ACTION CONCEPTS AND THE ENACTMENT EFFECT

SOPHIE KENNY

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by

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Abstract

When action lists are presented, participants do better on memory tests if they perform the action described while learning than if they remain still (Engelkamp & Krumnacker, 1980). According to the multimodal memory theory, this enactment effect originates at encoding, when motor information enriches the memory trace, leading to better performance at test (Engelkamp, 1998). In this thesis, a limiting condition for motor encoding to enhance memory for abstract arm motions was assessed: This was a test of the necessity of pre-existing action concepts for motor encoding to occur. A pilot study and three critical experiments were completed. The pilot study informed the design of the stimuli used throughout the thesis. Experiment 1 assessed the presence of an enactment effect with a recognition test. An enactment effect was demonstrated, but there was no interaction with conceptual processing. Experiment 2 tested whether the enactment effect would be also be obtained in recall, in the absence of action concepts. Contrary to Experiment 1, the enactment effect was not obtained. Experiment 3 replicated Experiment 2, with the change that conceptual processing was facilitated. The enactment effect was not obtained with this experiment either. The data provided mixed evidence for the multimodal memory theory, but one thing is clear: Action concepts are important for motor encoding, but not as specified by Engelkamp.

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Chapter 1

Introduction

Since the 1980s, several researchers (e.g., Cohen, 1981; Engelkamp & Krumnacker, 1980) have studied the experimental finding called the enactment effect: Participants learn lists of action phrases better if they act out, or perform, the corresponding movements than if they do not. Converging evidence has favoured an explanation for memory improvement based on the nature of information that can be encoded during a learning episode. In the multimodal memory theory (Engelkamp, 1998), which has provided the most comprehensive account of the enactment effect, it is proposed that performing actions allowed otherwise unavailable motor information to enhance memory for enacted items. This interpretation has been supported by thirty years of research: Motor encoding has accounted for the presence of the enactment effect in numerous variations of the typical study. Although several ramifications of the multimodal memory theory were tested during that period, and extensions to the multimodal memory theory were proposed to account for counter-intuitive findings, at least one implication of the theory was not directly challenged. In this thesis, I therefore set out to test the notion that pre-experimental conceptual knowledge of to-be-remembered movements is crucial in obtaining the enactment effect.

1.1 Literature Review

1.1.1 Overview of the Enactment Effect

In the early 1980s, two independent research groups studied the effect of motor performance on intentional list learning. In what will be referred to as the *typical experiment* (e.g., Cohen, 1981; Engelkamp & Krumnacker, 1980, in English in Engelkamp, 1998), an experimenter read lists of 12 to 48 to-be-remembered action phrases at a constant pace. These action phrases were verb-object pairs such as *comb your hair, hammer the nail, open the marmalade jar, touch your nose*, and *point to the door*. Participants assigned to the *listen* condition simply heard the action phrases. Participants assigned to the *act* condition, after each action phrase, received the object mentioned and performed the appropriate action. Regardless of the encoding condition, after the list presentation was over, participants wrote down in a *recall test* all the action phrases they remembered. When the researchers compared memory performance across these control and critical *encoding conditions*, they discovered the *enactment effect*: Participants who had enacted the action phrases performed better than participants who had simply listened to them. For example, enacting lead to a 9% (Cohen, 1981) and 15% (Engelkamp & Krumnacker, 1980) increase in action phrase recall relative to the listen condition.

The enactment effect was demonstrated to be robust, despite variations on the typical experiment. For instance, it did not matter if encoding conditions were varied between- or within- participants: A memory advantage was observed both when different participants (Cohen, 1981; Engelkamp & Krumnacker, 1980) and when the same participants (Engelkamp & Zimmer, 1997) were assigned to the act and listen encoding conditions. The memory test did not generally matter either, and the enactment effect was obtained with both free recall and recognition (for examples of studies including both tests, see Bäckman, Nilsson, & Chalom, 1986; Cohen, 1981, 1983). In addition, the mode of recall was shown to be irrelevant to obtain an enactment effect. Although most studies used *written* recall (e.g., Cohen, 1981), an enactment effect was also detected with *spoken* recall (e.g., Experiment 4 of Cohen, Peterson & Mantini-Atkinson, 1987). Additionally, overt motor recall (i.e., performing the actions for the recall test) was similar to written and spoken recall (Watanabe, 2003).

Inspired by Craik and Lockhart's (1972) idea that experimental instructions affected quality of encoding, Engelkamp and Krumnacker (1980; in English in Engelkamp, 1998) proposed that the cause of the enactment effect resided in differences in the encoding processes between listening to and enacting action phrases. They held that simply listening to action phrases allows the verbal information, the spoken action, to be encoded into the item's memory trace[1]. Performing the appropriate movement after hearing an action phrase allows encoding of both motor and verbal information. Enactment was said to lead to richer encoding than the control condition, and therefore, to better performance at the memory test.

At this point, the enactment effect is to be distinguished from the production effect (MacLeod et al., 2010). In the basic production effect, reading a word aloud at encoding results in better yes/no recognition performance than silent reading (Conway & Gathercole, 1987; Dodson & Schacter, 2001; Gathercole & Conway, 1988; Hopkins & Edwards, 1972; MacDonald & MacLeod,1998). This advantage for produced words was also seen in a two-alternative forced choice recognition test (Hopkins & Edwards, 1972; MacLeod et al., 2010). Macleod et al. propose distinctiveness as the underlying mechanism, with production making an item "stand out from other information at the time of encoding" (p. 680). The additional specific information encoded is simply the fact that

[1] Paivio (1986) proposes a definition of the memory trace which fits with Engelkamp and Krumancker's (1980) view. According to Paivio, it is a psychological construct that can be defined as a psychological record or representation of past episodic experience, the components or attributes of which correspond to the properties of the remembered event.

they were read aloud, and can be used as a diagnostic tool that an item was in fact studied. MacLeod et al. specifically reject a motor hypothesis for the production effect.

Cohen (1981) provided one of the first pieces of evidence supporting the idea that motor information was indeed nonverbal. He compared the shape of the serial position recall curve of the act and listen conditions. A classic description and interpretation of the serial position curve can be found in Murdock (1962). To obtain a serial position curve, one plots the proportion of recalled list items as a function of the list position they were presented in. In word recall studies, the resulting curve has two important characteristics: a recency effect, where the most recent items (i.e., the last items of the list) have the highest probability of recall, and a primacy effect, where the first few items presented have a higher probability of recall than those in the middle of the list. The primacy effect is typically smaller than the recency effect. According to Cohen's then-current analysis, recency effects were thought to be due to processes outside of the participant's control, and therefore reflected automatic processes. Primacy effects indicated use of effortful rehearsal strategies, a characteristic of verbal encoding (for a recent review of explanation of primacy and recency effects, see Brown, Neath & Chacter, 2007).

When Cohen (1981) compared the shape of the serial position curves in his enactment study, he saw that recall of action phrases encoded under the listen condition resulted in a serial position curve typical of word-recall studies. The curve showed the characteristic recency and primacy effects. This was taken as evidence that these action phrases were encoded similarly to single words, that is with contributions from automatic processes and with a large effortful rehearsal component. In the act condition, the shape of the serial position recall curve presented slightly different characteristics: Overall recall performance was greater in the act than in the listen condition, but the increase was not uniformly distributed across the lists and was restricted to a greater recency effect. The act curve showed a much larger recency effect, both in terms of greater proportion of recall for the last few items of the list, and in the fact that even middle items benefited greatly. There was a very slight primacy effect, and performance in the first few items was comparable to items encoded under the listen condition. Because the serial recall curve in the act condition reflected not only a verbal, but also a motor component, whereas that of the listen condition reflected only verbal components, changes in the curve could be attributed to motor information. Taken together, the primacy and recency effects indicated that motor encoding, and therefore the enactment effect, was not the product of effortful, verbal-based rehearsal processes, but of automatic, nonverbal-based processes.

1.1.2 Disentangling Confounds

Unpon inspection, it appeared that a critical detail had been overlooked in the design of the original experiments. Indeed, objects were never presented in the listen condition, but always were in the act condition. Under these circumstances, maintaining that encoding of motor information was the cause of the enactment effect was an untenable position: The counter argument attributing the enactment effect to visual encoding was equally likely. Bäckman et al. (1986) proposed one of those compelling competing theory: They hypothesized that the use of *real objects* was crucial for good encoding and enactment effect. For the authors, the improvement in memory could be explained primarily from encoding of sensory properties of objects, such as their aspect, texture, weight, smell, or temperature. Motor information was just one of many possibilities of rich encoding. Given that performing actions with objects would lead to greater availability of sensory information, Bäckman et al. hypothesized an enactment-object interaction. They thought that the size of the enactment effect would be greater when the performed actions included an object manipulation than when they did not. Researchers used three approaches to test the hypothesis.

