzed by Schank (1973); examples are swallow, drink, etc.

(vi) Non-coincidental verbs (Agent - external verbs)

Agent is different from theme, source and goal in this subclass. Push, transport, drive (transitive), carry are examples. It seems to be the case that for most or even all of these verbs the agent moves with the theme. Again, it seems hard to imagine causation of motion from a distance. Maybe this will change in our era of space travel.

As a summary of this section, Figure 2 depicts classification of verbs of motion in a schematic fashion.

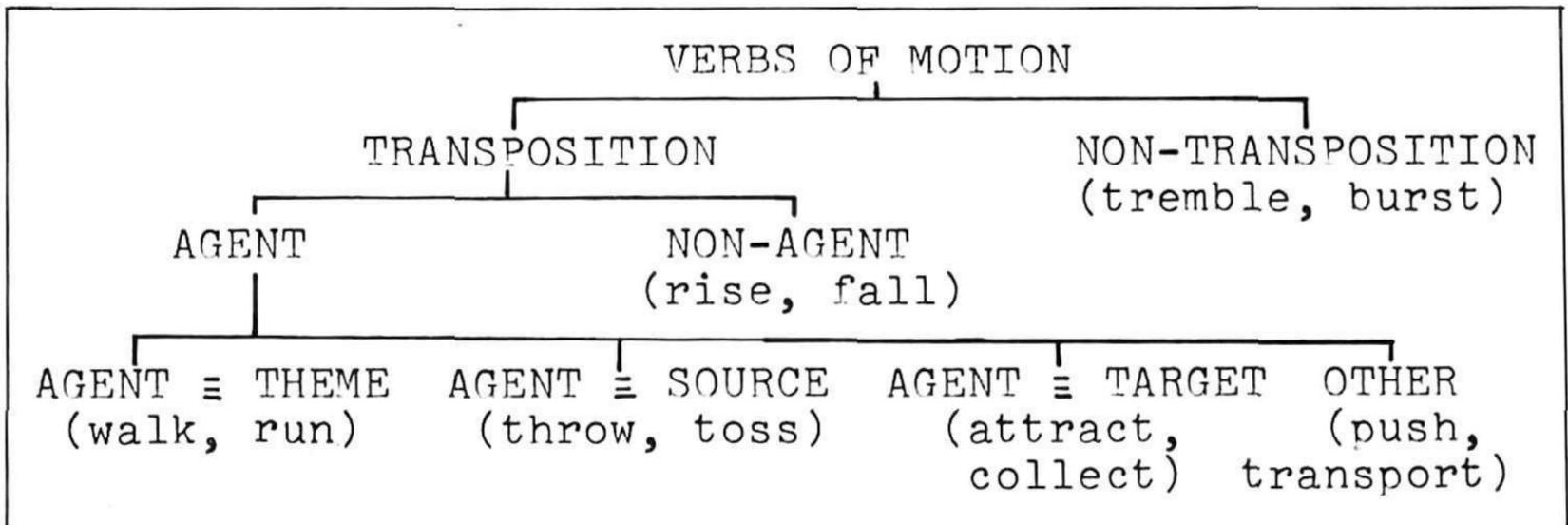


Figure 2 : Classification of verbs of motion in terms of thematic relations.

The classificatory properties of motion verbs will appear to be important for the way in which subjects use these verbs in inference tasks, as will be discussed in Section III.3.

II.2 Specificity of verbs and the principle of minimal negation

The schema in Figure 2 is an admittedly very rough classification. Much more subtle distinctions can be

made among verbs of motion. Take, for example, the subclass of agent \equiv theme verbs, and compare run, hop, and skate. It seems that each of these verbs over and above its general meaning of autolocomotion, has a further much more specific meaning component: run is used for indicating speed, hop for a particular use of the legs, and skate for a particular instrument. Moreover, this specific, or salient component is probably the one thing which is in the language user's centre of attention when he or she is using the verb. One does not say the children are skating if the information to be conveyed is only that the children are in locomotion. The sentence is used where locomotion is background information and where the new information is the particular instrument of motion.

Linguists use different means for representing such components. Jackendoff (1976) uses "restrictive modification", i.e. the simple addition of a marker to the semantic representation. Others would prefer to add such components in the form of higher order predicates. We are not in a position to judge the merits of these different formalisms. Here we only want to argue that these representations should allow for the expression of what we will call "hierarchies of saliency", a notion which will be worked out in some detail here.

Verbs, also verbs of motion, vary in complexity. Compare move and rise. Rise has all components of move, but in addition marks upward directionality. Rise, therefore is more complex than move. This additional component, moreover, seems to be the salient one, which is in the language user's centre of attention when he or she uses or understands the verb. If one moves from simple very generic verbs such as move and travel (in one of its readings) to very complex verbs like bounce or decelerate, more and more components are involved, and the obvious question then is: which of these components is the specific one for this verb, or better: is there a hierarchy of saliency among the meaning components, one being more "typical" for the verb than another? A partial answer to this question seems to be the following: In some cases one meaning component entails another: braking has a component of deceleration, which implies a component of velocity, which in its turn implies some form of motion. Such a chain of redundancy can probably be interpreted as a hierarchy of saliency: the more specific components are probably more available to the language user than the implied less specific components (see for a similar argument especially Miller,

1969). However, this is very partial answer indeed. In many cases components do not have implication relations at all. Compare swim: on the one hand the verb expresses that locomotion takes place in the water, on the other hand it conveys that the locomotion takes place by means of body parts as instrument. There is no redundancy between these two pieces of information, but one could still ask which one is the more salient meaning component for the language user. There is an empirical way to go about this question. It is based on what Noordman and Levelt have called the "principle of minimal negation" (see Noordman's paper at this conference) which has been independently called the "principle of minimal change" by Seuren (1976). The basic idea, however, is certainly older, and can for instance be found in Miller (1969).

