Psychol Res (1989) 51: 201–207

Psychological Research

Sensory and conceptual representations in memory: Motor images that cannot be imaged

Walter J. Perrig and Daniel Hofer

University of Basel, Department of Psychology, Bernoullistrasse 14, CH-4056 Basel, Switzerland

Summary. The paper argues for a distinction between sensory- and conceptual-information storage in the human information-processing system. Conceptual information is characterized as meaningful and symbolic, while sensory information may exist in modality-bound form. Furthermore, it is assumed that sensory information does not contribute to conscious remembering and can be used only in data-driven process repetitions, which can be accompanied by a kind of vague or intuitive feeling. Accordingly, pure top-down and willingly controlled processing, such as free recall, should not have any access to sensory data. Empirical results from different research areas and from two experiments conducted by the authors are presented in this article to support these theoretical distinctions. The experiments were designed to separate a sensory-motor and a conceptual component in memory for two-digit numbers and two-letter items, when parts of the numbers or items were imaged or drawn on a tablet. The results of free recall and recognition are discussed in a theoretical framework which distinguishes sensory and conceptual information in memory.

In this study we argue for the distinction of two types of control over human behavior. We distinguish between a conceptual and a sensory form of behavioral regulation in the human organism. We assume that our behavior is controlled by conceptual mechanisms when we willingly use our knowledge to behave in a certain way. By conceptual mechanisms we mean processes operating on the symbolic representation in memory that refers to the real world and constitutes our world knowledge. Thus we know how and why we write a letter, go shopping, listen to the radio, etc. Even automatic processing in the sense of Shiffrin and Schneider (1984), where basic elements have to be understood and repeated over and over, is in principle tied to this conceptual processing. The basic elements of conceptual information can be characterized as meaningful and symbolic. The information is represented in the form of a concept or idea. For the distinction that we postulate here, it is not important whether there are verbal labels connected to concepts or not. By "concept" we mean experiences or perceptual units that have meaning to a person. Concepts represent experiences that are classified, categorized, or interpreted in an episode. It does not matter whether this episode will be remembered later or not. The crucial issue of conceptual processing is, however, that a physical stimulation in a perceptual event is recognized or categorized "as" something. We could also say that a person has knowledge about what he or she is doing. In this sense the real world is seen as a meaningful configuration of objects, while in an unnatural world only parts can be interpreted meaningfully.

As for the modality-specific processing, conceptual processing certainly sometimes preserves some modality-specific features, but these features are not bound to a sensory modality. Here it is also the point to state that we consider imagery, as far as people report about it and as far as we measure some performances in top-down processing tasks such as free recall, as conceptual processing. The rational and the empirical evidence for this position has been presented in Perrig (1988a). The sensory-motor representations, which we manipulate in the two experiments to be presented below, are of a nature that cannot be imaged introspectively.

Information stored in the form of concepts is principally accessible to consciousness. We might even say that our subjectively developed concepts or our meaningfully categorized experiences are the constituents of consciousness. Thus we can reason, speak, or think about actions during or after performance of the action. In this sense conceptual processing is mainly conscious processing. Consequently, meaningful concepts are also the source for, and the content of, top-down processing. This means that we can think about any kind of real or imaginary worlds without any physical or sensorial input.

In addition, we have reports about behavioral phenomena in which behavior seems to be controlled by a representational basis that does not share the features of conceptual processing.

First, and most obviously, we find such phenomena in studies of subliminal perception. In these studies stimuli are presented for such a short time that the subjects cannot identify them. But later it can be demonstrated that the subjects' behavior must be directly related to the previous presentation. Such findings have never really produced much interest among the scientific community. The main reason has been the methodological problems in the studies. For instance, one could never be quite sure if some kind of partial perception was responsible for the results. But there are studies of such impressive methodological

---

Offprint requests to: W. J. Perrig

control that we have few reasons to question the results – e.g., a study of Marcel (1983) in which after the individual absolute visual-perceptual threshold had been measured, presentation time for words was reduced below this threshold. People then reported that they could not see the stimuli. Nevertheless, in a forced guessing task in which subjects had to select the one word of a word pair that was perceptually similar to the "unseen" word, and in a second task the word similar in meaning to the target word, subjects showed correct guessing. This means that their selection of the correct words was far above chance level.