A first approach consisted of removing objects entirely, contrasting the listen condition with symbolic enactment. Participants executed the former as in typical studies, without object presentation. In the latter, participants enacted the action phrase at encoding, but did not receive the corresponding object. Instead, they pretended to manipulate the object mentioned. Even without real objects, motor performance resulted in an enactment effect (Engelkamp & Krumnacker, 1980; Engelkamp & Zimmer, 1997; Zimmer & Engelkamp, 1989). Here, the results were congruent with Engelkamp and Krumnacker's (1980) idea that motor encoding improved the quality of the memory trace, and that objects were not necessary to obtain an enactment effect. Bäckman et al.'s (1986) hypothesis was not directly testable in this context.

The second approach consisted of verifying the presence of an enactment effect with action phrases that differed intrinsically with regards to object manipulation. When one examined the to-be-remembered items from the typical experiment, it was apparent that action phrases could be classified into one of two categories: with- and without-object actions. These had the same verb-object verbal structure, but the manipulation of object varied intrinsically. The with-object actions require the manipulation of a physical object (e.g., *ring the handbell, break the toothpick*). The without-object actions were either body-related (e.g., *snap your fingers*) or environment-related (e.g., *point to the door*) and did not involve manipulation of a physical object. According to Bäckman et al. (1986), if the enactment effect was due to motor performance, then the enactment effect should have been present in both categories. However, if the enactment effect was mainly due to the sensory characteristics of the objects, then it should have been much smaller in without- than in with-object actions. Cohen et al. (1987) found reverse effects of the hypothesized interaction in their Experiment 2: There was a larger effect of enacting in the subset of without-object actions than of with-object actions. In two other experiments (Experiments 1 and 4), they found the enactment effect was as large in each condition. Nyberg, Nilsson, and Bäckman (1991), found equivalent enactment effects in with- and without-object actions. Norris and West (1991) only compared memory performance for enacted action phrases, without a control condition, but also found equivalent memory performance for with- and without- object actions.

Nyberg et al. (1991) noted that environment-related actions, a subcategory of without-object actions, shared similarities with with-object actions. In both, the object mentioned in the action phrase was visible in the environment. Given that environment-related actions were always analyzed pooled with body-related actions, an enactment effect in the former could mask the absence of an effect in the latter. In their Experiment 3, they demonstrated that the subcategory did not matter either: the enactment effect was found with both environment-related and body-related actions. This further validated that motor encoding was the source of the enactment effect. A by-product of these studies was that they highlighted that the enactment effect could be obtained with a variety of actions, including body-related actions that involved no physical object.

In the end, Bäckman et al.'s (1986) proposal of a central role for objects in the enactment effect, instead of action performance, had not held up to experimental examination. Ultimately, researchers either failed to find the desired interaction altogether or found the opposite of their expectation. In other words, either the enactment effect was the same magnitude regardless of object status, or it was greater without objects. There was another by-product of these studies: motor encoding was further supported as the critical source of the enactment effect. Indeed, it was obtained in every comparison involving performance of action phrases. Thus, evidence for motor encoding no longer relied solely on the serial position curve analysis.

1.2 The Multimodal Memory Theory

The multimodal memory theory of Engelkamp (1998) is a comprehensive account of the enactment effect. It is particularly important because it specifies conditions under which the enactment effect can and cannot be obtained. In this respect, I describe its key components and implications in the following sections.

1.2.1 Structure of the Multimodal Memory Theory

1.2.1.1 Modality-Specific Input and Output Systems

The multimodal memory theory is highly influenced by code theories, a common theme of which is the distinction of different memory systems dedicated to the processing of various types of information, or codes. Perhaps the best-known examples are Baddeley and Hitch's (1974) working memory model and Paivio's (1971) dual code theory. In both models, two systems are distinguished: a memory system specializing in verbal information and another in nonverbal visual information. Engelkamp's (1998) multimodal memory theory is particular in that it specifies a motor system nested within the nonverbal system, that is dedicated to processing motor aspects of actions. The theory specifies the existence of independent *verbal* and *nonverbal memory systems*, with their modality-specific input and output systems. The nonverbal and verbal systems are illustrated, respectively, on the left-hand and right-hand side of Figure 1.1.

The input systems process incoming sensory information into modality-specific nodes. For example, an auditory signal of the spoken action phrase *take the pencil* is an organization of signals according to a verbal code. Action phrases presented in writing might be visual, but they too are conveyed in a verbal code. An action performed by an experimenter transmits visual information in a nonverbal code. The motor sensations

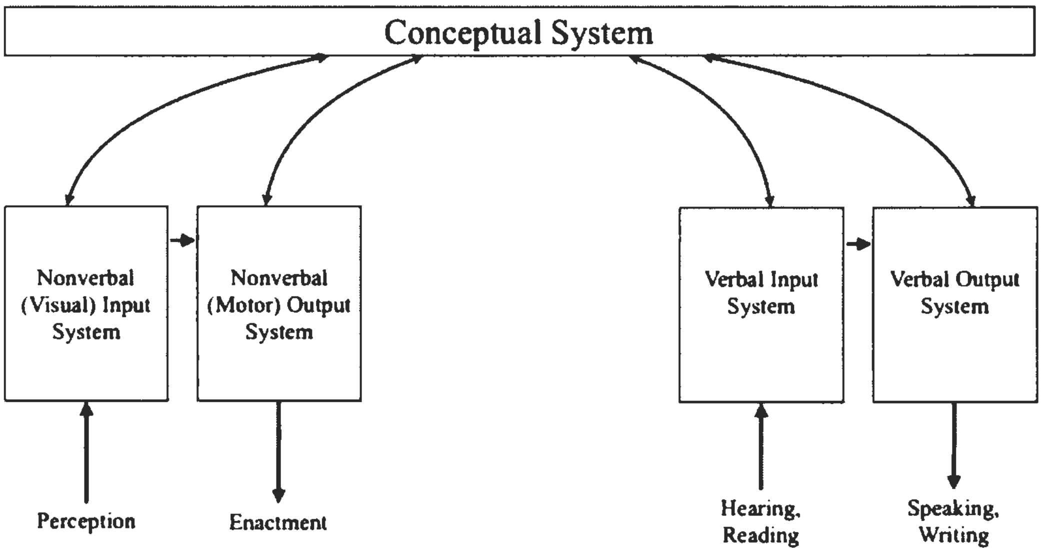


Figure 1.1: Schematization of the multimodal memory theory. Adapted from "General Architechture of the Multimodal Memory Theory", by J. Engelkamp, 1998, *Memory for Actions*, p. 36. Copyright 1998 by Psychology Press Ltd. *Note.* Although it is not indicated in Engelkamp's schema, the input system dedicated to motor information is part of the nonverbal system.

arising from action performance are also transmitted in a nonverbal code (Engelkamp, 1998).

1.2.1.2 Distinction Between Visual and Motor Input Systems

The enactment effect is obtained when comparing memory performance of an act and a listen condition, and was established to be due to better item-specific encoding in the former than in the latter. Enacting was confirmed to encode motor information in a memory trace, in addition to the information made available in the listen condition, namely, verbal information. It follows that the enactment effect should be obtained with different control conditions, insofar as they differ only in motor encoding.

According to the multimodal memory theory, when a participant views a person performing the to-be-recalled action—the watch condition—visual information pertaining to the motions are encoded: its form, process and speed. In other words, the limb positions involved, their sequence, and how fast the action is executed are encoded. When a participant performs the action—the act condition—an additional source is now available, the motor information. According to the multimodal memory theory, the enactment effect should therefore be obtained. The explanation is the same as in the comparison between the listen or watch control conditions and the act condition. In both controls, acting contributes additional item-specific information that is not available in the listen or watch control condition (Engelkamp, 1998).

