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Motor programme information as a separable memory unit

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Summary. Two experiments produced further evidence for the claim that motor programme information may be considered as a separate memory unit, partially independent of other memory representations. In Experiment 1, it was shown that for the comparison of shared movement components in two actions such as "turning the handle" and "stirring the ingredients", the activation of their motor programmes is required. This is demonstrated by the finding that the execution of the first action, which preactivates its motor programmes, leads to shorter reaction times than under control conditions in which the verbally described action is only spoken. In Experiment 2, it was further shown that the execution of the action does not in every case expedite the assessment of a connection between a prime item and a target item vis à vis verbal repetition, but only where the task requires the activation of motor programmes.

There are two aspects of memory that are increasingly widely accepted: first, the idea that memory is an active associated network, and secondly, the idea that memory representations about objects and events are complex, that is that they consist of different subunits that contain different information and which are partially independent of each other (e.g., Glass, Holyoak, & Santa, 1979, p. 21; Hoffmann, 1982; Klix, 1982; Lindsay & Norman, 1977, p. 389; Wickelgren, 1979, p. 283ff). The centre of the representation is usually called a concept, and associated with it is its name, and, in the case of concrete entitites, its sensory image. Following Klix's proposal (1982), we will refer to the name nodes as word marks (WM) and the sensory-image nodes as picture marks (PM). In a series of experiments Engelkamp and Zimmer (Engelkamp & Krumnacker, 1980; Engelkamp & Zimmer, 1983; Engelkamp & Sieloff, 1984; Zimmer & Engelkamp, 1984a, b; Zimmer, Engelkamp, & Sieloff,

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1984) have shown that with regard to concrete actions, there is a case for claiming the existence of motor programme nodes (MP) in addition to concepts, WM and PM.

Although we tend not only to consider these pieces of information as differing in content and as partially independent memory representations, but also to attribute different modality-specific properties to them, this point is of no importance for this study. In this context, it is essential that we assume that different and partially independent memory representations are stored together with words and can be activated by them. The difficult question of whether these representations have different codes can be ignored here (e.g., Kosslyn & Pommerantz, 1977; Pylyshyn, 1973). The distinction between concepts and motor programmes is critical for the following study.

We consider the representation of our knowledge about how to perform actions such as 'opening a wine bottle' to be a motor programme. We claim that this kind of information forms a representation unit that is associated with the concept under consideration, for instance, opening a bottle, but that is nevertheless partially independent of it.

The claim that a distinction can be made between concepts and motor programmes as partially independent memory units is closely connected with the additional assumption that hearing or reading an action phrase such as 'opening a wine bottle' does not necessarily activate the corresponding motor programme. Both assumptions are supported by a number of experimental results about which we reported elsewhere (e.g., Engelkamp & Zimmer, 1983; Engelkamp & Sieloff, 1984; Zimmer & Engelkamp, 1984a, b). Particularly strong support for this has been found in the selective interference paradigm (Zimmer, Engelkamp, & Sieloff, 1984). In selective experiments it could be shown, for instance, that identical learning and interference lists interact differently, dependent on whether the subjects had to perform the acoustically presented items in both lists symbolically, or merely saw them being performed by someone on a television screen. Recall of a learning list whose items had been performed symbolically was worse if the items on the interference list were also performed than if their performance was only seen.

The fact that there are different selective interference effects depending on whether the learning list phrases are either seen or performed strongly supports our assumption that different pieces of information are activated according to whether the modality of processing is seeing or doing. Furthermore, these pieces of information seem to be represented in different modality-specific subsystems of memory. In any case, we think that there is good reason to postulate that which kind of information is primarily accessed depends on the modality of processing (seeing or doing). The experiments in this study are designed to demonstrate again, and in a methodologically different way, that motor programmes are partially independent memory representations and that the activation of motor programme information is dependent on the modality of information processing. We want to show that subjects are able to solve a task which requires the use of motor programme information faster if part of the motor programme information is already activated than if it is not.

Experiment 1

We consider the assessment of whether two action phrases such as 'stirring the ingredients' and 'turning the handle' include the same movement patterns to be a task which requires the use of motor programme information. Zimmer and Engelkamp (1984a) were able to show that the recall performances of a list of phrases which were encoded by 'doing' were interfered with on the one hand by the assessment of whether two action phrases included the same movement patterns, and on the other hand by performing the action phrases to the same degree. We assume therefore that assessing whether two action phrases include the same movement patterns requires the activation of their motor programmes. In addition, we assume that performing an action phrase activates the motor programme information faster than only hearing the phrase, even if the task is to assess movement patterns. This means that if two action phrases are presented successively and have to be assessed according to their movement similarity, then performing the first phrase should activate the corresponding motor programme faster than verbally repeating it. We therefore expect that two action phrases presented in succession are assessed more quickly for movement similarity if the first phrase is performed than if it is verbally repeated. For the sake of simplicity, the first phrase will be called 'prime' and the second 'target' in the following.