We also find reports of correct guessing in clinical studies. Weiskrantz et al. (1974) describe an experiment with a patient whose visual cortex of one hemisphere had been surgically removed. When either a circle or a cross was presented in the hemianoptic field, the patient could not see anything. When forced to select one of the two now visible figures, he selected in 28 out of 30 trials the one previously presented to the hemianoptic field. In another clinical report Claparède (1911) describes an episode of a patient suffering from heavy amnesia. One day, Claparède hurt his patient while shaking hands by holding a thumbtack in his hand. The next day the patient refused to shake hands again, but was unable to tell the reason why he did so. Meanwhile we have a large literature comparing amnesic patients with the normal population. The general pattern shows that the patients' deficits are mainly restricted to episodic memory, while they show virtually the same positive effects from old information in implicit memory tasks with strong bottom-up processing components, such as word completion (Graf, Squire, & Mandler, 1984).

The phenomena reported so far show that some kind of behavioral regulation happens, of which subjects are not aware. It might be too early to equate this behavioral control with what we shall call sensorial control. Here one might argue that the fact that somebody is not aware of determinants of his or her behavior does not mean that the regulation happens on the basis of a sensorial representation. We want therefore to present some other observations that should show that it is almost impossible for the representational basis of this unconscious behavioral control to be of some conceptual or meaningful type. This observation comes from studies that investigate the so-called perceptual-repetition effect and from studies in procedural learning.

In several studies, it has been possible to show that visually presented verbal or pictorial stimuli were identified faster than new stimuli in a subsequent identification task. This effect seems to be independent of such factors as the depth of processing and the interval between the acquisition and test phases, factors that have strong effects on semantic memory or recognition memory. For this reason, some authors (Jacoby & Dallas, 1981; Jacoby, 1983a, b) suggested that the repetition effect in perceptual identification depends only on data-driven processes, while recognition memory also depends on conceptually driven processes.

However, there are some findings (Murrell & Morton, 1974) that are incompatible with this interpretation. It has been demonstrated that words that share only some physical features with the previously presented words produce a smaller repetition effect than words that share, beside the physical features, some conceptual components with the previously presented words (e.g., target: basis; test: basic or basin).

We carried out experiments to investigate further the influence of perceptual or conceptual components of memory on the repetition effect (Probst & Perrig, 1988). In an acquisition phase, a number of words and word approximations (pseudo-words: e.g., *ktrse*) were presented to the subjects on a screen, each for 3 s. Thus the semantic content of the stimuli was manipulated. The subjects had either to spell the items or to form a semantic association; in this way, the depth of processing was varied. In a subsequent test phase, subjects had to identify old and new items that were presented on the screen. The presentation was controlled by a recursive function in which a mask with continuously decreasing presentation time was followed by an item with continuously increasing presentation time. After identification of an item, subjects had to indicate whether the item was shown in the acquisition phase (recognition test) or not.

We were able to show that old items were identified faster than new items. While this repetition effect did not depend on the depth of processing in the acquisition phase, performance in the recognition test was heavily influenced by the level of processing. Beside this replication of known findings, it was possible to demonstrate that the repetition effect was largest with word approximations (although not significantly different from the effect found with actual words). A weak repetition effect was also demonstrated in the case of synonyms of old words that shared no perceptual features with these. This fact suggests that not only perceptual, but also conceptual, components of memory contribute to the repetition effect. This contradicts the interpretation of Jacoby and his collaborators (1983). It seems, however, that the perceptual components are the major determinants.

Results of a second experiment in which an interval of 48 hours was introduced between acquisition and test phase suggest that the conceptual component of the repetition effect is of shorter duration than the perceptual component. While the repetition effect was as extensive as in the first experiment, the performance in the recognition test had deteriorated. Furthermore, with synonyms no repetition effect could be shown anymore. A highly interesting perspective is opened up by the fact that the repetition effect was also demonstrated with misses, i.e. items the subjects did not remember having been shown in the acquisition phase. This fact suggests that the repetition effect depends at least partly on memory traces that are of purely perceptual features and are not accessible to conscious retrieval, suggesting a form of unconscious, sensory control of behavior.