Seuren shows that, normally, when a listener is given a negative statement he will only make minimal changes in the knowledge structure which is relevant for understanding the sentence (its "interpretation domain"). The listener who is in an appropriate context confronted with John didn't give the book to his brother, will probably infer that actually no transfer took place, or, alternatively - and very much dependent on prosodic features of the utterance - that it was not his brother to whom it was transferred. Whatever the negated element, the important observation is that it is a single one: The listener will not at the same time infer that it was in fact neither John nor the book that were involved, or similarly for other combinations of elements.

Noordman and Levelt's experiments show that also for lexical negation there is a principle of minimal change. The experiments, involving the negation of kinship terms, clearly show that subjects change one meaning component at a time.

In inference tasks where they may correctly conclude from not father to either uncle, mother or aunt, they never give aunt as a response. Aunt differs in two components from father: sex and parenthood, whereas uncle and mother involve only a one-component change. Similarly, uncle is evaded as a response in inferences from not mother; here father and aunt are the preferred responses.

How can this principle of minimal negation be used for determining relative saliency of meaning components?

The answer is based on the assumption that it is the most salient component which is the probable candidate for change under negation. We have described a salient component as a component which is typical, specific, highly available; it easily gets into the foreground of attention. The assumption adds that it is this foreground component which is most likely the one to be affected by negation.

Applying this to the kinship terms, Noordman and Levelt have found that for father parenthood is far more salient than sex (most subjects gave uncle rather than mother as a response in the above mentioned inference task). For mother, however, sex and parenthood are about equally salient (father and aunt are about equally frequent responses).

The empirical procedure, then, which we propose for determining the most salient meaning component of a motion verb is to negate the verb and to register the subject's interpretation. More specifically, we presented subjects with the incomplete sentence "They do not verb (X), but they ..." and they were requested to find an appropriate completion. (X stands for an optional direct object.)

Take again ski as an example. Presented with They do not ski, but they ..., most subjects reacted with skate, indicating that the most salient component is the instrument 'ski', which is changed into instrument 'skate(s)'.

We have applied this procedure to our 157 verbs of motion. Twenty subjects did the completion test for each of these verbs. For each of the verbs the twenty completions were categorized in (near-)synonymous groups. The complete results will be reported elsewhere, here we will limit to a few observations: Figure 3 gives the frequency distribution of the largest group size. For instance, for travel 9 subjects complete with stay home, all other reactions, like wander are produced by smaller numbers of subjects. The largest group for travel, therefore, has size 9. This same size 9 is reached by 17 verbs in the sample, which can be read from the figure. It appears from the figure that the median major group size is 7. For the median verb one third of the subjects give the same reactions under negation. The completions, therefore, are far from random, and in fact fairly systematic. A typical median verb is wenden (to turn, especially a

car, a ship, etc.). The 7 completions are to go (or) drive on straight. It is the directionality component which is affected by negation here: change of direction seems to be the salient component of turn. There are verbs at both sides of the median. At the right side are the verbs which we will call specific: their most salient meaning component is much more salient than any of the others.

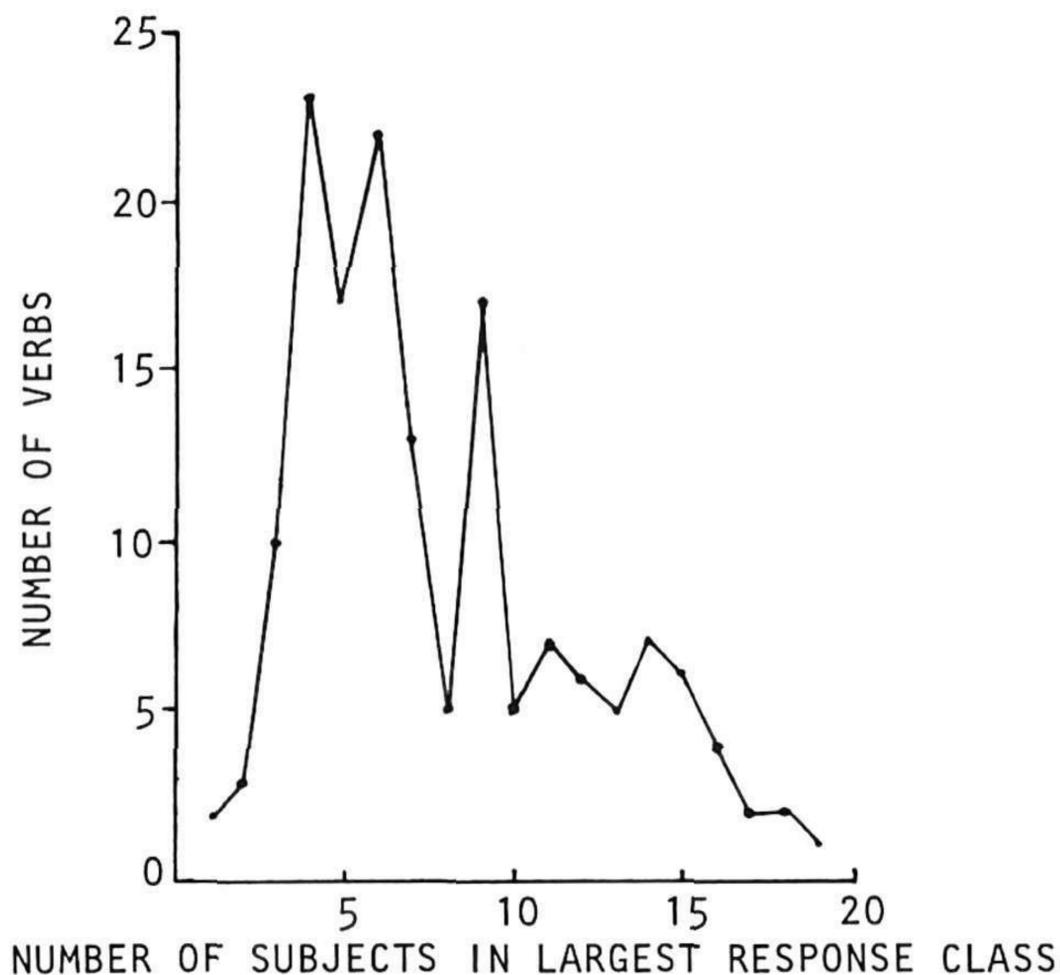


Figure 3 : Frequency distribution of largest response class in negation test.