The remaining factors of the design are dictated by technical considerations. One of these factors is nevertheless of theoretical importance and will therefore be mentioned here. The use of action pairs that do not have similar movement patterns as well as those with identical movement patterns produces the factor of item relatedness. Although this factor is confounded with the type of reaction (yes/no), it is theoretically interesting. The kind of prime processing which we will call the encoding factor should show greater assessment differences with related than with unrelated item pairs.

Under the related condition, performing activates not only the motor programme of the prime item, but because of the relatedness of the motor programmes of the two phrases, it also preactivates the motor programme of the target item. This does not hold true for target items of unrelated pairs. We therefore expect an interaction between the two factors of encoding condition and relatedness.

Method

Subjects. Forty-eight subjects, students of the University of the Saarland, took part in the experiment. They were paid for their participation.

Material and design. The material consisted of 20 triplets. Each triplet comprised three action phrases, two of which had the same central movement patterns, whereas the third differed from the other two. One phrase acted as a target item and the other two as prime items. One prime item was related to the target item as regards similarity of movement and the other was unrelated. The list of items is to be found in the appendix. The material was split into two half lists to balance it across the encoding factor.

The nucleus design consists of a 2 × 2 plan with repeated measurements. The factors are prime encoding: verbal repetition/doing, and item relatedness: related/ unrelated. Repeated measurements were taken for both factors to minimize error variance and to hold the encoding time of the target items constant. Thus, target items from both lists are presented twice, but were paired with different prime items. This constitutes a repetition factor: first or second presentation of the target item. The sequence of the presentation of the prime target pairs was balanced. This consitutes a further factor. Since the sequence of the encoding conditions was also balanced, this brings the total number of factors to five: verbal repetition/'doing' (*ve/do*); related/unrelated (*re/ur*); first versus second presentation of the target item; sequence *ve* – *do* versus *do* – *ve*; and List factor L1/L2.

The measurement of the first factors was within subject, and that of the last two was between subject. With respect to the items, only the last factor was measured independently, whilst measurement of the first four was dependent.

Procedure

First, the subjects heard an action phrase acoustically. This was to be either verbally repeated or carried out, according to the condition. They were given 4 s in which to do this. Then, after a warning signal, a second action phrase was offered to them by means of rear projection. Its appearance started a timer, which was stopped to the nearest millisecond by the response of the subject. The subject's task was to decide whether the actions corresponded in parts of their movements. They were to give the answer 'Yes' with related phrases, and 'No' with unrelated. The reaction was registered with a voice key. Figure 1 illustrates the test procedure.

Instructions were given to the subjects by means of examples. These were followed by a trial run with four items, in which the subjects practised the test procedure with the relevant instruction.

If mistakes arose in this phase, the subjects were corrected and the correct answer was justified. At the start of the experimental phase, the four items were again presented, together with ten others, as practice items. After presentation of half the experimental items, the condition was changed from verbal repetition to "doing", or vice versa. A short practice phase with four items followed the change in instruc-

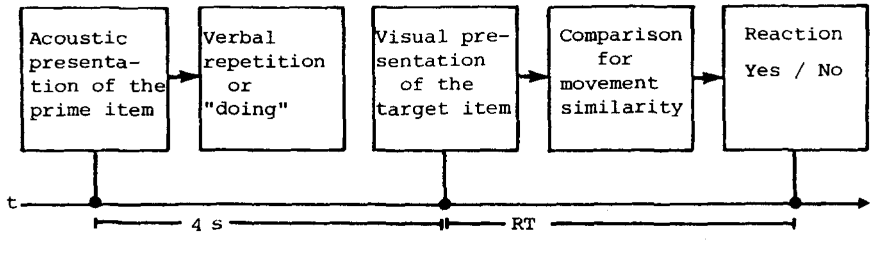

Fig. 1. Test procedure

tions, so that the subjects could accustom themselves to the altered sequence. There was no break between the practice and experimental phases.

Results

The data were evaluated in two separate analyses, with first the subjects as random factor, and then the items as random factor. Only significant results are presented here.

All values over 2,000 ms and all incorrect assessments were excluded from the analysis. These values were estimated by taking the average cell value across the remaining items with the same subject and condition. If more than 10% of a subject's assessments had to be estimated, then the subject was replaced by a new subject. Altogether, fewer than 1% of the values had to be estimated. The number of errors is independent of experimental conditions.

Judgement of whether parts of the movement in the two actions are identical is made more quickly with "doing" (1056 ms) than with verbal repetition (1145 ms): $F(1,44) = 38.92$, $p < 0.001$ across subjects, and $F(1,18) = 75.14$, $p < 0.001$ across items.