Congruent with this assumption are some other features of the repetition effect in perceptual-identification tasks: as already mentioned, the repetition effect is not influenced by factors known to be very effective in semantic or conceptual-memory tasks. The decay of the memory trace seems to be much slower than in conceptual memory. Furthermore, the repetition effect seems to be modality specific (Jacoby & Dallas, 1981; Clarke & Morton, 1983); at least, the effect is very weak when modality is changed in the test phase (Kirsner & Smith, 1974; Roediger & Blaxton, 1987).

A very nice demonstration of nonconceptual acquired working knowledge that later on facilitates performance

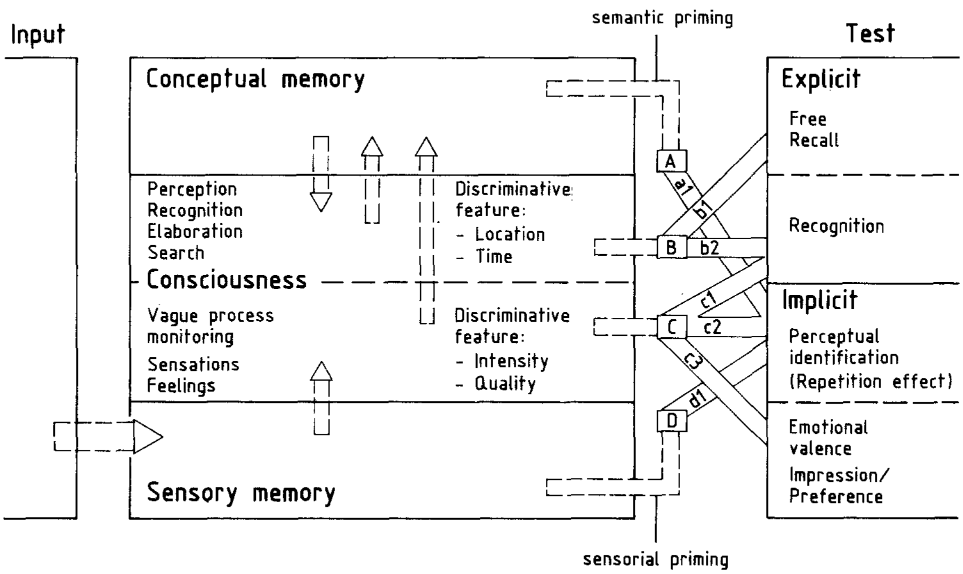

Fig. 1. Theoretical components measured by implicit- and explicit-memory tests

was recently presented by Lewicki, Hill, and Bizot (1988). Their subjects had to search for a target in one of the four quadrants of a computer screen. The sequence of target locations in some trials was random; in other trials it followed a rule-governed complex pattern. Accuracy and latency of the subjects' responses indicated that they had acquired a specific working knowledge about the pattern that facilitated their performance. But in fact, extensive postexperimental interviews with the subjects showed that none of them noticed anything even remotely similar to the actual nature of the manipulation.

From the observations mentioned so far we summarize the following crucial conclusions:

(1) Memory traces of previous experiences influence performance in implicit memory tests without reaching the level of conceptual or conscious reasoning. Construction, usage, and decay of these memory traces seem markedly different from conceptual representations.

(2) Subjects' verbalizations suggest that these unconscious memory performances are correlated by vague impressions or feelings.
This awareness is a kind of process monitoring in that, e.g., repetition effects result in impressions or verbalizations such as *this is familiar to me*, *the task is somehow easier*, or *I like this more.* From this it is clear that the basis of this behavioral determination is not a symbolic or categorial apprehension, but has much more vague dimensions, which nevertheless have discriminative meaning. We think that these vague experiences or this process monitoring could be the most basic principle for the development of conceptual knowledge. Maybe such a process monitoring is the basic interface between a sensorial low-level learning and cognitive and conceptual learning.

Next we would like to present a memory model that distinguishes four functional units and their possibly combined contributions to different memory tests (Fig. 1).

According to this model, a specific-memory test is controlled by different components. In data-driven processes we might isolate on the operational level measured by an implicit-memory test, the effects of semantic priming (a 1) (lexical decision) or sensorial priming (d 1) (repetition effect in perceptual identification), which are not the subjects of willingly and consciously made decisions. On the contrary, in free recall we measure conscious remembering exclusively in terms of conceptual reasoning and conceptual memory (b 1). In recognition we first have the influence of a channel that is rooted in memory traces that are willingly accessible (b 2). But there is also a second channel (c 1) influencing performance: an old item can reactivate the sensory memory, which might be paralleled by some vague conscious sensations. These sensations, based on some kind of emotional intensity and quality, can bias a "yes" or a "no" response, depending on the previous sensorial activation. This model assumes that sensory traces cannot be searched voluntarily by conscious reasoning processes. They receive their power to control behavior either directly (D) or through a conscious process monitoring (C) in data-driven bottom-up processes.