Examples are ascend (19 completions descend), come (18 go), open (18 close), arrive (16 depart), seesaw (16 swing), as well as all the inverses of these. In many of these cases the salient component is directional in some way or another, but also instrument is often involved (like in seesaw), or size (swell - shrink). At the other side of the median there are the less specific verbs: two or more of their components are close in saliency. Examples are swim (6 dive, 4 row), throw (5 catch, 3 fling), follow (6 lead, 5 stay).

It should be added, however, that there may also be specific verbs at this side of the median. If the

salient feature is an instrument or means, like in pour, the subject may replace it by a variety of other instrument or means. For pour we find sprinkle (6), spirt (3), spray (3). Pour, therefore is a rather specific verb. However, in order to make this inference, one must have explicit ideas about the component involved. In other words, one cannot at the same time use the negation test as a discovery procedure, and as a means for determining the saliency of components, except where subjects give equal or about equal reactions. A similar problem arises when we ask the question whether the principle of minimal negation works in this test. The decision whether one or more components are changed under negation depends on the definition of components. However, at scanning the most frequent type of completion for the different verbs, we have not found a single case where, on intuitive grounds, that completion differed in more than one component from the original verb meaning. Less frequent reaction types do show multiple feature changes in certain cases. An example is drive, where we find walk (6) as first reaction type. This is a change of instrument. The second reaction type is sail (5), also involving change of instrument, but moreover a change of medium.

Turning back to semantic representations which allow for treatment of hierarchies of saliency, it should be noticed that none of the existing linguistic systems are very natural in this respect. In Jackendoff's way of representation one could, of course, give special marking to the modifier(s) or function(s) which is (are) salient, but that is a trivial solution. Also a solution in terms of predicate hierarchies seems to be somewhat forced since, mostly, components do not have implication relations which are strong enough to determine the predicate hierarchy. We would welcome representations where the thematic structure of the verbs integrates naturally with its more specific semantic aspects.

III Use of motion verbs

In this section two uses of motion verbs will be discussed. The first is the use in perceptual verification tasks, i.e. in tasks where the subject is presented with visual motions, and where the reaction is either the choice of a verb out of a set, or a yes/no reaction with respect to a single verb. Here some experiments and further plans will be discussed. The second is the use of motion verbs in inference tasks.

Here only plans are available, no experimental results.

III.1 Perceptual verification tasks

In the introduction it was observed that there exist noteworthy correspondences between Michotte's perceptual categories and semantic components in linguistic analyses of verbs of motion. The experimental programme started out with a set of verification experiments with Michotte-type motions such as push, launch, pull, pass, brake, bounce, etc. These experiments are reported in van Jaarsveld's (1973) thesis. Here one of his experiments will be reported in some detail since it is one of the typical tests of the theory we started out with:

Theory 1 Sequential elimination

The theory describes the decision process for the situation where the subject is presented with a visual motion and has to make a choice among n alternative verbs, one of which is a correct description of the motion picture. The theory can be extended to the one-verb yes/no decision task.

The theory states that the underlying decision process has a tree-like structure: the subject is supposed to apply a series of tests to the perceptual trace. Each test involves one semantic component. If the component is m -valued, there are m possible outcomes of the test. For each of the outcomes a further test may be applied, etc. Testing proceeds until a single verb-alternative is left, i.e. the process is selfterminating.

Take as example the set of verbs which was actually used in the experiment to be described: Meenemen (a rather generic term for Michotte's entrain, we will translate it by take along), passeren (pass), wegstoten (launch), ophalen (pick up, collect). Pretests had shown that subjects prefer to use these verbs for describing two-object motions of the four types shown in Figure 4. Table 1 gives a componential analysis for the four verbs in terms of two semantic components: causality, and (change of) direction. Causality is two-valued, direction three-valued. If it is supposed that the subject successively applies perceptual tests related to these components, and if the procedure is self-terminating, there are two possible decision trees. They are presented in Figure 5. They only differ with respect to the order of testing, but they predict rather