However, this effect interacts with the sequence of verbal repetition and "doing" $F(1,44) = 6.01$, $p < 0.025$ across subjects and $F(1,18) = 20.62$, $p < 0.001$ across items. Figure 2 illustrates these interactions.

In the comparison of pairs under both sequence conditions, the main effect was shown to favour "doing" to a significant extent: $t = 6.48$ ($p < 0.001$), when verbal

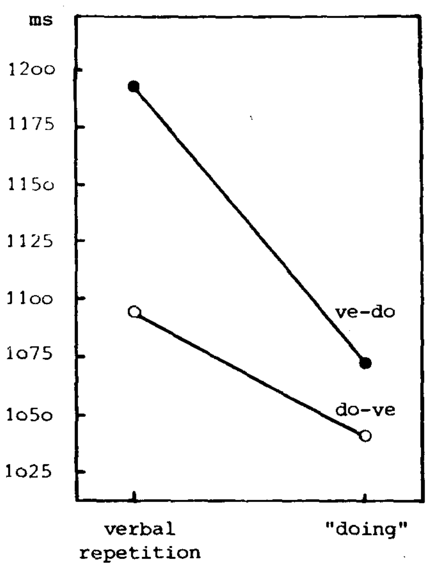

Fig. 2. Interaction between the condition *ve/do* and the sequence of presentation

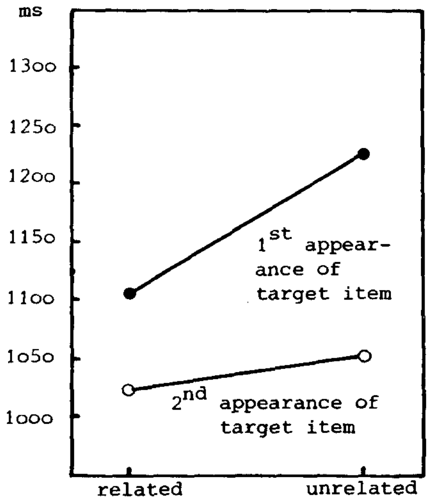

Fig. 3. Interaction between the factor of item relatedness with the 1st or 2nd appearance of the target item

repetition precedes, and $t = 2.40$ ($p < 0.025$) when "doing" precedes. The effect is more marked when verbal repetition is first, as a comparison of the differences between reaction times for verbal repetition and "doing" shows: $t = 2.37$ ($p < 0.025$). If "doing" precedes verbal repetition, then the advantage of "doing" is reduced. However, the assessment of whether parts of the movement are identical is arrived at more rapidly under a "doing" condition than under one of verbal repetition.

Judgement as to whether parts of the movement in both actions are identical is arrived at more quickly with related items (1063 ms) than with unrelated (1138 ms), $F(1,44) = 20.55$, $p < 0.001$ across subjects, and $F(1,18) = 24.73$, $p < 0.001$ across items.

A further significant main effect is due to the presentation sequence $F(1,44) = 159.53$, $p < 0.001$ across subjects, and $F(1,18) = 131.45$, $p < 0.001$ across items. The judgement is made more quickly if the target is repeated (1038 ms) than if it is presented for the first time (1163 ms). This factor interacts with the factor of relatedness, $F(1,44) = 10.17, p < 0.01$ across the subjects and $F(1,18) = 13.01$, $p < 0.01$ across items. The interaction is illustrated in Figure 3.

The assessment advantage for related items is almost entirely lost (to 1060 versus 1053 ms) when the target item appears for the second time. On the other hand, assessment advantage for related items on first appearance is very high (1102 versus 1224 ms).

The relatedness factor interacts further with the factor of verbal repetition/ "doing", $F(1,18) = 5.20$, $p < 0.05$ across items, and this effect does not quite reach the 5% significance level across subjects, $F(1,44) = 3.47$.

The difference between related and unrelated items is more marked for the condition of "doing" than for verbal repetition (see Fig. 4).

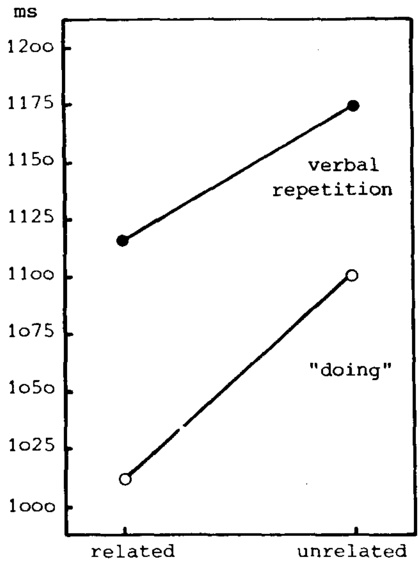

Fig. 4. Interaction between the factors of relatedness of items and verbal repetition/doing