In two experiments we selected free recall and recognition to test different effects of conceptual and sensory memory on human behavior. We tested the memory for numbers or letter pairs, which previously had either been drawn symbolically or imaged on a tablet, to investigate the characteristics of motor-memory traces.

With this goal we are, at the operational level, situated in a research area that has been put forward by Engelkamp and Zimmer (1985). What these authors repeatedly found was improved free recall of verbally presented action phrases when these action phrases were enacted symbolically in the learning phase. Engelkamp and Zimmer relate this effect to "motor programs", memory traces in the form of "sensory-motor representation" that had been established beside the representation of the conceptual meaning of the auditorily presented action phrases. This position is quite different from our theoretical framework, presented above. In our view, the effects found in free recall must be the result of some conceptual process in the form of elaboration, discrimination, organization, etc., and cannot be the result of reactivated sensory traces, since sensory representations as characterized above should not be accessible by a top-down retrieval process such as free recall. In a previous study (Perrig, 1988 b) it was shown that a "motor" group, enacting action phrases, did not have better free recall than an "image" group, imaging action phrases, when both groups were informed that "... only actions are presented, which you can perform by yourself." We concluded that this information equalized the search domain, an influential factor in conceptual memory during the retrieval of the heard action phrases, and wiped out the recall differences previously found. Meanwhile we know of other conditions preventing differences in free recall between "motor" and "nonmotor" groups (Helstrup, 1988).

According to our distinction between a conceptual and a sensorial type of behavioral regulation, we should be able to separate both components in the case of someone performing a motor behavior. After an episode of this sort, the human organism should have available the conceptual and meaningful knowledge or memory about the action performed, which can be used in all top-down or imaginary processing. Beside this knowledge, the organism should also have available a sensory-motor representation that can only be used to facilitate later processing when data-driven or bottom-up processing occurs in a process repetition.

Experiment 1

To test our assumptions, in a first experiment we chose a learning phase in which the subjects were presented with two-digit numbers. With one half of the numbers, subjects had to image how they would draw them on a board located on their desk. For the other half of the numbers, they were advised to trace the shape of the numbers with their index finger. It was an incidental-learning task. After this task subjects had to free recall all the numbers they could remember. This task was followed by a recognition task with old and new numbers, in which subjects had either to image or to image and to draw half of the numbers before they made the decision whether the number was an old or a new item. In our hypothesis we predicted differential effects for the two memory tests. Because we assumed that free recall has no access to the sensory trace of the movement and because of the uniform two-digit numbers, we did not expect that the movements would have any organizational effects in terms of selective attention, semantic elaboration, or discriminative traces, etc. We did not expect to get any movement effect in free recall. On the other hand, we expected that the sensory-motor memory trace would positively influence performance in recognition that is influenced by bottom-up processing. According to our theoretical framework, the awareness of redoing an action should bias subjects' reactions toward "yes" responses when old items are presented. That is, we expected improved recall only in the recognition condition in which previously drawn numbers had to be drawn again before the old-new judgement was made.

Method

Subjects. These were 20 psychology students (16 female and 4 male) from the University of Basel, Switzerland.

Materials. Two 44-number lists were constructed from the two-digit numbers from 10 to 97. These numbers were assigned randomly to the lists. A four-channel multitrack tape (TEAC A-3440) was used to present the numbers to

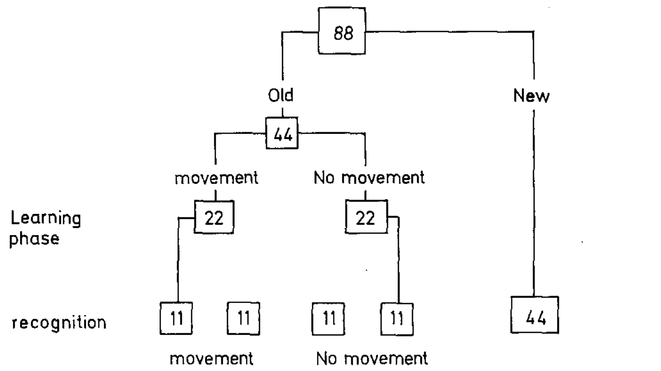

Fig. 2. Construction of the list with the numbers ranging from 10 to 97 in Experiment 1

the subjects via headphones. All responses from the subjects were recorded on a PC (ATARI 1040ST).