Although the watch and listen conditions are generally equivalent with regards the explanation of the enactment effect, they differ in memory performance: Typically, performance in the watch condition is greater than in the listen condition (for e.g., Cohen, 1981; Cohen et al., 1987; Engelkamp & Zimmer, 1997). It follows that whereas, with the listen control condition, the enactment effect has been obtained consistently in both within-participants and between participants designs (for a study presenting data from both designs, see Engelkamp & Zimmer, 1997), it has not been the case for the watch control condition. The enactment effect with a watch condition has always been observed in within-participants designs (e.g., Cohen, 1983; Cohen et al., 1987; Engelkamp & Zimmer, 1997; Zimmer & Engelkamp, 1984), but not as consistently with a between-participants design (for a study obtaining the enactment effect, see Engelkamp & Zimmer, 1983).

Engelkamp and Dehn (2000) explained this pattern of results, which varies as a function of experimental design, with the *item-order hypothesis* (Nairne, Riegler, & Serra, 1991), which makes a distinction between *item-specific* and *relational information*. Item-specific information relates to specific features of an item, and relational information relates to the associations between items in a study list, for example, serial order.

According to the item-order hypothesis, there is a trade-off in processing: Item-specific information is processed at the expense of relational information, and relational information is processed at the expense of item-specific information.

Engelkamp (1995) had already proposed that item-specific information should be better for the act than for the watch condition because the execution of an action forces the individual to focus on action-relevant information and to ignore action-relevant context information. Focusing solely on action-relevant information is necessary to guarantee smooth enactment. In contrast, watching does not restrict attention to item information, and allows for context encoding. Hence, watching the experimenter performing actions should be better suited to encode order information than self-performing actions, which promotes its own memory improvement.

Engelkamp and Dehn (2000) described how the above may combine with different memory tests. Serial recall tests are thought to emphasize relational rather than item-specific processing whereas recognition tests emphasize item-specific information (Nairne et al., 1991). Free recall tests are somewhere in between: Both item and order information can help memory. According to Engelkamp and Dehn (2000), acting leads to better item-specific encoding which will result in an enactment effect on tests that benefit from such processing (e.g., recognition, free recall). In a within-participants design, it is more likely that relational information will be the same for act and watch items. Therefore, the main difference is better item-specific encoding in the act condition and a reliable enactment effect. In between-participants conditions, the participants do not experience both conditions, and therefore it is more likely that relational processing differs between the two groups. When relational processing leads to better encoding in the watch than the act condition, it can mask the enactment effect. Engelkamp and Dehn therefore predict that the enactment effect should be more reliably observed with recognition tests than recall tests in a between-participants design because the reliance on relational information is minimized. Similarly, the enactment effect is thought to be less reliably observed with a strict serial order test in a between-participants design because relational information is critical to successful performance. Finally, the enactment effect is thought to be somewhat reliable in a free recall test that draws from both serial and item-specific information.

1.2.1.3 Conceptual System

Action concepts are the semantic meaning of the actions. They are stored at the level of the *conceptual system*. Relational information, relating both to action concepts and to the associations between items of a study list, also occurs at the level of the conceptual system. Action concepts behave as in models of spreading activation (e.g., Collins & Loftus, 1975) and are co-activated with input nodes due to habit. The conceptual system is represented at the top of Figure 1.1 with its connections to the modality-specific memory systems. Engelkamp (1998) proposed that action concepts are necessary for the coherent interpretation of motor input information, and especially, for their integration in a memory trace. He stated that in intentional learning situations and explicit recall tests:

> The sensory processes are only effective within the context of conceptual processes. In other words, [w]ithout recalling a concept it is not possible to remember sensory properties which are connected to the concept in an explicit test. On the other hand, if I explicitly recall a concept, this recall is supported by the sensory properties connected to it [. . .] Motor processes that take place in the learning phase are only retention efficient within the context of conceptual encoding too. (p. 38)

Zimmer and Engelkamp (2003) presented data congruent with this interpretation. In a series of experiments, they first demonstrated that normal-hearing participants fluent in sign language performed better in a memory test when they produced the appropriate sign to a word at encoding than when they did not. Doing so, they demonstrated that performance of motor-based language was similar to performing action phrases. This indicated that motorically, sign language was more similar to actions than to oral language. Engelkamp and Zimmer then varied the type of enactment so that the motor performance did or did not match the verbal utterance. They presented lists of noun-verb pairs in which, for example, the noun *stone* could be followed either by the related verb *throw* or by the unrelated verb *drink*. Participants memorized the noun and performed the action denoted by the verb. The multimodal memory theory implies that memory should be enhanced only if the motor performance is conceptually related to the item. Performing unrelated actions should not be effective. As expected, performing signs related to the noun yielded an enactment effect, but performing signs unrelated to the noun did not. On the basis of these results (for a related discussion, see Zimmer, 2001), Zimmer and Engelkamp (2003) specified action concept conditions for an enactment effect to occur. They concluded that it is sufficient that two components are present at encoding, conceptual processing and an action component associated with the item to be remembered. They assumed that action-specific motor information can be encoded when the movement is overtly performed and conceptually related to the item.

1.2.2 Task Demands and System-Based Processing

Understanding how the modality specific input and output systems and the conceptual system are recruited is relatively straightforward. First, encoding conditions dictate the availability and nature of to-be-processed information. Second, if pre-experimental knowledge of the information exists, a modality specific input node is activated. Third, a memory trace, which is the compound of these nodes, is formed and is more or less rich depending on its content. Fourth, in the event that pre-existing action concepts exist, there is a spread of activation in the conceptual system, allowing relational information to contribute to the memory trace. Finally, the output retrieval system is controlled willfully and does not depend on the nature of the encoded information. In the context of a memory experiment, participants comply with test demands (Engelkamp, 1998). The following examples illustrate how different task demands recruit the memory systems:

- In the control condition of a typical enactment effect experiment, all processing can occur in the *verbal* system: it involves listening to an action phrase and written recall. An experimenter speaks the action phrase such as *take the pencil.* The participant recognizes the auditory signal as the speech node *take the pencil.* As this is the only information available at encoding, only the verbal system is recruited. The speech node activates the corresponding action concept in the conceptual system, and the meaning[2] of the node is understood. A memory trace is formed. The information in the memory trace, because the memory test implicates written recall, is transmitted through the verbal output system in written form.

- Action processing can occur entirely in the *nonverbal* system. This is the case for a situation which involves seeing an action and performing it back to demonstrate retention. A participant sees a model *take the pencil.* The nonverbal information is inputed as a visual node. It activates the *take the pencil* action concept. The memory trace is transmitted through the nonverbal output system in a motor performance.

- Conditions can also be manipulated to be cross modal and to use both the *nonverbal* and *verbal* systems. For example, this is the case when participants see an action phrase and write down the corresponding action phrase at test. This is possible because the visual input node can activate the appropriate action concept node, and participants can choose to convey the content of the memory trace through the verbal output system. Yet, here, only visual information is encoded.

[2]The word *meaning* is to be interpreted loosely.

1.3 Thesis Statement

Throughout the previous literature review, I demonstrated that many empirical studies support the soundness of the multimodal memory theory, suggesting that producing an action results in motor encoding. It is also accepted that motor encoding can enhance the quality of memory traces when added to auditory or visual encoding. I believe, however, that further research is desirable. Athough the basic processes of motor encoding have been clearly defined, a key component of multimodal memory model has generally been forgotten: the conceptual system.

Zimmer and Engelkamp (2003) demonstrated that a conceptual relationship was required between an action concept and a performed action for motor encoding to occur. Doing so, Zimmer and Engelkamp stressed the pivotal role of the conceptual system as a limiting condition of the enactment effect: This result can be interpreted as a finding that false expectations of the upcoming actions does not allow integration of the motor information in the memory trace. Following this reasoning, the structure of the multimodal memory model (Engelkamp, 1998) implies that in the absence of a pre-existing action concept, it is impossible for the motor information of a produced movement to be integrated to the memory trace. In other words, when one has no idea what to expect in a movement sequence, producing motor information has no effect on memory. Memory performance would be the same as when someone was immobile during list learning.

Consider the following experimental learning situation contrasting watch and act conditions. In the watch condition, participants know they will soon see a movement sequence performed on video. However, this sequence is unfamiliar to participants and is not structured in ways coherent with action concepts they already possess. Without these action concepts, predicting how the current and subsequent movements of the sequence will unfold is impossible. A new action concept, specific to the movements represented in the video, must perforce be created. This action concept, however, will only be created when participants have seen most of the movie. It follows that in the watch condition, the viewing of the video took place in the absence of action concept. Of course, this new action concept will be part of the memory trace and can will be drawn upon during the memory test.