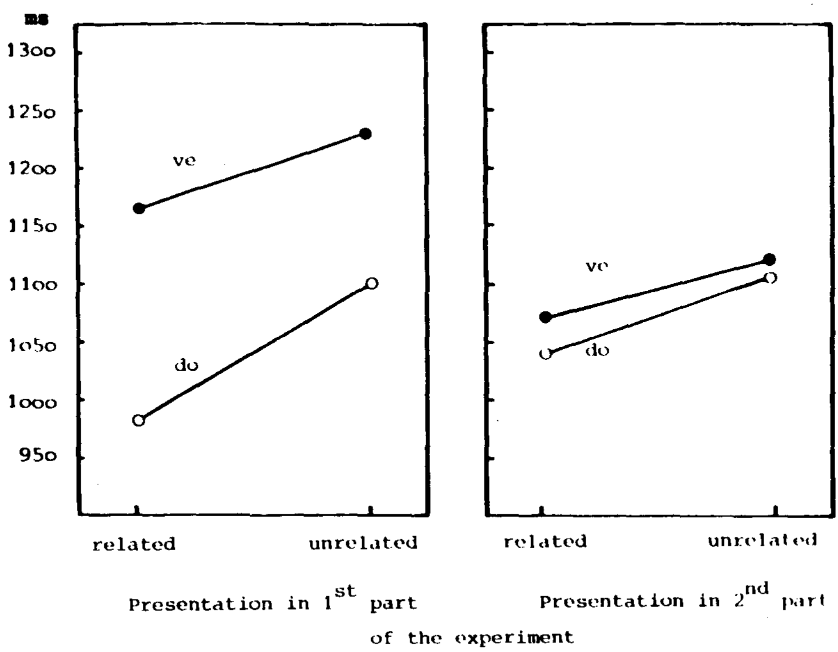

Fig. 5. Threefold interaction between the factors of verbal repetition/doing, their sequence of presentation and item relatedness

A threefold interaction with the sequence *ve – do* versus *do – ve* differentiates this effect, $F(1,44) = 4.46$, $p < 0.05$ across subjects and $F(1,18) = 5.69$, $p < 0.05$ across items, as illustrated in Figure 5.

If the condition of verbal repetition or of "doing" appears at the beginning of the experiment, then the expected twofold interaction between this factor and item relatedness shows up clearly. If both conditions appear in the second half of the experiment, that is, after the change in instruction, this interaction disappears. Compared with the first presentation, reaction times with verbal repetition are consistently shorter by about 100 ms. Reduction of reaction time with related items in comparison with unrelated items approaches that of verbal repetition, for the condition of "doing".

The interaction between the factor of verbal repetition/"doing" and item relatedness is also overlaid by a list effect, so that a further threefold interaction between the factors of list, verbal repetition/"doing" and item relatedness produced $F(1,44) = 16.09$, $p < 0.01$ across subjects, and $F(1,18) = 15.59$, $p < 0.01$ across items. The threefold interaction reveals that the twofold interaction already observed is essentially attributable to List 2. Finally, the slightly differing behaviour of the two lists is also expressed in the resulting interaction which is only revealed by the analysis across items. Here, the list halves interact with the relatedness factor, $F(1,18) = 5.13$, $p < 0.05$. The relatedness effect is greater for List 1 than for List 2. These two effects will not be further discussed, however; nor will the list factor. They only show that the effects are marked to different degrees with different items, which is not surprising.

Discussion

In order to discuss the various effects of this experiment let us start by looking at the hypothetical decision-making process of our subjects. Subjects have to decide whether parts of the movement of the prime and target items are identical. To do this, they must look for identical movement components. How do they do this? All subjects heard the prime item. Under the condition of *doing* they then activated their motor programme to enact the prime item. Then they saw the target item, activated the corresponding motor programme and compared it with the previously activated one for commonalities. If they found a common part of a movement they answered "yes", if not, "no". In the case of *verbal repetition*, this process is the same except that the activation of the motor programme of the prime item occurred at the moment of comparison. We assume that there is scarcely any activation of a motor programme until presentation of the target item.

Since "doing" activates the motor programme during presentation of the prime item, and since verbal repetition only does this later, during comparison, we expected a main effect favouring "doing". We further expected an interaction effect between the factors of verbal repetition/"doing" and relatedness. In the case of related items with the "doing" condition, two factors work together: first, the *prime* item *MP* is already *activated* during execution of the action, and secondly, the target item *MP* is *preactivated* by the shared movement components of the prime and target items.

In the case of unrelated items, in place of preactivation, there is only activation of the prime item. As a result of these activations not appearing with verbal repetition, there is an interaction effect.

Therefore, we expected "doing" to lead, in general, to shorter reaction-times than verbal repetition, because the *MP* of the first item is already activated before presentation of the second. This effect was clearly demonstrated. Further, it became evident that the size of the difference depends on the sequence of verbal repetition and "doing". If the verbal repetition condition appears in the second half, and the subject has already carried out the action with "doing", then the differences are smaller and the reaction times shorter than when the task is to be accomplished at the beginning, with verbal repetition.