Design and procedure. The experiment was conducted in single sessions. A whole session was divided into three phases (learning, free recall, and recognition) and lasted about 45 min. At the beginning of each phase written instructions were given to the subjects. Before the learning phase a few numbers (ranging from 1 to 10) were read aloud so that the subjects could learn the procedure and the timing. In the learning phase one of the 44-number lists was read aloud to the subjects. According to the aim of the experiment, half of the list (22 numbers) had to be learned to the accompaniment of a corresponding movement, and the other without movement. The subjects first heard a number and then had to image that number space filling a blank blue sheet (A4) in front of them. After 4 s a high or a low peep sound was given, indicating that they should either draw the imaged number with a finger on the sheet (movement condition) or only imagine how they would draw the number (no-movement condition), respectively. Subjects were given 5 s to draw the number. The next number on the list followed. This procedure was repeated until the 44 numbers were presented.

Immediately after the learning phase an unexpected free recall was initiated. The subjects had to say aloud all the numbers they remembered. The experimenter registered all the responses on the PC. During the last phase of a session a recognition test was given. The 44 numbers previously learned and the new 44-number list were mixed randomly. Also in this phase the subjects had first to image the given number (4 s) and then, according to the peep sound, to draw the number or only to imagine the act of drawing (4 s), respectively. Half of the 22 numbers on the learning list, which had been learned to the accompaniment of a corresponding movement, were now given with a no-movement instruction (indicated by the peep sound). Half of the numbers that had been learned with no movement had to be recognized with a movement instruction (the construction of the lists is shown in Figure 1). Then a verbal command "NOW" indicated that the subject had to respond with "old" (the item was in the learning list) or "new" respectively. The procedure was repeated until all 88 numbers were presented. All responses were registered on the PC by the experimenter.

All the subjects received the same list in the same order. A 2 × 2 factorial design was obtained with the two

Table 1. Mean responses in free recall (Experiment 1) (n = 19)

Correct responses		False responses
movement	no movement	
7.63	5.16	3.79

within-subjects factors Learning (movement, no movement) and Test (movement, no movement). Discrimination scores (d′) were calculated on the basis of z-transformed hit and false-alarm rates.

Results and discussion

The results of the free recall are shown in Table 1. The data of one male subject were lost, so only 19 subjects are included in this analysis. All correctly recalled two-digit numbers were counted. Numbers that were learned with a movement were recalled better than numbers without movement. An analysis with the paired t-test revealed a significant effect, $t = 4.16$, $p < .01$. We expected that there would be no difference in free recall between the two learning conditions. The results we found suggest that our subjects in free recall had access to the movement information. It is possible that the change between drawing and not drawing in the within-subjects design produced a selective effect in favor of the items drawn. These items could have received more attention, leading to better recall.

The d′-transformed recognition data were analyzed by an analysis of variance (ANOVA) for repeated measurements. The results are shown in Table 2. While the test condition had no effect, $F = 0.83$, the ANOVA revealed a significant main effect for the learning condition, $F(1,19) = 7.82$, $p < .05$. Of the numbers drawn in the learning phase more were recognized correctly than of the numbers that had only been imaged. We expected that the sensory-motor memory trace could only be accessed in the condition in which previously drawn items had to be drawn again before the recognition judgement. Although there is a tendency toward our hypothesis (Table 2: if an item was learned with movement and again presented with a movement instruction, then performance was better than an item was presented with no movement instruction), the expected interaction between learning and test condition was not significant, $F = 0.85$. The congruent-movement condition (movement in learning and test) led to better performance than the congruent-nomovement condition (no movement in learning and test), $t = 2.92$, $p < .008$, excluding simple congruency interpretations.