It is in the act condition that timing of the action concept creation plays a critical role. Indeed, by giving participants the instruction to imitate performance in real time, motor information is produced before the action concept exists. It follows that if the enactment effect is not detected, the multimodal memory model does not have to be changed. However, if it appears that the enactment effect is detected, it is not necessary to specify the primacy of action concept for motor encoding.

The actions used in typical enactment experiments or in Zimmer and Engelkamp's (2003) study do not lend themselves to testing the hypothesis above. Indeed, the typical action phrases used are always highly familiar to participants, and, according to the multimodal memory theory, they are automatically co-activated with sensory input nodes (Engelkamp, 1998). It is therefore unrealistic to imagine blocking access to action concepts using actions such as *take the pencil* or *touch your nose*.

A different type of action is better suited to test the necessity of pre-existing action concepts, yet has never been used in studies of the enactment effect before: *abstract arm motions*. I define them as sequences of arm movements never before seen nor performed by participants. They further differ from typical actions used in the enactment effect in that they are non-representational, nonverbal, and do not involve object manipulation. Participants do not possess pre-existing action concepts for the abstract arm motions. For example, when seeing them for the first time, they would not be able to predict the sequence of to-be-remembered movements. They would thus only be able to form the action concept as they see the abstract arm motions unfold.

The objective of this thesis is to test the necessity of pre-existing action concepts, as an interaction between conceptual processing and encoding condition. The multimodal memory theory predicts that no enactment effect will be obtained with abstract arm motions when participants are unfamiliar with the action concept of to-be-remembered abstract arm motions. However, an enactment effect will be obtained when participants are given opportunities to conceptually process these stimuli.

Chapter 2

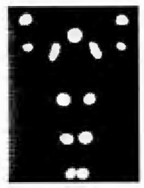
Research Plan

Experiments were planned with the objective of demonstrating the necessity of pre-existing action concepts for obtaining an enactment effect. To do so, I used a class of actions I call abstract arm motions, the creation of which is described in Section 2.1. Design choices for the encoding conditions and the memory tests are described in Sections 2.2 and 2.3. In the last section of this chapter, Section 2.4, I present an overview of the experiments.

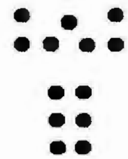
2.1 Abstract Arm Motion Stimuli

2.1.1 Point-Light Motion

Two different stimulus sets were used, and while common aspects will be described in this section, their differences will be described in detail in Chapters 2 and 3. The stimuli were created using point-light motion displays, a presentation format of biological motion pioneered by Johansson (1973). In point-light motion, a model dressed in black is filmed standing in front of a black background. The model wears white circles taped on the major joints and all that is visible are moving white circles in front of a black background. The model itself is invisible (see Figure 2.1a for a screen capture of a point-light motion stimulus, and Figure 2.1b for its schematic representation).



(a) Screen capture



(b) Schematic representation.

Figure 2.1: Screen capture of a point-light motion stimulus (a) and its associated schematic representation (b).

Point light motion has the advantage that from the point of view of the observer, the richness and complexity of real-life human motions are preserved. The perceptual information is confined to the motion of the white circles, so the possibility that participants' attention would be attracted to aspects of the stimuli other than the motion itself is greatly reduced compared to normal video stimuli. Therefore, visual information encoded will be constrained to motion information. In addition, this removes any unwanted visual cue which participants may have used to prompt memory if normal video tapes had been used.

In the previous chapter, the role of item-specific and relational information was discussed as a potential confound in obtaining the enactment effect across memory tests. It is possible to argue that by virtue of directing focus to movement rather than to extraneous information, compared with normal videotapes, point-light motion has the effect of enhancing item-specific information and reducing relational information. If this is the case, it should not be an issue in subsequent memory tests, as item-specific information is supposed to be at play in both recognition and recall, and is not made more or less available accross act and watch conditions. Therefore, the stimulus itself should not impact on probability of obtaining the enactment effect.

Johansson (1973) has shown that point light motion displays lead to immediate and correct identification of various human activities, such as walking or running on a track, two people dancing, or gymnastic feats. We can rest assured that even complex movement is easily identifiable.

2.1.2 Technical Aspects

The technical aspects of stimulus design and construction are detailed here. Point-light motion stimuli can be built with many techniques, from crude drawing directly on videotapes to capturing motion with infrared computer systems (Dekeyser, Verfaillie, & Vanrie, 2002). In this thesis, I used computer processing of digital videotapes.

2.1.2.1 Model and Room Setup

A female model was dressed in a black hooded bodysuit covering her entire body, with the exception of her eyes. Thirteen important body parts were highlighted and practical measures were taken so that the markers would always be visible (see Figure 2.2 for identification of the body body parts as they relate to markers). Specifically, seven non-reflective white felt circles approximately 10 cm in diameter were attached to non-moving body parts: the top of the head, the hipbones, the knees and the top of the ankles. Non-reflective white hockey tape was wrapped about 10 cm wide around four moving body parts: the elbows and the hands, bound into fists. Despite the fact that the shoulders were technically non-moving body parts, as no rotation of the torso was to be made, they were also wrapped with hockey tape. Otherwise, when in a test videotaping session felt circles were used, moving the arms around resulted in disappearing white circles and other aberrations.

The back wall of the room in which the stimuli were filmed was covered with non-reflective black cloth from floor to ceiling. A 4-feet wide rectangular cloth also

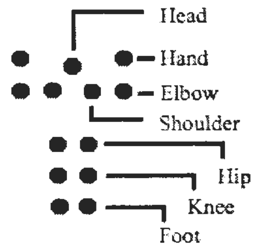


Figure 2.2: Body markers as represented in Figure 2.1

carpeted the floor. A digital video camera was set up on a tripod at the other end of the room. The position of the model and the tripod feet were marked so that filming, which was conducted over several days and required taking down the cloth and the cameras at the end of each session, could remain constant.

2.1.2.2 Filming

During filming, a laptop computer was put on the floor. With a remote control hidden inside her bodysuit, the model initiated a timed animation on Keynote '09 (Apple Computer Inc., 2011), a slide creation software. A start sound played loudly enough to be recorded by the video camera, and a schematized version of the to-be-modeled actions appeared on the computer screen. Key segments were represented sequentially with timed animations indicating how long each component should last. An end sound indicated completion of the movement. Several takes of would-be-stimuli were taped, as only perfect performance by the model was acceptable.

2.1.2.3 Video Editing

The videos were uploaded in iMovie '09 (Apple Inc., 2010), a video editing software, and files were created for each stimulus. All stimuli within a set were the same duration. The best model performance was selected. Contrast was set to the highest level so only moving white dots were visible on the final stimuli. Finally, a blur filter was applied to smooth out the jagged edges that resulted from the higher contrast.

2.2 Encoding Conditions

All experiments in this thesis involve a comparison of memory performance between the *act* condition, and the *watch* control condition. This control condition was chosen because participants do not have pre-experimental word-action associations for those movement sequences, therefore making the use of a listen control condition inadequate. Given that the multimodal memory theory (Engelkamp, 1998) attributes the source of the enactment effect to item-specific motor encoding in addition to the information available in a control condition, substituting the listen condition for the watch condition is trivial. Remember that an enactment effect has been detected repeatedly in act versus watch contrasts (e.g., Cohen, 1983; Cohen, Peterson, & Mantini- Atkinson, 1987; Engelkamp & Zimmer, 1983, 1997; Zimmer & Engelkamp, 1984). As long as the experimental design takes into account the trade-off between relational and item-specific information in watch and act conditions from Engelkamp and Dehn (2000), the results and interpretation of a watch versus act comparison should be almost identical to a listen versus act comparison.

2.3 Memory Tests

The necessity of pre-experimental concepts will be assessed with the two main memory tests used in typical enactment effect studies: recognition and free recall. However, given that abstract arm motions are entirely new to participants, it would be overly ambitious to combine both tests in a single experiment, as was done by Bäckman et al. (1986) and Cohen (1981, 1983). Indeed, the fairly long list length which is appropriate for recognition tests is not adequate for testing the same difficult stimuli with recall. It is sufficient for the current purpose to demonstrate the possibility that an enactment effect can be obtained with the two tests.

Using abstract arm motions that are not pre-experimentally associated with verbal labels implies a departure from typical studies: recall cannot be performed verbally. Instead, participants will perform with overt arm motions, or mimic, to the best of their abilities, all that they remember from the presented stimuli. Notice that the change from a verbal to a nonverbal mode of recall should not affect the probability of obtaining the enactment effect, for both theoretical and experimental reasons. The multimodal memory theory (Engelkamp, 1998) specifies that the enactment effect takes place at encoding, not at retrieval. This is supported by Watanabe's (2003) demonstration that performing actions for the recall test led to the same results as written or spoken recall.