We explain this as a "drag" effect, on the basis of a general system activation. In our view, this means that a preceding "doing" condition leads to the motor programme being activated, even with verbal repetition. The motor programme system is, so to speak, tuned.

We further expected an interaction effect between the factors of verbal repetition/"doing" and item relatedness. The difference between related an unrelated items should be more marked with the condition of "doing" than with verbal repetition. This is indeed the case. However, this effect is smaller than expected. This could mean that preactivation of this kind is of little importance in the system of motor programme representations or that motor programmes are only loosely connected.

Furthermore, the expected interaction is overlaid by other effects. First, the expected interaction effect obviously depends on the material. This is indicated by a list effect. At the moment we are not able to say why, since the placing of items in a list was random. Second, the expected interaction is overlaid by the sequence of the encoding conditions. Because of the 'drag' effects, the processing strategy of our subjects may have been changed in the second half of the experiment, that is, after reversing the encoding instructions.

Finally, the relatedness effect is influenced by the target item repetition. The favourable assessment for related items in comparison with unrelated items is almost entirely lost when the target item is repeated.

Because these three factors – sequence, repetition and items used – overlaid the interaction of relatedness and prime encoding, no clear picture emerges about it. However, a clear relatedness effect could be observed. The assessment of movement similarities was made more quickly when there was similarity than when there was none. Two factors may have contributed to this effect: Differences in the mode of reaction (yes/no), and differences in the comparison process. It can be seen from the interaction between item relatedness and item repetition that the relatedness effect cannot be explained by the reaction mode alone. The shorter assessment times for related items in comparison with unrelated items are almost entirely lost when the target item is repeated. On the second target presentation, the reaction 'no' comes as quickly as the reaction 'yes'. Therefore, the comparison process must be important here. When the target item was unrelated on its second presentation, then it was related on its first presentation, that is, parts of its movement pattern were identical to those of the prime item. Perhaps the subjects remember what part of the movement was identical, and can therefore now decide very quickly that both movement patterns are different. The situation is different if the target item is related at the time of repetition. Here the target item is unrelated at first presentation and therefore no part of the movement stands out. Only the (re)activation of the motor programme may be facilitated and produce a small repetition effect. This could lead to the observable interaction effect.

To summarise, we can say that independent of the small interaction effect between prime encoding and item relatedness our main hypothesis has been confirmed. There are shorter reaction times after 'doing' than after verbal repetition for related and unrelated item pairs. We assume that this holds true because the motor programme of the prime item is already activated on presentation of the target item when the prime item was performed, but not when it was verbally repeated. In our view, performing the task of assessing whether two actions share movement patterns requires information that is represented in memory as motor-programme nodes.

But, there remains a problem. 'Doing' could, in principle (i.e. for all tasks), lead to quicker reaction times than verbal repetition. If this were the case, the main effect favouring 'doing' would not be task specific, that is, would not only appear where the task required activation of the motor programmes. It would therefore be desirable to demonstrate an interaction between the type of encoding and the kind of task in the experiment. Experiment 2 serves this purpose.

Experiment 2

Experiment 2, like Experiment 1, is set usp as a priming experiment. Action phrases such as "pluck the flowers", "squeeze the sponge", etc. again serve as prime items. As in Experiment 1, the prime items are repeated verbally and carried out. However, in order to obtain differential effects according to the type of taks, the situation with target items is modified.

Our starting point is that our action phrases consist of a verb and an object. It is the verb which produces the close relationship with the motor programme. Although the object is involved as the goal of the action, its representation is semantic and sensory, rather than motor. It should therefore be possible to relate the main task to the object or to the verb, by choosing either a noun or a verb as target stimulus, and in such a way that the nominal stimulus stands in relation to the object of the action phrase, and the verbal stimulus to the verb of the action phrase. A relationship based on the motor programme of the action phrase may only be produced for the verb as target stimulus. Only here should execution of the action phrase accelerate judgement about the connection between prime and target stimulus, as compared with verbal repetition. However, the reverse effect should be observable with the object when the target word is so chosen that a semantic relationship exists between the object of the prime stimulus and the target stimulus. In this case, the assessment about the connection between prime and target stimulus should be made more quickly with verbal repetition than with "doing". Here, we assume that verbal repetition in addition to the word mark or, to be more precise, the word marks, primarily activates the concepts belonging to them. This can happen with a frame activation (e.g., Sanford & Garrod, 1981), or with activation of class relationships (e.g., Loftus, 1973). In this sense, a semantically similar stimulus to "pick flowers" would be "vase" (frame reference), just like "rose" (class reference), and for "squeeze out the sponge" "blackboard" (frame reference) as also "cloth" (class reference).