Compared to the free-recall data, the discrimination scores of this experiment at least bring suggestive support for our theoretical rationale given above, but clearly these results are not those we expected. The within-subject manipulation of the encoding strategy (movement vs. no movement) could be one reason for the discriminative encoding of the two types of items. From our subjects' verbal reports it is highly plausible to infer that conceptual processing might have overwritten our expected pure bottom-up effects of sensory-motor traces in recognition and produced the unexpected effects in free recall. According to this experience, we designed a second experiment in which the material, as well as the design, was changed to get better control for these conceptually effective factors.

Experiment 2

Method

Subjects. These were 40 students between 20 and 40 years old from a secondary school in Basel.

Material. The same technical equipment was used as in Experiment 1. But we now constructed two two-letter item lists, one with 20 items (learning list), the other with 15 items. We constructed the letter pairs so that they were meaningless in that they did not immediately offer associations with well-known word pairs or abbreviations. For the recognition test we chose 15 items from the learning list (old), and mixed them randomly with the 15 items not shown before (new).

Design and procedure. The experiment was conducted in single sessions. The procedure was the same as in Experiment 1 except that (1) between the learning phase and free recall another experiment was included (lasting about 30 min, so that we got a delayed free-recall test), and (2) we used a between-subjects manipulation for the movement condition (movement vs. no movement) in the learning phase and in the test phase.

Thus a 2 × 2 factorial design was obtained with the between-subjects factors Learning (movement, no movement) and Test (movement, no movement). Before the learning phase we familiarized the subjects with the procedure and timing. In the learning phase a two-letter item was read aloud. According to instructions, all subjects had first to image the item on the blank sheet and then, depending on the experimental group, to draw the letters or to image the drawing. After 10 s the next item was given. This was continued until all 20 items had been given. After the delayed free recall a recognition test was presented. First a two-letter item was read aloud. Then the subjects had 8 s to image that item and, depending on the experimental group, to draw it. A peep sound prompted the subjects for their recognition judgements "old" (item in the learning list) or "new" (item not given before) respectively. The procedure was repeated until all 30 items were presented. All the responses were registered on a PC by the experimenter.

Table 2. Mean d'values in recognition test (Experiment 1) (n = 20)

Learning	movement		no movement	
Recognition	movement	no movement	movement	no movement
	0.95	0.73	0.41	0.40

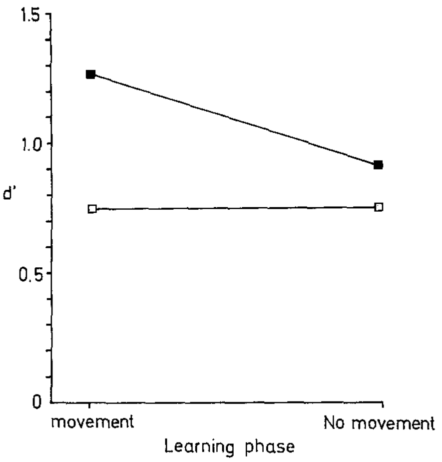

Fig. 3. Mean d'values in recognition test in Experiment 2 (n = 40). Test phase ■ movement □ no movement

Results and discussion

The free-recall data showed that this time the group with no-movement instruction had better performance (3.36 items) than the group with movement instruction (1.64) items, t = 3.09, p <.01. This effect is the reverse of the one found in Experiment 1. However, this effect is congruent with findings presented by Engelkamp (1986) and Engelkamp, Zimmer, and Denis (1989). They found that the learning of item pairs is worse under an enacting condition than in an imagery condition. It seems that the enactment of the single items prevents the association of the pair. Here we do not want to elaborate further on the interpretation of their findings. But a general conclusion is possible. It seems that drawing the letter pairs somehow interfered with the conceptual organization of these pairs, leading to impaired recall. It is notable that the recall level is very low in both groups, indicating that no efficient encoding strategy had been used to enhance conceptual representation. These data seem to prove that in this experiment we succeeded in avoiding discriminatory or organizational conceptual factors that might influence the memory for the movement items. Thus we should be able to measure the influence of the sensorial representation on the performance in recognition test (c1 in the model) in the absence of any influence of a conceptual representation (b2 in the model).

The results of recognition memory in the four groups are presented in Figure 3.

As can be seen from Figure 3, the movement-congruence group has by far the best performance in the discrimination task (scores = d′) among the experimental groups. The ANOVA revealed no significant effects. However, the planned comparisons between groups showed significantly better discrimination for the movement-congruence group compared to that of the group that had movement instruction during learning, but not during test, t = 2.10, p <.05. As in Experiment 1, the results show that this is not simply a congruency effect because the no-movement-congruence group showed significantly worse results, t = 2.24, p <.05, than the movement-congruence group.