Using overt motor performance in a recall test leads to another challenge, in that the accuracy of recall must be assessed. Indeed, given that abstract arm motions are unfamiliar to participants, I anticipated that their motor performances would not be clearly dichotomizable into correctly or incorrectly recalled motions. I therefore created a gist-based rating scale that reflected different levels of accuracy of memory for the abstract arm motions. With it, different magnitudes of errors are be represented quantitatively. This scale is described in Experiment 2, Section 5.2.4.3.

2.4 Overview of the Experiments

A pilot study and three experiments were conducted. The pilot study was conducted with the primary purpose of assessing the ease with which participants could form memory traces of the stimuli. This was important because the stimuli were designed expressly for this thesis. Memory was evaluated with a recognition test in which participants saw a subset of the presented stimuli and later identified them among similar, never before seen stimuli. Results from the overall memory performance were used to inform the design of the stimulus set used in the critical experiments. The enactment effect was assessed as a between-participants *encoding condition*, with one group encoding under the watch condition, and the other, under the act condition. The effect of *conceptual processing* was implemented as a *repetition condition*: at encoding, a subset of stimuli were shown once, and another, four times. In this way, participants would not have formed an action concept for the subset of stimuli seen only once, but they would have been more likely to for the subset seen multiple times.

Experiment 1 was the first critical experiment of this thesis. It was modelled closely on the pilot study, but two changes were made. First, a modified set of stimuli was used. Second, although the pilot study's between-participants design was not theoretically problematic to obtaining an enactment effect, given that recognition memory tests rely mainly on item-specific information, and therefore should not be affected by design (Engelkamp & Dehn, 2000; Nairne et al., 1991), a within-participants design was used for the encoding condition. This was motivated by a desire to raise the experimental power of the encoding condition. At encoding, participants saw a subset of stimuli under the watch condition, and an other subset under the act condition. Again, conceptual processing was assessed as a repetition manipulation.

Experiments 2 and 3 involved recall instead of recognition. In these experiments, based on Engelkamp and Dehn's (2000) interpretation of Nairne et al.'s (1991) item-order hypothesis, minimizing relational encoding was critical to obtaining the enactment effect. This was done by following Engelkamp and Dehn's recommendation, using a within-participants design for the encoding condition and a free recall at test. In Experiment 2, I specifically tested whether or not an enactment effect could be obtained in total absence of pre-existing action concepts. Experiment 3 was modelled on Experiment 2 and the conceptual processing manipulation was based on the addition of a verbal label chosen to reflect the content of the stimuli. This *labeling condition* was designed to facilitate conceptual processing of the stimuli in a between-experiment comparison with Experiment 2. The critical test of necessity of pre-existing action concepts for motor encoding was analyzed as an interaction between the two experiments and the encoding condition.

It should be noted that even though I believe the conceptual processing manipulations will be effective, I do not make the claim that they will result in very high action-concept associations. Indeed, with the highly complex movement information used in this study, it is unreasonable to expect robust conceptual processing to occur. For conceptual processing to reach a level comparable to that of actions typically used in enactment effect research, intensive training sessions with the goal of fvorming long term memory for the stimuli, should be conducted. The focus of this thesis is on short-term memory, yet conceptual processing is still expected to play an important role in the apparition of an enactment effect.

Chapter 3

Pilot Study

3.1 Introduction

3.1.1 Rationale and Predictions

The pilot study was conducted with the primary purpose of assessing the ease with which participants could form memory traces of the stimuli. This was important because the abstract arm motions used in this thesis were designed expressly for this thesis. Memory for the stimuli was evaluated with a recognition test, which unfolded in two phases. In the learning phase, participants were presented with a subset of stimuli that they were instructed to remember. In the testing phase, these stimuli were presented again within a subset of never-before-presented stimuli. Participants' tasks were to classify each of the stimuli as old or new in the yes/no procedure and to rate their confidence in their judgment. Participants made their decision on the basis of how familiar the stimulus was to them, therefore, one can look at the proportion of correctly and falsely recognized stimuli to assess memory performance. (Snodgrass, Levy-Berger, & Haydon, 1985).

The enactment effect was assessed as a between-participants variable, with one group encoding under the watch condition, and the other, under the act condition. Given that enactment is thought to create a richer, item-specific memory trace, evidence for motor encoding should be reflected through better recognition for stimuli encoded under the act than under the watch condition. A recognition test was used first because it emphasizes item-specific information at test, hereby maximizing the probability of obtaining an enactment effect (Engelkamp & Dehn, 2000).

The effect of conceptual processing was implemented as a repetition condition: At encoding, a subset of stimuli was presented once, and another subset, four times. In this way, participants would be unlikely to have pre-existing action concept for the subset of stimuli presented only once, but they would be likely to have developped an action concept for the subset presented multiple times. Surely, after several stimulus presentations, an action concept will have begun to be formed. A main effect of repetitions was expected, because the additional processing opportunities strengthen the memory trace of repeated actions. The critical test lies in the detection of an interaction between encoding condition and repetition condition.

The critical test of the necessity of pre-existing action concepts for the presence of an enactment effect was assessed as an interaction between encoding condition and repetition condition: If motor encoding enhancement can only occur with pre-existing action concepts, then the enactment effect will not be observed in the subset of stimuli presented only once, but it will be observed in the subset of stimuli presented four times.

3.1.2 Note on a Test

At this early stage of thesis design, I initially wanted to examine the conscious experience that accompanies retrieval of stimuli encoded under the different encoding conditions. Particularly, I wondered if, in the case of learning new action concepts, the motor information would translate to a particularly vivid recollection. The pilot study included remember/know judgments on stimuli participants identified as old. The interpretation of the judgments was to be modeled on those given by Rajaram (1996) in a picture recognition study. In short, if at test, participants felt that they had a vivid recollection of the stimulus in the learning phase, then they remembered it. If, however, they were certain they had seen the stimulus before, but could not recall a specific memory, then they know the stimulus. This judgment was originally put in the pilot study before a deeper literature review cast doubts on the possibility of an enactment effect with abstract arm motion stimuli. For completeness, the test will be described in Section 3.2.3. However, results will not be examined.

3.2 Method

3.2.1 Participants

Forty volunteers ($M = 24.4$ years, $SD = 6.3$ years; 25 females, 15 males) took part in the pilot study. This number was chosen partly on considerations of experimental power. Given the novelty of the methods, an a priori effect size could not be computed. However, it was estimated that if the size of the effect size for the enactment effect was large (i.e., equivalent to d = .8), a power of .69 would have been achieved in the pilot study. Of these 40 volunteers, 31 were students, 8 held other occupations, and 1 did not share this information. They were volunteers who had originally answered to advertisements posted on the Memorial University of Newfoundland campus or signed up on a participant contact list during classroom recruitment. The testing sessions were conducted individually and lasted approximately 40 minutes. Participants received a $10 stipend for their time.

3.2.2 Materials

The computer-controlled experimental program was presented on a 15-inch cathode ray tube screen. Stimuli consisted of point-light motion movies constructed as described in Chapter 2.

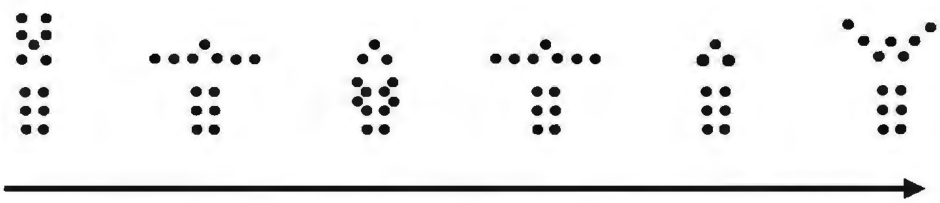
3.2.2.1 Stimuli

A set of 48 abstract arm motion stimuli was designed so that the performed arm motions were made of six semi-randomly determined straight-arm positions (for examples, see Figure 3.1; for the full set, see Appendix A). The transitions between each position were constrained to a 90° amplitude, and executed along a straight line. There were two levels of stimulus complexity, in regard to the relationships of the left and right arms at any given position. In the twenty-four simple stimuli (see Figure 3.1a), the right and left arm positions were always mirror images of each other. In the twenty-four complex stimuli (see Figure 3.1b), the right and left arm positions were independently determined, though they could be mirror images of each other by chance. Stimulus duration was 7 s.