We thus constructed the nominal target stimuli in accordance with their semantic reference to the prime stimulus, while the verbal target stimuli were constructed in accordance with their motor action reference to the prime stimulus. This kind of motor reference exists, for example, between "pick the flowers" and "break off", and between "squeeze the sponge" and "press". Here, the construction principle was the same as in Experiment 1. Prime and target stimuli exhibited identical movement patterns.

Since both types of target stimuli – nouns and verbs – were to be offered to the same subject as a random sequence, we kept the instruction constant and gave the subjects the general task of looking for a reference between prime and target stimuli. We assumed that the type of reference is made self-evident by the concrete items.

Finally, in Experiment 2, as in Experiment 1, we used related and unrelated stimulus pairs, and in this experiment item relatedness is also confounded with the reaction type. However, this is of lesser importance since the aim of Experiment 2 is to demonstrate an interaction between the type of encoding (verbal repetition/ "doing") suggested or enforced by the secondary task, and the type of main task – to search for a reference between the prime item and the object-target stimulus or the verb-target stimulus.

Method

Subjects. Forty subjects took part in the experiment. They were students from various departments at the University of the Saarland. They were paid for their participation in the experiment.

Material. We compiled a list of 20 prime items, for each of which a related object or verb was chosen as target item. For example, for the prime item "eat the apple", the related object was "pear" and the related verb was "to bite". Finally, for the two target items an unrelated prime item was constructed that should not be related either to the object or the verb. In the example mentioned, this was the item "open the yardstick". In this way, a list of 20 item quadruplets was obtained. The complete list is given in Appendix 2.

Design. The design is based on two factors: the encoding condition of verbal repetition versus "doing", and the target item class. A verb or an object functions as target item. In order to exclude transfer effects, measurement of the encoding condition factor should be between subject whereas item class was within subject. Since the subjects had to decide whether there was a connection between the prime and target items, all items should be unrelated as well as related. Therefore item relatedness enters as the third factor. As the relatedness factor is manifested in the same target item through a change of prime item, a fourth factor also appears in this experiment – the sequence of related-unrelated versus unrelated-related. Finally, a fifth factor is that of the list half from which the target item is taken. In order to exclude repetition of the prime item, one half of the material was presented in a verb pairing and the other half in an object pairing, since measurement of the target item class factor is within subject and since a verb and an object each belong to a shared prime item.

This design resulted in five factors: encoding condition, target-item class, item relatedness, sequence of relatedness and list half. Measurement of the encoding condition factor was between subjects. Further list halves and item classes were confounded. Whenever a subject received the verbs from part-list (a), the objects came from part-list (b) and vice versa. Measurement of the remaining factors was within subject. The factors of target item class and list half seen across items were measured between items but measurement of all other factors was within items.

Procedure

Subjects heard a warning signal and then the prime item. With the verbal repetition condition, they had to repeat this item verbally, and with the "doing" condition, they had to carry out the action symbolically. Six seconds were available for presenting the items and carrying out the instruction. After this, the subjects heard the warning signal again and then saw the target item, which was rear projected onto a screen. The subjects were now asked to decide whether or not a connection exists between the prime item and the target item. They were to make this decision as quickly as possible and to communicate it by saying "yes" or "no". The reaction time from the beginning of the slide projection to the decision being given was measured precisely, to the nearest millisecond, with the help of a voice key and a timer.

Instruction of the subjects was carried out with the help of examples. As in Experiment 1, the procedure was practised with practice items. If mistakes occurred at this stage, the subjects were corrected. The subjects then received further practice items (7) followed without a break by the 40 experimental items. In this part of the experiment, subjects' mistakes were no longer corrected.

Results and discussion

As in Experiment 1, the reaction times obtained were adjusted for mistakes and extreme values. It transpired that there were more mistakes in this experiment than in Experiment 1, since somewhat less than 7% of the values had to be estimated. As regards the number of mistakes, there is no connection between the encoding condition and the item class.

Analyses of variance with the adjusted reaction times were carried out, treating first the subjects and then the items, which were defined according to the target items, as random variable. These analyses produced highly significant multiple interactions between the part lists and the experimental conditions, which occurred as random variable in the item analyses, but not in the analyses across subjects. Closer analysis reveals that the reason lies in the large differences in average reaction times between the various groups of subjects, independent of the conditions. Since the item analysis is averaged across the subject values and not every person has contributed to every cell of the matrix, these differences influence the mean value of reaction time produced by a part list, and are not added to error variance, as in the subject analysis. As a consequence, the interactions with the part-list factor are not interpretable, since, in addition to the influence of the material, they contain an influence of group differences whose extent cannot be determined. For this reason, the following discussion involves only those three factors to which all subjects and items contribute. They are encoding condition, target item class, and relatedness.

Of these three factors, only relatedness produces a significant main effect, $F(1,36) = 17.88$, $p < 0.001$ across items, and $F(1,36) = 24.34$, $p < 0.001$ across subjects. In order to find a relationship between the two items, a time of 1070 ms is required for related itmes and 1149 ms for unrelated. This effect can be explained as in Experiment 1.