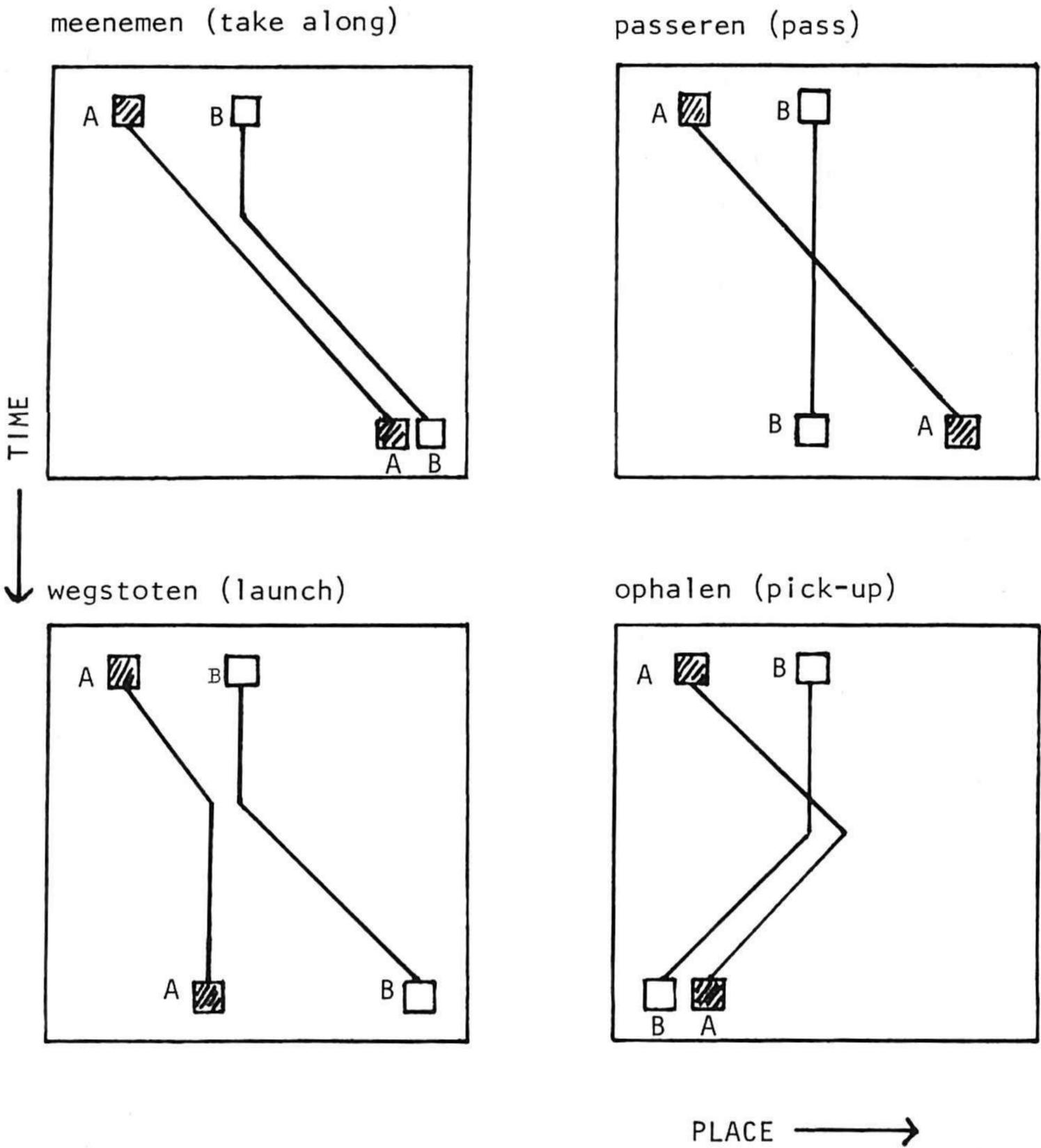


Figure 4 : Motion patterns with their preferred verbal description as used in van Jaarsveld's (1973) experiment.

Table 1 Componential analysis of four verbs

VERB	CAUSAL	DIRECTION OF A AFTER IMPACT
1 take along	+	+
2 pass	-	+
3 launch	+	0
4 pick up	+	-

different patterns of reaction times: the first tree predicts that pass will be decided quicker than the other three verbs. The second tree predicts that launch and pick up are the fastest to decide on. This should suffice to exemplify the theory.

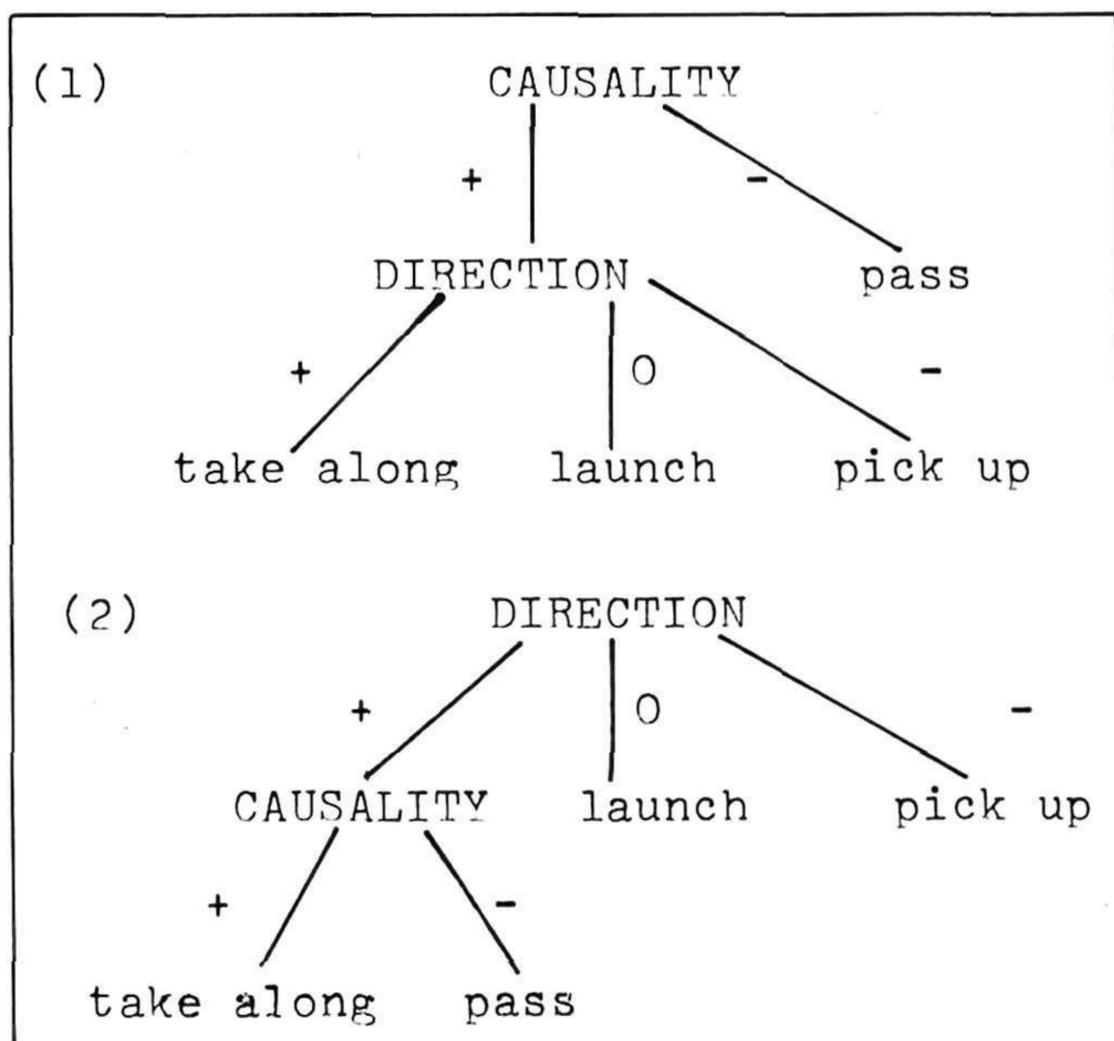


Figure 5 : Decision trees for the verbs: "take along", "launch", "pass" and "pick up".