In summary, the results of Experiment 2 reveal strong support for our theoretical distinction between a conceptual and a sensorial representation and their differential characteristics. We predicted that a human organism is able to store a sensory trace of a perceptual event which cannot be used in consciously and willingly performed top-down processing, but will influence or control behavior in data-driven bottom-up processes. The findings of Experiment 2 mirror this prediction exactly. While a motor movement and its assumed memory trace does not improve free recall, (but actually decreased free recall in this experiment), it clearly does enhance recognition, but only in the case when the same movement immediately precedes the judgement in the test phase.

General discussion

The reported observations from different research areas should closely mirror the theoretical distinction at an operational level. The data presented (1) from studies in subliminal perception, (2) from studies in clinical observations, and (3) from the results of studies working with perceptual identification, successfully served this function. Common to all observations is the fact that some kind of learning takes place, of which no traces are left in conscious remembering, and which is not affected by factors known to be highly influential on conceptual memory. Notions like implicit learning, implicit knowledge, working knowledge, anoetic memory, remembering without awareness, etc., could have been used to make reference to the phenomena under consideration here. But at this time, all these notions are merely descriptive names for the state of affairs to be explained. The theoretical framework presented here should demonstrate our decisive attempt to spell out and to elaborate the psychological basis for a wide range of highly fascinating, but, to the same degree mysterious, observations. Common to these phenomena are components that suggest a behavioral regulation that shares rather few features with conceptual or reasoning processes. Our model distinguishes between a conceptual and a sensory storage of information and their counterparts in subjective consciousness and awareness. The influence of these different functional units on different implicit- and explicit-memory tests can be predicted.

The two experiments demonstrate our approach to finding further empirical justification for the distinction sketched between a conceptual and a sensory form of representation. The crucial assumption tested was that a human organism is able to store – in addition to conceptual information constituting conscious and rational high-level cognition – a sensory trace of a perceptual event, which cannot be used in consciously and willingly performed top-down processing such as free recall, but will influence or control behavior in data-driven bottom-up processes such as recognition. In our experiments we initiated finger movements (drawings of digits and letters), which accompanied the imagery of some letters or digits, but not of others.

By the use of uniform stimuli to be learned (two-letter items and two-digit numbers), we tried to avoid discriminatory representations in conceptual memory for drawn and imaged items. Therefore, in accordance with our theory, we did not expect an encoding effect in free recall. But we did expect better recognition with enacted items when these items could be redrawn before the "yes" or "no" decision. We predicted this result because we expected that in this data-driven, bottom-up recognition process stored sensory information is reactivated and influences the human judgement. The recognition data of Experiment 1 revealed a strong tendency toward our hypothesis. Although the items drawn in learning and drawn again before the recognition judgement were recognized better than the items not drawn again in the test phase, the difference was not statistically significant. In fact, of the items drawn in the learning phase, more were recognized correctly than of the items only imaged. Contrary to our expectation, we found the same effect in free recall. Items that were learned with a movement are recalled better than items without movement. These results suggest that our subjects may have had access to the movement information in free recall. Verbal reports of subjects supported the assumption that the within-subject manipulation of the encoding strategy (movement vs. no movement) could be one reason for the discriminative encoding of the two types of items. It might have been possible for the subjects to discriminate between the movement and nonmovement condition and to use this as a cue, which caused higher free recall so that nonmotor components were important. From these reports it is highly plausible to infer that such conceptual processing might have overwritten our expected pure bottom-up effects of sensory-motor traces in recognition and produced the unexpected positive effects in free recall and recognition in Experiment 1.