The main effect for the encoding condition factor, on the other hand, only achieves an F value smaller than 1 in both analyses. It thus appears that the "doing" condition does not generally accelerate the reaction, as in Experiment 1. Rather, there is a significant interaction between the factors of encoding condition and target item class, $F(1,36) = 11.76$ across items ($p < 0.01$) and $F(1,36) = 4.36$, $p < 0.05$ across subjects.

With a verbal repetition condition, the *verbs* are analysed more *slowly* than with a "doing" condition, whilst the *objects* are analysed *more quickly* with a verbal repetition condition than with a "doing" condition (see Fig. 6).

This interaction effect corresponds to our expectations, although the results from Experiment 1 had led us to anticipate larger numerical differences. However, these smaller differences (especially with verbs as targets) possibly result from the fact

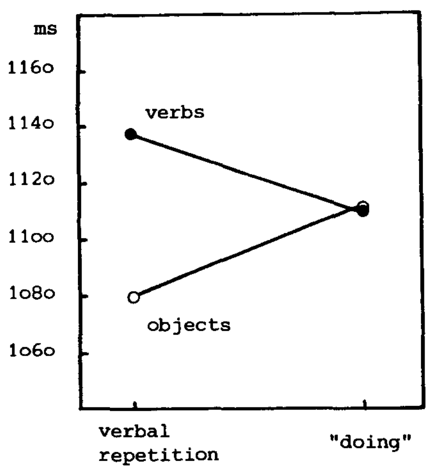

Fig. 6. Interaction between the factors of verbal repetition/doing and item class

that the instruction to decide whether or not a connection exists between the prime and the target item is less specific than the instruction in Experiment 1, and that there is a relatedness between the related primes and the verb targets with regard to their conceptual information on the one hand, and their motor programmes, on the other. The judgement about whether there is a connection between, for instance, "pick flowers" and "break off" or "eat the apple" and "bite" can probably be made on the basis of conceptual representation, as well as on the basis of motor programmes. The probability of the use of conceptual information with verb targets is further enhanced by the fact that prime object and prime verb pairings were mixed and processing of conceptual information was required with the prime object relationships. It is therefore all the more remarkable that the expected interaction between the encoding condition and the target item class can nevertheless be observed. This interaction clearly proves that 'doing' does not lead to quicker reaction times than verbal repetition for all tasks. Thus, in Experiment 1, the effect of 'doing' has to be considered as task specific and related to the motor programmes involved in the task.

General discussion

It was the goal of the present study to show also in the priming paradigm that it is useful to distinguish motor programme information, that is the knowledge that enables us to perform an action, from other knowledge that is connected with action phrases and that is called concept knowledge. Both representations are claimed to be partially independent memory units. The partial independency implies in particular that both representations can be activated independently. For both representations, special conditions for their activation should exist. While the processing of words automatically activates their concepts, the corresponding motor programmes should be activated only with specific task demands, especially with the instruction to perform an action.

This led us to demonstrate that the comparison of two action phrases for shared movement components takes less time when the first is performed, than when it is verbally repeated. This should be the case because the comparison judgement postulated requires the activation of motor programmes and because the execution of the first action led immediately to the activation of its motor programme while the verbal repetition of the first action tended to hamper this activation. 'Doing' should therefore shorten the comparison process, as compared to the verbal repetition condition.

Experiment 2 removed the objection that the shortening of assessment times with 'doing' compared to those with verbal repetition has its origins in a nonspecific effect of the execution of the action, which has nothing to do with a motor representation. We were able to show that execution of the action did not in every case facilitate assessment of a connection between prime and target items compared to verbal repetition, but only where activation of motor programmes is theoretically necessary for the task to be accomplished. This indicated that the difference in assessment times with verbal repetition and 'doing' is indeed based on motor representations and their differential activations.

The differential encoding effect applies equally to related and unrelated items. In the particular case of related items this difference should be intensified, since execution of the action with 'doing' preactivates not only the *MP* of the first action, but also the overlapping part of the *MP* of the second action at the same time. This additional effect should only occur with related items, and should result in a greater difference in reaction time between related and unrelated items with 'doing' compared to verbal repetition. This interaction between prime encoding and item relatedness could not be observed as clearly as we had wished. On the one hand, this interaction effect is overlaid by a series of other unintended effects, and on the other hand, it might also be possible that the motor programmes are less firmly interconnected than are concept nodes in a semantic network.

Although the results as a whole support the claim that concepts and motor programmes should be distinguished as separate memory units whose activation depends on different modality-specific processing conditions, the question about the code characteristics of these units cannot be answered on the basis of the experimental data given here.

Appendix 1

The list of prime and target items used in the first experiment (the pairings correspond to the related condition). It is to be noted that these are the translations of the originally used items that were presented in German.