Apart from the two decision trees derived from Table 1, van Jaarsveld derived four more by adding a second directional feature involving object B. All six theories were put to test in an experiment where subjects

had to make a forced choice between the four verbs.

Each verb corresponded to a prototypical motion (see Figure 4); all motions were identical up to the moment of impact, and all differed from then on. Of each motion 8 variants were created: four variants were slight spatio-temporal variations, four other variants were the mirror images of these (i.e. starting from right, going to left). The 4x8 different motion patterns were presented in random order on the screen of a Vector-General, connected to a PDP 11/45. The objects A and B were differently striped rectangular forms. The subject was seated before the screen with his index finger on a rest-button. After each presentation he or she left the button for one of the four reaction keys.

In order to prevent lifting the finger before a decision was made, catch trials were introduced. They consisted of motion patterns also starting out with A approaching B, but then A simply stopped. Subjects were instructed not to lift their finger in such cases. Reaction times were measured from the moment of impact to the lifting of the finger. Responses were recorded; error rate was smaller than 5%. The experiment was repeated 10 times in succession for each subject. Twenty subjects served in the experiment.

Figure 6 presents the average reaction times for the four verbs (correct reactions) over the ten repetitions of the experiment. The pattern is fairly consistent: the mean RT's of the four verbs are all highly significantly different. Ordered from long to short they are take along, pick up, pass, launch. The result could not have been worse for the theory: none of the six patterns of reaction times are in agreement with this rank order. This result, combined with several other experimental failures, forced us to reconsider the theoretical starting point of these experiments.

Theory 2 Testing the salient component

There were several findings in van Jaarsveld's experiments which indicated a different direction of theorizing. Take along (meenemen) is a rather generic verb in Dutch which can be true for a large variety of motion patterns. The interesting finding was that in the above experiment take along produced the longest reaction time, but not only there, also in free naming experiments. Moreover, it appeared that also other generic verbs like meet and disappear gave rather long

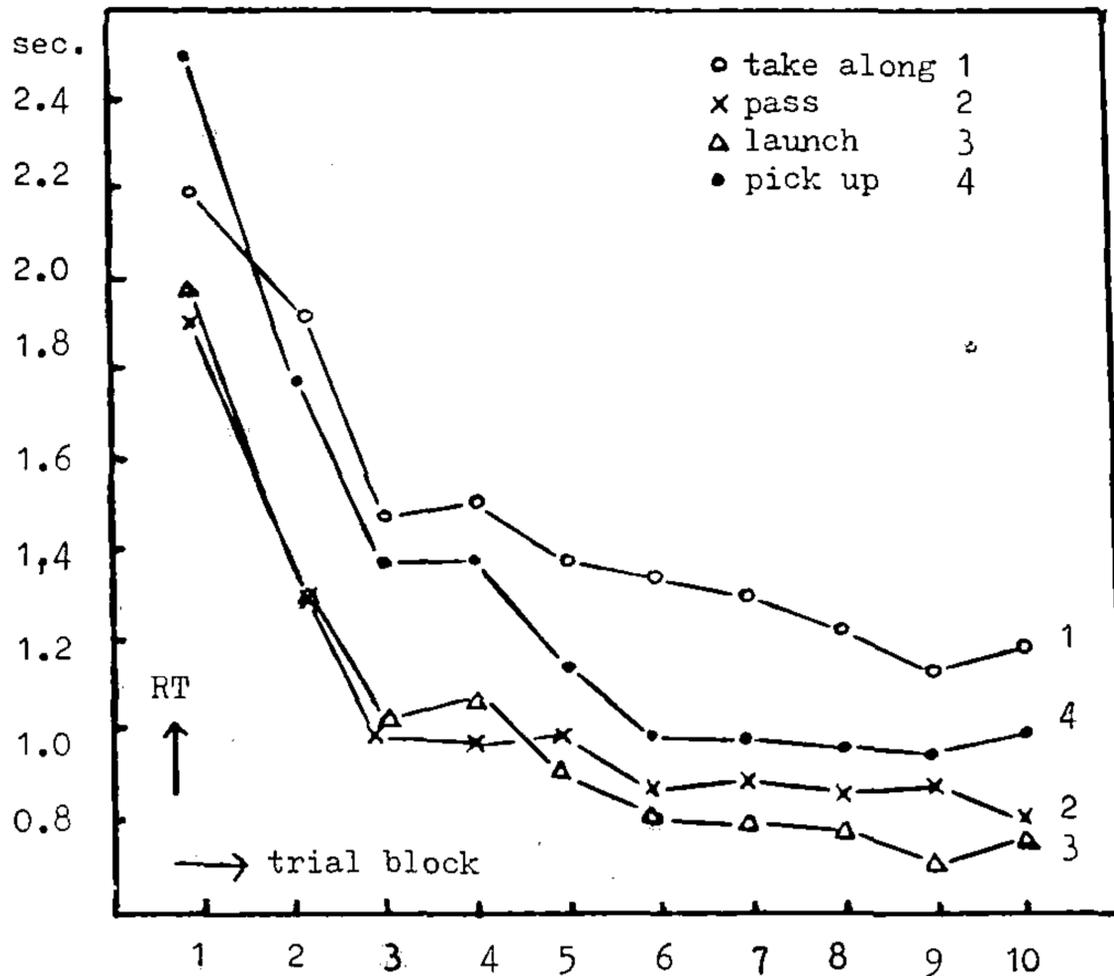


Figure 6 : Average reaction times for the four verbs over ten repetitions of the van Jaarsveld (1973) experiment.

reaction times in free naming situations. This does not seem to be a frequency affect as these more generic verbs have a higher frequency count than more specific verbs as pick up, pass and launch. (Uit den Boogaart, 1975) Could it be possible that subjects find it easier to produce and verify specific verbs than non-specific verbs?