While the results of Experiment 1 only brought marginal support, Experiment 2 revealed stronger support for our theoretical assumptions. In Experiment 2 the results showed that while a motor movement and its assumed memory trace does not improve free recall (conceptual top-down processing), it does enhance recognition, but only in the case when the same movement immediately precedes the recognition judgement in the test phase (data-driven, bottom-up processing). In fact, the movement condition even impaired free recall. The subjects in the movement condition in the learning phase recalled fewer letter pairs than the subjects who did not draw the letters. In the recognition test, however, the movement-congruence group (drawing in learning and test) had by far the best performance, while among the lower performances of the other groups no differences were found. These results nicely support our theoretical framework. They suggest that in Experiment 2 the movement information could not be used at the conceptual level. The act of drawing even seemed to interfere with the learning of the letter pairs. At the same time, the recognition data show that movement information had been stored that positively influenced the recognition judgement when it could be reactivated in a performance of the same movement again. Here, we assume that this control of behavior takes place on a sensorial basis which cannot be accessed by conscious high-level cognition in a top-down manner.

Acknowledgements. This research was supported by Grant 1000-002445 from the Schweizerischen Nationalfonds.

References

Claparède, E. (1911). Recognition et moiitè. *Archives de Psychologie, 11,* 79–90.

Clarke, R., & Morton, J. (1983). Cross modality facilitation in tachistoscopic word recognition. *Quarterly Journal of Experimental Psychology, 35 A,* 79–96.

Engelkamp, J. (1986). Nouns and verbs in paired-associate learning: Instruction effects. *Psychological Research, 48,* 153–159.

Engelkamp, J., & Zimmer, H. D. (1985). Motor programs and their relation to semantic memory. *German Journal of Psychology, 9,* 239–254.

Engelkamp, J., Zimmer, H. D., & Denis, M. (1989). Paired associate learning of action verbs with visual or motor imaginal encoding instructions. *Psychological Research, 50,* 257–263.

Graf, P., Squire, L. R., & Mandler, G. (1984). The information that amnesic patients do not forget. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 10,* 164–178.

Helstrup, T. (1988). Performed memory acts in loci contexts: Some data and some theoretical reflections. Paper presented at the second workshop on imagery and cognition. University of Padua, Italy.

Jacoby, L. L. (1983 a). Perceptual enhancement: Persistent effects of an experience. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 9,* 21–38.

Jacoby, L. L. (1983 b). Remembering the data: Analyzing interactive processes in reading. *Journal of Verbal Learning and Verbal Behavior, 22,* 485–508.

Jacoby, L. L., & Dallas, M. (1981). On the relationship between autobiographical memory and perceptual learning. *Journal of Experimental Psychology: General, 110,* 306–340.

Kirsner, K., & Smith, M. C. (1974). Modality effects in word identification. *Memory & Cognition, 2,* 637–640.

Kolers, P. A., & Roediger, H. L., III (1984). Procedures of mind. *Journal of Verbal Learning and Verbal Behavior, 23,* 525–449.

Kolers, P. A., & Smythe, W. E. (1984). Symbol manipulation: alternatives to the computational view of mind. *Journal of Verbal Learning and Verbal Behavior, 23,* 289–314.

Lewicki, P., Hill, Th., & Bizot, E. (1988). Acquisition of procedural knowledge about pattern of stimuli that cannot be articulated. *Cognitive Psychology, 20,* 24–37.

Marcel, A. J. (1983). Conscious and unconscious perception: experiments on visual masking and word recognition. *Cognitive Psychology, 15,* 197–237.

Murrell, G. A., & Morton, J. (1974). Word recognition and morphemic structure. *Journal of Experimental Psychology, 102,* 963–968.

Perrig, W. J. (1988 a). *Vorstellungen und Gedächtnis.* Berlin: Springer.

Perrig, W. J. (1988 b). On the distinction of memory codes: Image versus motor encoding. In M. Denis, J. Engelkamp, & J. T. E. Richardson. *Cognitive and neuropsychological approaches to mental imagery.* Dordrecht: Martinus Nijhoff.

Probst, R., & Perrig, W. J. (1988). Perzeptuelle und konzeptuelle Anteile gespeicherter Erfahrungen. *Zeitschrift für experimentelle und angewandte Psychologie, 35,* 259–281.

Roediger H. L., III & Blaxton, T. A. (1987). Effects of varying modality, surface, surface features, and retention interval on priming in word-fragment completion. *Memory & Cognition, 15,* 379–388.

Shiffrin, R. M., & Schneider, W. (1984). Automatic and controlled processing revisited (theoretical note). *Psychological Review, 2,* 269–276.

Weiskrantz, L., Warrington, E. K., Sanders, M. D., & Marshall, J. (1974). Visual capacity in the hemianoptic field following a restricted occipital ablation. *Brain, 97,* 709–728.