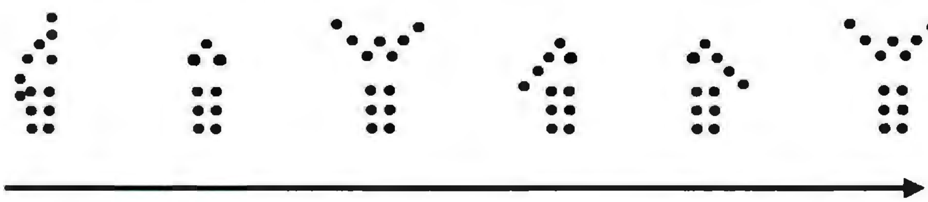
3.2.3 Procedure

3.2.3.1 Preparation

The experimenter administered the informed consent form and emphasized the anonymous and voluntary nature of participation. Participants were encouraged to reschedule their appointment if they felt unwell during the day of the study. Accordingly, they could leave at any time and still collect their stipend. All participants completed the experiment. Prior to testing, the experimenter informed participants about the nature of the memory test using the instruction sheet found in Figure 3.2. Participants were only tested after the experimenter verified that they understood the instructions. They sat in front of



(a) In this *simple stimulus*, hands are first raised above the head, then lowered parralel to the floor. After, they are rested next to the body, raised parralel to the floor, positioned in front of the shoulders and finally, raised 45° from the head.



(b) In this complex stimulus, the left hand is first raised next to the head while the right hand is rested next to the body. Second, both hands are positioned in front of the shoulders, then raised 45° from the head. After, the right hand is lowered 45° from the lower body while the left hand is repositioned in front of the body. The previous position is mirrored, and finally, both hands are raised 45° from the head.

Figure 3.1: Graphical representation of stimuli from the pilot study. Each figure represents a position within a stimuli. Read from left to right.

the computer screen while they performed both encoding and testing phases of the recognition test.

3.2.3.2 Encoding Phase

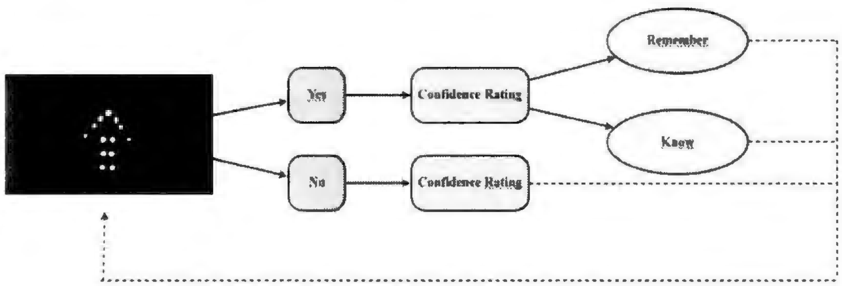
Half of the participants were assigned to the watch condition and instructed to sit still while memorizing the movements performed in the stimuli. The other half were assigned to the act condition, and were instructed to sit and follow along the arm motions presented in the stimuli, in essence mimicking the stimuli as if seen through a mirror. Asking participants to perform as they watched ensured that they processed both visual and motor modalities at the same time. It also ensured that participants could not have fully formed an action concept before the start of motor encoding. Participants' ability to follow along the movies was not monitored during the pilot study.

A different randomized list of 60 movies was built from 24 stimuli for each participant, according to the following procedure. First, a random sample of 12 simple and 12 complex stimuli was drawn from the 48 stimulus set. Second, half of the simple and complex stimuli were randomly assigned to a repetition condition. Each stimulus was to be presented either once (12 stimuli x 1), or four times (12 stimuli x 4). Finally, the order of presentation was randomized. During the encoding phase, lasting about 9 minutes, these 60 movies were presented one after the other, separated by a black screen, a 1s inter-stimulus interval.

3.2.3.3 Testing Phase

A different randomized list of forty-eight stimuli, both old and new, was created for each participant. Stimuli were presented one at a time, with each stimulus playing in a loop until two to three recognition judgments were made by button press. First, participants indicated in a yes/no recognition judgment, if they remembered having seen

Instructions for Making Recognition Judgements.



If you have any question regarding these judgements, please ask the experimenter.

1. **Yes vs No**: If you think that the motion sequence you see now was in the previous film montage, chose *yes*; otherwise, chose *no*.
2. **Confidence Rating**: Indicate on a scale of 1 to 5, how confident you are that you made the correct *Yes vs No* decision (from "completely guessing" to being "absolutely certain").
3. **Remember vs Know**: If you chose *no* in *Yes vs No*, a new motion sequence will now appear. If you chose *yes*, indicate whether you *remember* or *know* that you saw the sequence in the film montage. Read the following instructions for how to make either judgement:

Remember: Your recognition of the motion sequence is accompanied by a conscious recollection of its prior apparition in the film. To *remember* is to become consciously aware again of some aspect of what happened or what was experienced at the time the motion sequence was presented (e.g., aspects of the physical appearance of the motion sequence, or of something that happened in the room, or of what you were thinking and doing at the time). In other words, the motion sequence should bring back to mind a particular association, image, or something more personal from the time of study or something about its appearance or position (e.g., what came before or after that motion sequence).

Know: You recognize that the word was in the study list, but you cannot consciously recollect anything about it's actual apparition, or what happened, or what was experience at the time. In other words, chose *know* when you are certain of recognizing the motion sequence but it fails to evoke any specific conscious recollection from the study list.

Figure 3.2: Recognition instructions used in the pilot study.

the stimuli during the encoding phase. Second, they indicated on a scale from 1 to 6 (from *complete guess* to *absolutely sure*) how confident they were in their recognition judgment. Finally, if they indicated yes to the recognition judgment, they made a third response, the remember/know judgment, qualifying the nature of their reminiscence.

3.3 Results

All results were analyzed at the critical two-tailed $\alpha = .05$ level. Indicators of recognition memory performance were computed in accordance with Snodgrass et al. (1985). A recognition judgment is a *hit* when a participant correctly states that *yes* the *old* test stimulus was presented during encoding. A recognition judgment is a *false alarm* when a participant mistakenly states that *yes*, the *new* test stimulus was presented during encoding. Hit rates (H_{rate}) and false alarm rates (FA_{rate}) are the proportions of occurrence of each judgment, calculated independently for each participant. Snodgrass et al. recommend using analysis measures that take into account both H_{rate} and FA_{rate} in the assessment of a participant's performance. In this thesis, A', a non-parametric discrimination measure analog to d', was used. A' is preferred to the more common d' measure because in experiments with few recognition trials, such as in this thesis, it is not strongly influenced by extreme H_{rate} and FA_{rate}. A' values are computed for *each participant*, and *not* on overall data. Equations 3.1 to 3.3. were used to compute A':

If $H_{rate} > FA_{rate}$,

$$A' = .5 + \frac{(H_{rate} - FA_{rate})(1 + H_{rate} - FA_{rate})}{1H_{rate}(1 - FA_{rate})} \tag{3.1}$$

If $H_{rate} = FA_{rate}$,

$$A' = .5 \tag{3.2}$$

If $H_{rate} < FA_{rate}$,

$$A' = .5 - \frac{(FA_{rate} - H_{rate})(1 - H_{rate} + FA_{rate})}{1FA_{rate}(1 - H_{rate})} \tag{3.3}$$

An A' of 1 is obtained when $H_{rate} = 1$ and $FA_{rate} = 0$. Chance performance is denoted by $A' = .5$. When $A' < .5$, more false alarms than hits were made, this most likely due to sampling error.

3.3.1 Overall Recognition Performance

Overall recognition performance was examined before the presence of an enactment effect was assessed. Participants correctly recognized old stimuli on an average of .58 of the time ($SD = .18$), a performance which, according to a single sample t-test, was significantly above the .5 chance level, $t(39) = 3.08$, $SE = .028$, $p = .004$. False alarm rates were very high, as they occurred on an average of .51 of the time ($SD = .20$) and did not differ significantly from the chance level, $t(39) = .396$, $SE = .032$, $p = .694$. However, they were significantly lower than the hit rates, as shown by a paired sample t-test, $t(39) = 2.76$, $SE = .027$, $p = .009$. On average, A' analysis revealed that participants were able to, but had difficulty, discriminating old from new stimuli ($M = .57$, $SD = .15$), a result statistically above the .5 chance level as shown by a single sample t-test, $t(39) = 2.89$, $SE = .023$, $p = .006$.