At this point in the project, international cooperation came to our help. Dr. Johnson-Laird asked us to help him run an experiment on motion verification which could easily be done on our system. His interest was in possible differences in verification reaction times for simple and complex verbs. The background of that interest is not at issue here; it will be discussed, together with the details of the experiment, in an independent publication. Here only one result of the experiment will be mentioned which is essential for the just mentioned theoretical question. In the experiment 19 pairs of simple and complex verbs were used. The meaning of the complex verb always implied the meaning

of the simple verb, so for instance rise and move, fall and travel. That is, the complex verb always had an additional feature. If both verbs applied to a certain perceptual event, the complex verb could therefore be a more specific description of that event. The way in which it would then be possible to understand that specific verbs could be easier to verify than generic verbs is depicted in the flow diagram of Figure 7. It describes the process involved in verifying a verb which is presented to the subject right after presentation of a motion pattern. The idea is that the perceiver stores the perceptual event, but has his attention directed to the most pregnant feature of that event: here any striking perceptual Gestalt quality may figure: symmetry, force of impact, speed, etc. Also the perceiver stores the verb and directs his attention towards the salient meaning component (in sense described above).

The subject then makes a comparison between perceptual feature and salient component. It is first decided whether the perceptual feature is in the domain of the meaning component, and if yes, whether their values match. This latter is not the case, for instance, if there is high speed perceptually whereas the salient speed component of the verb has the value 'low'. What happens if the perceptual feature is not in the domain of the salient meaning component? Then the subject has to check back and find another feature of the perceptual event to which he has not yet attended, but which corresponds to the salient component of the verb.

Let us now take move and rise as examples of simple and complex verbs. The subject is presented with an object moving up from the bottom of the screen, and then with the verb rise. Pregnant perceptual feature is upward direction, salient component of rise is directionality, with value 'upward'. The component corresponds to the feature, the values match, and the response is "true". Now consider move. The same motion pattern is presented; the attention getting feature is again upward direction. The salient component of the verb, however, does not correspond to this, it is something like '+ displacement', and the perceiver has to redirect his attention to this displacement aspect of the motion. Only then it is possible to judge whether '+ displacement' is true for the perceptual event. Prediction, therefore, is that the complex verb will take less reaction time to verify than the simple verb. This prediction is somewhat counter-intuitive in the light of what is known about

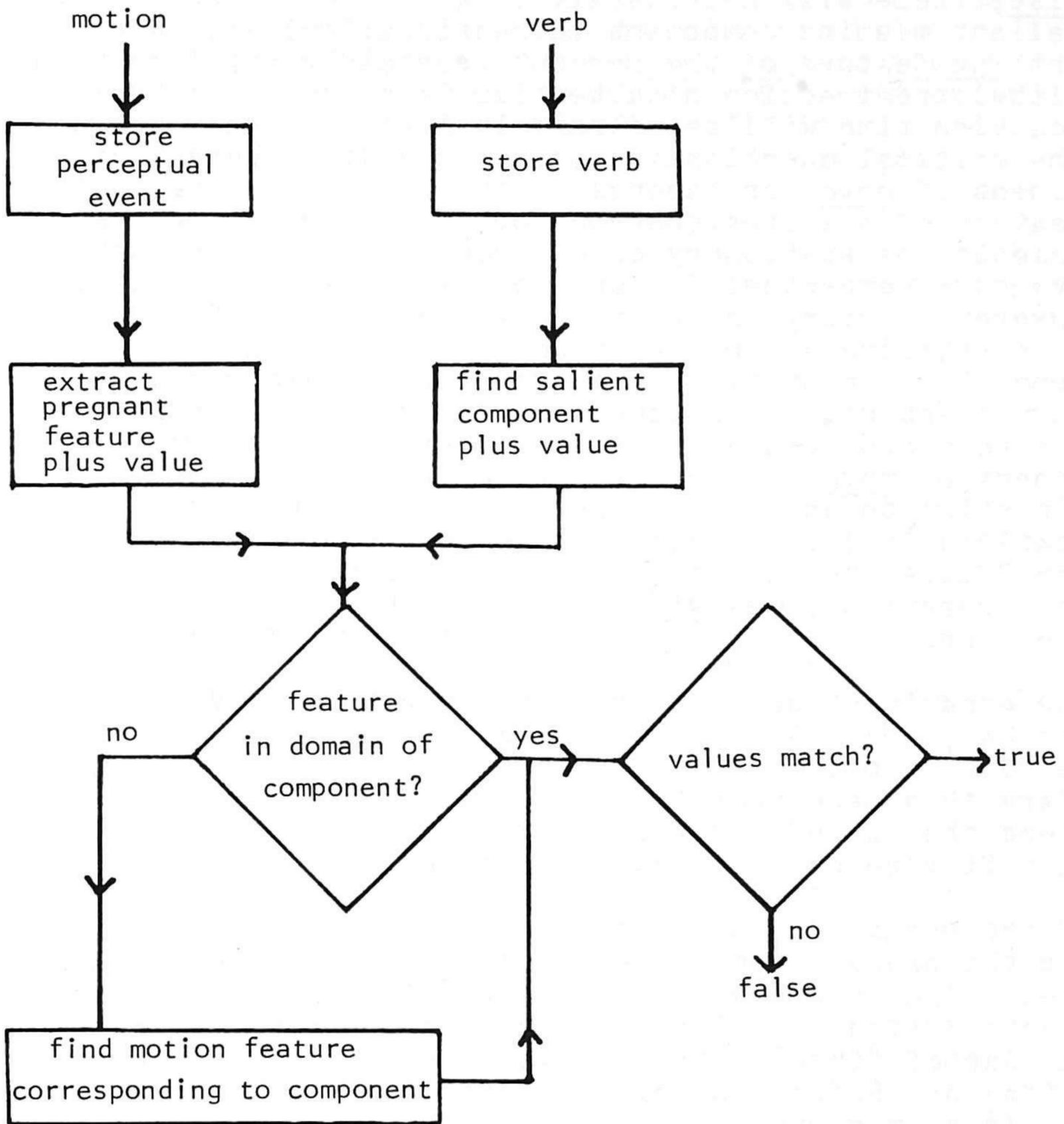


Figure 7 : Flow diagram of verification process of motion verbs.

verification times for simple and complex sentences. So far verification times for "true" responses.