List 1

Prime	*Target*
stir the ingredients	turn the handle
nail down the board	beat the carpet
open the drawer	draw the cup nearer
clench the fist	squeeze the sponge
pour the coffee	water the flowers
cut the paper	cut through the wire
polish the car	wipe the blackboard
screw in the light bulb	screw on the petrol cap
rub the hands	shape the dumplings
smooth the material	stroke the animal

List 2

Prime	*Target*
frank the letter	thump the table
cut the meat	saw off the branch
type (with a typewriter)	play the piano
rub the piece of paper between the fingers	wind up the watch
put on the thimble	put on the ring
hammer in the post	chop the wood
hand out the leaflets	deal the playing cards
turn on the tap	unscrew the bottle top
paint the door	wave the handkerchief
stick in the drawing-pin	ring the doorbell

Appendix 2

The list of prime and target items used in the second experiment. Here also, all items are translated from German. As a result, the verb of the prime and target item is the same in some cases. This was not the case in German.

	Prime items	*Target items*		*Prime items*
	related	*objects*	*verbs*	*unrelated*
List a:	pick the flowers	roses	break off	throw the dice
	squeeze the sponge	blackboard	press	put on the thimble
	rub out the word	sentence	rub	stack the logs
	eat the apple	pear	bite	open the yardstick
	close the sliding door	entrance	pull	crumple the envelope
	change the light bulb	light	screw	break the toothpick
	uncork the bottle of wine	glass	turn	draw the lottery ticket
	fan oneself	coolness	fan	wind the skein of wool
	look up in the dictionary	book	turn the page	open the purse
	kick the ball away	game	kick	take out the cigarette
List b:	undo the coat	trousers	unbutton	swing the pendulum
	clean the window	panes	wipe	bend the wire
	blow out the candle	wax	puff	press the key
	mix the ingredients	pastry	stir	press down the rubber stamp
	nail down the board	wood	hammer	take off the label
	hang up the washing	sock	peg	shake the rattle
	trace the drawing	picture	go over again	lift up the stone
	offer the sweets	chocolates	hand	switch on the torch
	write out the cheque	money	sign	stretch the eraser
	lock the chest	box	turn	tear up the paper

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References

Engelkamp, J., & Krumnacker, H. (1980). Imaginale und motorische Prozesse beim Behalten verbalen Materials. *Zeitschrift für experimentelle und angewandte Psychologie, 27*, 511–533.

Engelkamp, J., & Zimmer, H.D. (1983). Zum Einfluß von Wahrnehmen und Tun auf das Behalten von Verb-Objekt-Phrasen. *Sprache und Kognition, 2*, 117–127.

Engelkamp, J., & Sieloff, U. (1984). Differentialpsychologische Aspekte eines motorischen Gedächtnissystems. Arbeiten aus der Fachrichtung Psychologie der Universität des Saarlandes, Nr. 85. Saarbrücken.

Hoffmann, J. (1982). *Das aktive Gedächtnis.* Berlin: VEB Deutscher Verlag der Wissenschaften.

Holyoak, K.J., & Glass, A.L., Santa, J.L. (1979). *Cognition.* London: Addison-Wesley.

Klix, F. (1982). On structure and function of semantic memory. In: Klix, F., Hoffmann, J. (eds) *Cognition and memory.* Berlin: VEB Deutscher Verlag der Wissenschaften.

Kosslyn, S.M., & Pomerantz, J. (1977). Imagery, propositions, and the form of internal representations. *Cognitive Psychology, 9,* 52–76.

Lindsay, P.H., & Norman, D.A. (1977). *Human information processing.* New York: Academic Press.

Loftus, E.F. (1973). Category dominance, instance dominance, and categorization time. *Journal of Experimental Psychology, 97,* 70–74.

Pylyshyn, Z.W. (1973). What the mind's eye tells the mind's brain: A critique of mental imagery. *Psychological Bulletin, 80,* 1–24.

Sanford, A.J., & Garrod, S.C. (1981). *Understanding written language.* Chichester: Wiley.

Wickelgren, W.A. (1979). *Cognitive psychology.* Englewood Cliffs, N.J: Prentice Hall.

Zimmer, H.D., & Engelkamp, J. (1984a). An attempt to distinguish between kinematic and motor memory components. *Acta Psychologica* (in press).

Zimmer, H.D., Engelkamp, J. (1984b). Planungs- und Ausführungsanteile motorischer Gedächtniskomponenten und ihre Wirkung auf das Behalten ihrer verbalen Bezeichnungen. *Zeitschrift für Psychologie* (in press).

Zimmer, H.D., Engelkamp, J., & Sieloff, U. (1984). Motorische Gedächtniskomponenten als partiell unabhängige Komponenten des Engramms verbaler Handlungsbeschreibungen. *Sprache & Kognition, 3,* 70–85.

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