The relatively low hit rates and high false alarm rates highlighted the poor stimulus set characteristics, and directly challenged whether an enactment effect could be obtained. Nonetheless, encoding conditions were analyzed for an enactment effect. Searching for ways to enhance recognition of stimuli in subsequent experiments, I included the posteriori comparison of recognition performance across the two levels of stimuli complexity.

3.3.2 Enactment Recognition Performance

Given the possible importance of having conceptual knowledge of an action for motor information to be efficiently integrated in the memory trace, the presence of the enactment effect was assessed according to the repetition condition. A main effect of repetitions was expected: Presenting a stimulus four times at encoding should yield better recognition performance than presenting it once. This would be because multiple viewings offer more opportunities to create a solid conceptual representation, resulting in higher hit rates. If the presence of an enactment effect relies on the existence of a conceptual representation, then an interaction is also expected: An enactment effect should be present when stimuli were presented four times, but not only once. Because of the poor overall performance described in Section 3.3.1, it was important to assess the encoding condition and repetition condition at both levels of stimulus complexity. Although this variable was originally only implemented to provide a greater variation in stimulus design, it was possible that the enactment effect and its interaction could be detected only in simple or complex stimuli.

A 2x2x2 mixed-measures ANOVA on the A' recognition measure was conducted with encoding condition (watch vs. act) as a between-participant factor and repetition condition (once vs. four times) and complexity of stimulus (simple vs. complex) as within-participants factors. The results of the ANOVA analysis can be found in Table 3.1. Results concerning the two hypotheses were as follows. The first hypothesis concerned the presence of an enactment effect interacting with the conceptual encoding condition. First, no main effect of encoding condition was found, as discrimination performance as assessed by A' was the same in the watch condition ($M = .59$ $SD = .16$) and in the act condition ($M = .55$, $SD = .14$). There was an effect of repetition condition. Stimuli presented four times ($M = .60$, $SD = .18$) were better discriminated than were stimuli presented only once ($M = .53$, $SD = .16$). However, there was no significant interaction between the repetition and encoding conditions. Overall, these results indicated that giving more opportunities to the participant to form a concept associated with a given stimulus generally enhanced memory for action stimuli, but did not facilitate encoding of motor information as part of the memory trace in the act condition. In addition, participants' performance was not statistically different for simple (M = .60, SD = .19) and complex stimuli (M = .54, SD = .17), p =.116.

3.3.3 Confidence Ratings

A 2X2 mixed-measures ANOVA on a 6-point confidence ratings scale for old stimuli was conducted with encoding condition (watch vs. act) as a between-participant factor and repetition condition (once vs. four times) as a within-participant factor. Overall, participants were somewhat confident in their answers (M = 3.83, SD = .11). Participants in the watch and the act condition were as confident in their recognition performance in the watch (M = 3.96, SD = .64) as in the act condition (M = 3.70, SD = .70), $F(1, 38)$ =1.57, MSE = 1.40, p = .218, η_p^2 = .04. Participants were as confident in the once condition (M = 3.85, SD = .76) as they were in the four times condition (M = 3.81, SD = .74), $F(1, 38)$ = .18, MSE = 0.203, p = .677, η_p^2 = .01. There was no significant interaction between repetition condition and encoding condition, $F(1, 38)$ = 3.80, MSE = 0.203, p = .059, η_p^2 = .09.

3.4 Discussion

This pilot study was designed to enable the examination of the two main hypotheses: First, that there should be an enactment effect when watch and act conditions are manipulated between-participants, and second, this enactment effect should be observed in an interaction with the repetition condition. Examination of the A' measures showed that none of these hypotheses were supported, as there was neither a main effect of encoding condition, nor an interaction with repetition condition. The only significant finding was that stimuli presented four times were better discriminated than stimuli presented only once. These results, however, could not be deemed conclusive because of participants' poor overall performance on the recognition test. Especially concerning was the high average false alarm rate (.51), because it indicated that participants were only capable of creating a very superficial memory of the stimuli. An enactment effect could have failed to appear because the stimuli need to be more distinct from each other for motor information to become an efficient retrieval aid. The homogeneity of confidence ratings across encoding condition and repetition condition also points to the poor stimulus set characteristics. Searching for ways to enhance recognition of stimuli in subsequent experiments, I compared recognition performance across the two levels of stimuli complexity. It appeared that neither simple nor complex stimuli produced acceptable recognition performance for my needs. Because of this, subsequent experiments were conducted with a modified set of more easily discriminable stimuli.

Table 3.1: *Mixed-Measures ANOVA of Recognition Performance With Encoding Condition, Repetition Condition, and Complexity of Stimulus as Factors*

Source	df	Mean Square	F	η_p^2	p
Encoding	1	0.055	0.71	.02	.403
Error(Encoding)	38	0.078			
Repetition	1	0.246	7.20	.16	.011
Repetition * Encoding	1	0.048	1.39	.04	.245
Error(Repetition)	38	0.034			
Complexity	1	0.096	1.99	.05	.166
Complexity * Encoding	1	0.002	0.04	.00	.843
Error(Complexity)	38	0.048			
Repetition * Complexity	1	0.097	3.72	.10	.061
Repetition * Complexity * Encoding	1	0.015	0.57	.02	.455
Error(Rep*Complexity)	38	0.026			

Note. Encoding = watch and act encoding conditions; Repetition = number of times, once or four times, stimuli were presented; Complexity = simple and complex stimuli. The * indicates assessment of an interaction.

Chapter 4

Experiment 1

4.1 Rationale and Predictions

Experiment 1 was modeled closely on the pilot study, but two changes were made. First, a modified set of stimuli was used to make it easier for participants to form memory traces. Second, a within-participants design was used. This was motivated by a desire to raise the experimental power of the encoding condition: At encoding, participants were presented with a subset of stimuli under the watch condition, and another subset under the act condition. As in the pilot study, for the act condition, participants were told to act along with the movies. They were expected to better discriminate old from new stimuli than if they were only watching at encoding. However, this enactment effect was hypothesized to only be detected in a critial interaction with conceptual processing, implemented again as a repetition condition. If prior encoding is necessary for motor encoding, then the enactment effect will be observed in the subset of stimuli presented four times, but not in the subset presented only once.

4.2 Method

4.2.1 Participants

Twenty-one volunteers ($M = 21.0$ years, $SD = 2.4$ years; 15 females, 6 males) [1] took part in Experiment 1. As with the pilot study, this number was chosen partly on considerations of experimental power. Given that the results of the pilot study could not be thought a good estimation of the effect size due to methodological shortcomings, they could not be used to compute a a likely effect size. However, it was estimated that if the size of the effect was large (as in the pilot study, equivalent to d = .8), with 21 participants, a power of .92 would have been achieved in Experiment 1. Of these participants, 20 were students, and 1 did not share this information. As in the pilot study, they were volunteers who had originally responded to advertisements posted on the Memorial University of Newfoundland campus or signed up on a participant contact list during classroom recruitment. The sessions were conducted individually and lasted approximately 45 minutes. Participants received a $10 stipend for their time. None had participated in the pilot study.

4.2.2 Materials

Materials used were the same as in the pilot study, except for one difference. The screen used to display stimuli was a stand-mounted, 32-inch high definition flat screen television. This change allowed participants to stand farther from the screen and gave them more room to act.

[1]One participant did not to write down his/her age. Therefore, the mean and standard deviations are computed on 20 out of the 21 participants.

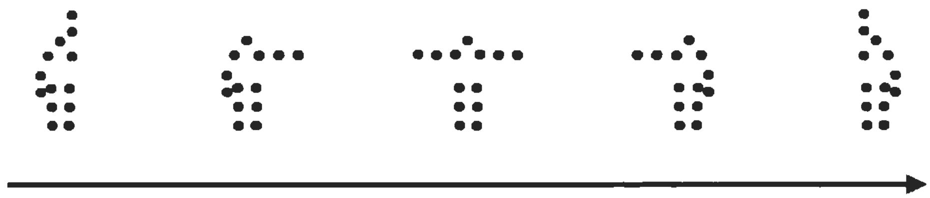
4.2.2.1 Stimuli

A new set of 48 stimuli was designed for Experiment 1. As in the pilot study, they were built using the point-light motion method and only the arms moved. However, there were several key differences. First, the semi-random procedure used in the pilot study to determine arm positions within a stimulus sequence was dropped entirely. Instead, the arms could be either completely straight, bent 90° at the elbows, or bent 180° so that hands were on the shoulders. In addition, there could be 2 to 6 specific arm positions per stimuli, and transitions between arm positions were not limited to 90° amplitudes, nor to straight paths. Stimuli varied in complexity of the motions performed as a by-product of the aforementioned rules, but were not rated as simple or complex as the stimuli were in the pilot study. Finally, stimulus duration was 10 s. Three examples can be seen in Figure 4.1 (for the full set, see Appendix B).