What about "false"? Imagine the subject to be presented with a stationary object (e.g. an O). If the verb is rise, there will necessarily be a mismatch between salient meaning component (directionality) and attention-getting feature of the percept (certainly not directionality): redirection of attention is needed, and the reaction time will be relatively long. But now for move. The critical question is whether the displacement component of move corresponds to the dominant perceptual feature of the stationary object. This would be the case if the stationary object would have as its most pregnant perceptual feature 'no displacement'. This, however, is very unlikely. Clark & Chase (1972) argue on convincing grounds that perceptual coding will normally be positive. The pregnant Gestalt property of our object will be something like 'round' or 'circular', and this produces a mismatch for the displacement component of move. Here also, then, redirection of attention to another aspect of the percept (its stationarity) is necessary in order to verify the verb. For "false" responses, therefore, the prediction is that reaction times will not differ for simple and complex verbs.

The experiment was run in Nijmegen with 20 native speakers of English as subjects. For each of Johnson-Laird's 19 pairs of verbs one perceptual event was made where they were both true, and one perceptual event where they were both false. So, in fact, each subject made 76 true or false judgements.

Of the results we only mention the one which is relevant for the present considerations: in agreement with the predictions there was a significantly ($p < 0.01$) longer reaction time for simple verbs than for complex verbs in case of "true". For "false" there was no significant difference between simple and complex verbs. But it should be remarked that these results have to be taken with caution: different pairs of verbs behaved rather differently, and there is a general, though non-significant tendency for complex verb reaction times to be shorter also in case of "false". Further experiments are necessary (and are in the planning stage) to substantiate these results.

III.2 Human locomotion

At the beginning of the project, when a sampling of Dutch motion verbs was made (see Schreuder, 1976), it was at once clear that most of these verbs could indicate human patterns of motion, and that a substantial part of the verbs specifically referred to human locomotion. Distinctions here are highly subtle: shuffle and shamble, limp and hobble, jog and trudge. The extent of this vocabulary suggests that variations in gait are extremely important in daily life. They may signify moods, intentions, individual styles, etc.

These considerations led to the decision to give special attention to human locomotions in the project. For this it would be necessary to generate and manipulate human locomotions as stimuli for verification and naming tasks. Perceptual studies of human motion hardly exist, and for a simple reason: locomotion patterns are highly complex natural stimuli which are very hard to control experimentally.

A marked exception is Johansson's (1973) beautiful study on the visual perception of biological motion. Johansson developed various techniques to register the motion patterns of humans. One of them consisted in attaching light spots to the joints, and then making film registrations in the dark. If shown to subjects such patterns were immediately recognized as human gait, even if the presentation time was no more than 100 ms. We have adapted this method in order to be able to manipulate the registered motions by computer. (Johansson himself developed a rather different method for the same purpose.) It consisted of using infrared light sources (LED's actually) to attach to the joints (shoulder, elbow, wrist, hip, knee, and ankle of the right side, and elbow, wrist, knee and ankle of the left side).

These LED's switched on and off in turn in a very rapid cycle (1000 Hz.). A so-called Selspot camera registered the coordinate of each of the LED's at each successive cycle, and x and y signals were digitalized and fed in the PDP 11/45 for further processing. Further technical details can be found in Hoenkamp (1976). A list of 46 verbs was made (like stroll, trip, limp, hop, race, etc.), and an actress was provided⁵ with this list some two weeks before the registration. Because of the infrared system, the registrations could be made in daylight, which made it possible to simultaneously make video recordings of them. In this way we could get an indication of the quality of performance.

Five subjects watched the video pattern on monitors during the performance. Each of them was provided with a list of ten verbs, one of them being the correct one. The 45 incorrect ones were distributed over the five subjects. If three or more subjects were able to detect which verb was being played, the Selspot registration was kept in the "Motion Library" (i.e. on disc). If not, the verb was played again later on. Only five verbs could not be recognized even at repeated performance.

Various transformations were made of these patterns. The most important being the so-called "conveyor-belt" transformation. This consists of taking one full phase out of a periodic motion pattern, choose a tracking frame of reference, and connect end and beginning of the movement. Looking at such a pattern gives the impression of the camera following the actress, so that the (invisible) background moves while the actress keeps in the middle of the screen. In this way the motion pattern can be presented to the subject for any length of time. Figure 8 shows the original registration and the conveyor belt transformation of hopping. Other

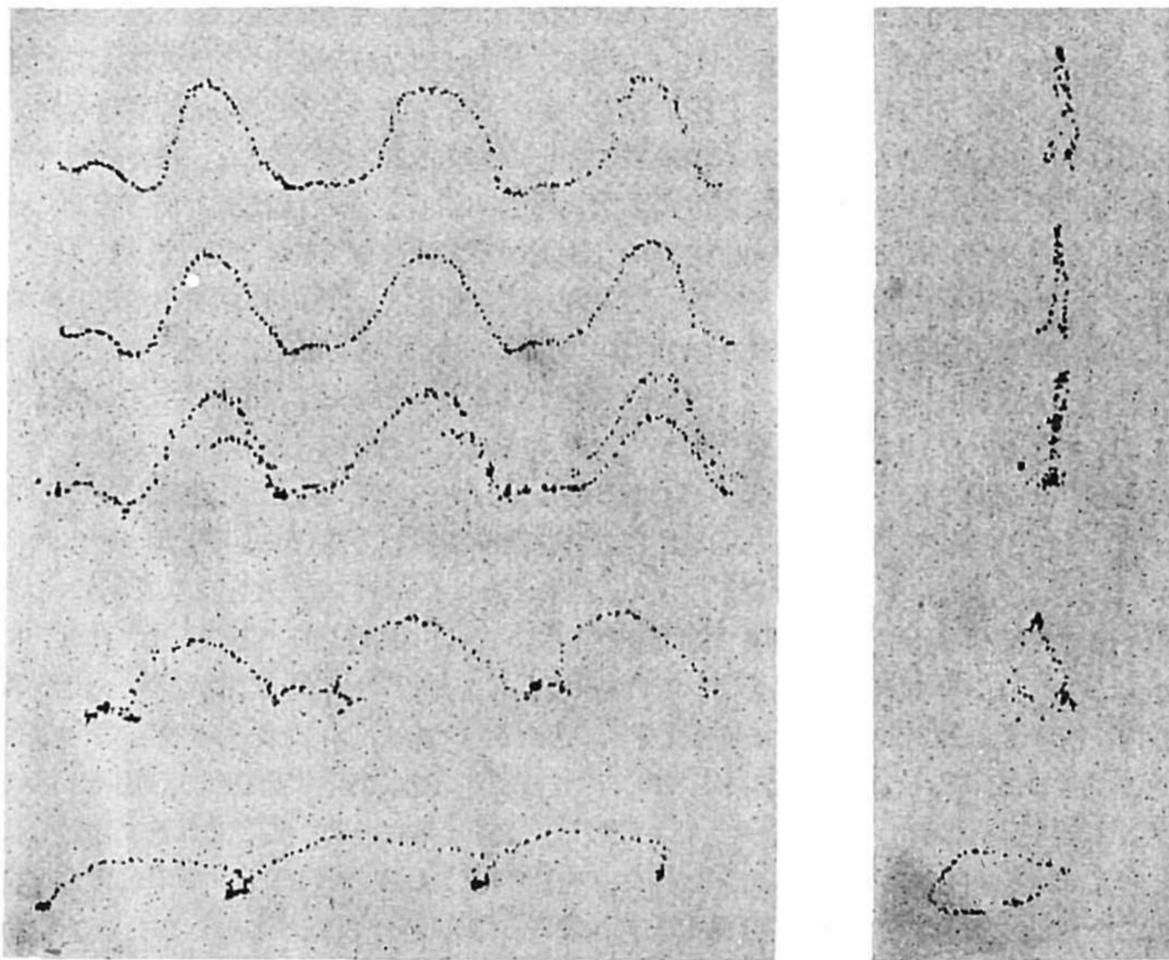


Figure 8 : The verb "hop"

left : the original pattern

right : the same pattern transformed to a conveyor-belt image (no noise reduction).

transformations are easily made. Joints can be connected by limbs, joints and limbs can be removed, or changed in their motion patterns. One can have walking feet and running arms, etc. The technique being available now, we will soon start verification experiments with human locomotions as stimuli.

III.3 Inference tasks

There are many tasks involving verbs of motion where the salient component has to be ignored by the user. His or her attention has to be directed towards other aspects of the verb's meaning in order to cope with the task requirements. Good examples are various sorts of inference tasks. Take for instance the situation where the subject is presented with sentence (1):

(1) John just kicked the ball in the canal.

and the subject is then asked where the ball is just after this event. This can be done by means of sentence (2):

(2) Where is the ball?

The answer should be "in the canal", but the answer is independent of the salient component of kick ("by forceful foot movements" or the like). It would have been the same for the sentence (3):

(3) John threw the ball in the canal.

Actually, the answer would be the same for all agent \equiv source verbs and it seems to be only dependent on relations in the thematic schema of section II.1. This is especially apparent if one questions the position of the ball just before the event, e.g. by sentence (4):

(4) Where was the ball?

Since the source is identical to the agent, the answer should be "with John" or some synonymous expression. Again, this does not depend on the verb, but on the thematic class.

Locative inferences of this sort show an interesting interaction between thematic class and tense of the locative question.

There are two basic semantic questions at stake with inferences of this sort. The first is to show how the inference follows from the semantic representations of the sentences involved. Rules specifying an inference in terms of semantic representations are called meaning rules. Jackendoff presents two sets of meaning rules. The first set he calls rules of (logical) inference. The two rules required to answer questions (2) and (4) are of this sort. They basically say that if a theme goes from source to goal, it must have been at the

source at some time t_1 and at the goal at some time t_2 , and t_1 is before t_2 .¹ Jackendoff does not build tense² conditions into his rules, which makes it rather complicated to handle the just-mentioned tense-dependency of the inference. Tense-dependency is nicely treated by Stillings (1975) in his account of the meaning rules involved in inferences about borrow and loan. The second set of meaning rules are rules of invited inference, or "implicatures". An invited inference would for instance go from John didn't kick the ball to the ball didn't move. Here the first sentence could very well be true while the second is false. But the implicature should hold if, on the principle of minimal negation only the highest predicate is affected by negation. Both sets of inference rules may have pragmatic conditions to them. An example is the inference of the authors went from Holland to Scotland from the authors went from Nijmegen to Stirling on the pragmatic condition that Nijmegen is part of Holland and Stirling part of Scotland.

The second basic semantic question is how to relate the actual inference behaviour of the language user to these meaning rules. Stillings's (1975) paper is an exemplary study of this question. He uses the subject's reaction times for solving inferences on borrow and loan to test alternative sets of meaning rules in combination with so-called control programmes which control the inference procedure by choosing appropriate meaning rules at each step in the inference.

It is our intention to use Stillings's paradigm to analyse meaning rules for the different classes of motion verbs discussed in section II.1.

Footnotes

- 1 Sponsored by the Netherlands Organization for the Advancement of Pure Research (ZWO).
- 2 The selection of these verbs is discussed in Schreuder (1976).
- 3 \equiv stands for "coincides with".
- 4 This cooperation was possible under the twinning arrangement between the Sussex Laboratory of Experimental Psychology and the Nijmegen Unit of Experimental Psychology sponsored by the ETP.
- 5 We are very grateful to Evelyn Schippers who studied these motion patterns, and patiently performed them during a whole afternoon of registration.

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