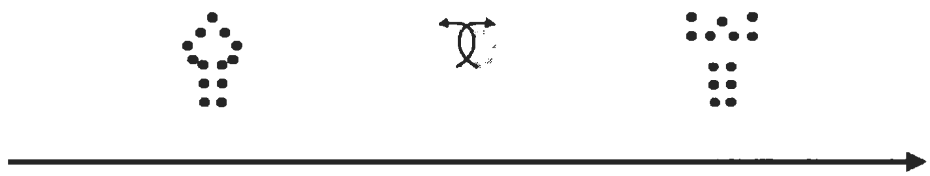
4.2.3 Procedure

4.2.3.1 Preparation

As in the pilot study, the experimenter administered the informed consent form and emphasized the anonymous and voluntary nature of participation. Participants could leave at any time and still collect their stipend. All participants completed the experiment. The experimenter informed participants of the nature of the memory test, as well as the type of actions they would see using the text and images of the instruction sheet reproduced in Figure 4.2. The experimenter paraphrased the instructions and verified that participants understood them. There were no practice trials or stimuli, but the experimenter described how the stimuli would look like and used the Figure 4.2 flowchart to describe the mode of response.



(a) In this stimuli, the model first starts with the left arm up, extended next to the head and perpendicular with the ground, right arm by the hips. The model then lowers the left hand so that it extends directly parralel with the ground, followed by the right hand. The left hand is lowered by the hips, and finally, the right hand is raised perpendicular with the ground.

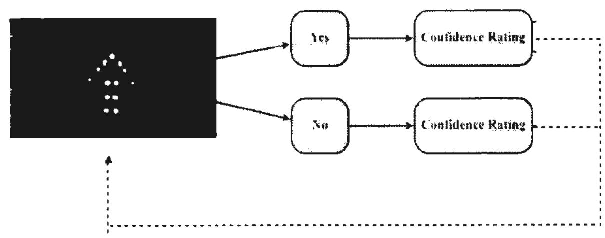


(b) The model starts with hands on the hips. Keeping the elbows bend at 90°, the model transitions to the final position by performing an inwards circle-like motion. The motion is completed when elbows are raised at shoulder level, arms still forming a 90° angle.

(c) The model starts by forming a diagonal, right arm up. Each arm forms a 45° acute angle with the body. The model then bends the elbows so as to place the hands over the shoulders. Both elbows are then simultaneously lowered or raised as to mirror the previous position. Finally, the arms are extended.

Figure 4.1: Graphical representation of stimuli from Experiment 1. Figures (a), (b), and (c) are examples from the full stimulus set presented in Appendix B. They represent a variety of stimulus length, complexity, and positions. Refer to each figure's subcaption for a complete description of the action depicted.

Instructions for Making Recognition Judgements.



Many motion sequences will be presented one after the other. You will have seen some of them in Phase I, others will be new. Your task is to identify which ones you have and have not seen before.

1. **Yes vs No**: If you think that the motion sequence you see now was in Phase I, chose *yes*; otherwise, chose *no*.
2. **Confidence Rating**: Indicate on a scale of 1 to 6, how confident you are that you made the correct *Yes vs No* decision (from "Guess" to "Absolutely Sure").

If you have any question regarding these judgements, please ask the research assistant.

Figure 4.2: Recognition instructions used in Experiment 1

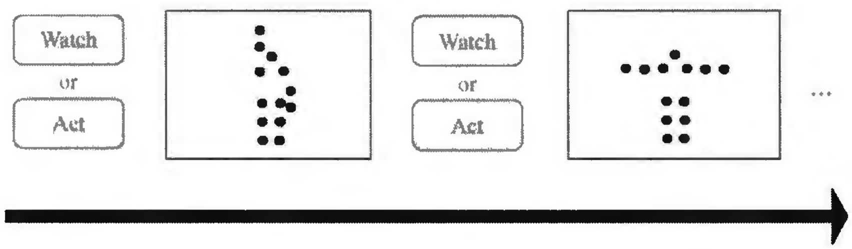


Figure 4.3: Design of the encoding phase of Experiment 1. Following the instruction to watch or to act, participants saw a stimulus and performed the appropriate action. Some stimuli were presented once, others, four times, always with the same instruction.

4.2.3.2 Encoding Phase

The design of the encoding phase is summarized in Figure 4.3. A different list of 60 stimuli was generated for each participant. Twenty four stimuli were drawn from the stimulus set: Half of these were randomly assigned to one of two repetition conditions, where each stimulus was presented once or four times. Additionally, half of the stimuli (12 from the once and 12 from the four times repetition conditions) were randomly assigned to the watch condition, and the other half to the act condition. Finally, the sequence of presentation was randomized and stimuli were presented sequentially, preceded by their specific instruction (WATCH or ACT) set in bold type in 32 pt size font. When participants saw the watch instruction, they had to stand still and memorize the actions performed in the stimuli. When they saw the act instruction they had to follow along the arm motions, mimicking the stimuli as if seen through a mirror. This encoding phase lasted about eleven minutes.

4.2.3.3 Testing Phase

All forty-eight stimuli from the set were selected once and rearranged in a different random order for each participant. Stimuli were presented one at a time, looping to the beginning until the two recognition judgments were made by button press. First, participants indicated in a recognition judgment, if yes or no they remembered seeing the stimulus in the encoding phase. Second, they indicated on a scale from 1 to 6 (from *complete guess* to *absolutely sure*) how confident they were in their recognition judgment.

4.3 Results

4.3.1 Overall Recognition Performance

All results were analyzed at the critical two-tailed $\alpha = .05$ level. Indicators of recognition memory performance were computed as in the pilot study. When assessed against the .5 chance level, single sample t-tests showed that participants correctly recognized old stimuli in the test phase ($M = .71$, $SD = .16$), $t(20) = 6.00$, $SE = .034$, $p < .001$. False alarm rates were low ($M = .16$, $SD = .20$), and much smaller than the hit rates, paired sample t-test, $t(20) = 13.63$, $SE = .040$, $p < .001$. On average, A' analysis revealed that participants were able to discriminate old from new stimuli ($M = .86$, $SD = .09$), and that this average performance was statistically different from the .5 chance level as determined with a single sample t-test, $t(20) = 18.84$, $SE = .019$, $p < .001$.

The modified stimulus set along with the changes in design were clearly adequate for use in a critical test of the enactment effect. The hit rates were high, yet on average, there was much room for an enactment effect to be detected. The false alarm rates were fairly low, but enough errors were made to demonstrate that the task had a degree of difficulty. Even more importantly, contrasting this result with the overall A' value obtained in the pilot study ($M = .57$, $SD = .15$), we can see that the changes made to the stimuli and the design were beneficial to participant's ability to form distinctive memories of the stimuli. Remember that $A' = .5$ indicates chance performance, and $A' = 1$, perfect discrimination. The improvement from the pilot study to Experiment 1 was excellent. In addition, Figure 4.4 illustrates that all but two of the participants performed above the .5 chance level in both encoding conditions.

4.3.2 Enactment Performance

A 2x2 repeated-measures ANOVA on A'was conducted with encoding condition (watch vs. act) and repetition condition (once vs. four times) as within-participants factors. There was a main effect of encoding condition. As expected, performance in the act condition ($M = .88$, $SD = .08$) was greater than in the watch condition ($M = .83$, $SD = .11$), $F(1, 20) = 5.11$, $MSE = 0.009$, $p = .035$, $\eta_p^2 = .20$. It was also confirmed that showing a given stimulus four times ($M = .92$, $SE = .03$) resulted in greater discrimination than showing it once ($M = .78$, $SE = .01$), $F(1, 20) = 48.40$, $MSE = 0.008$, $p < .001$, $\eta_p^2 = .707$. However, there was no significant interaction between repetition condition and encoding condition, $F(1, 20) = .94$, $MSE = 0.008$, $p = .345$, $\eta_p^2 = .05$. Repetition condition did not affect the size of the enactment effect.

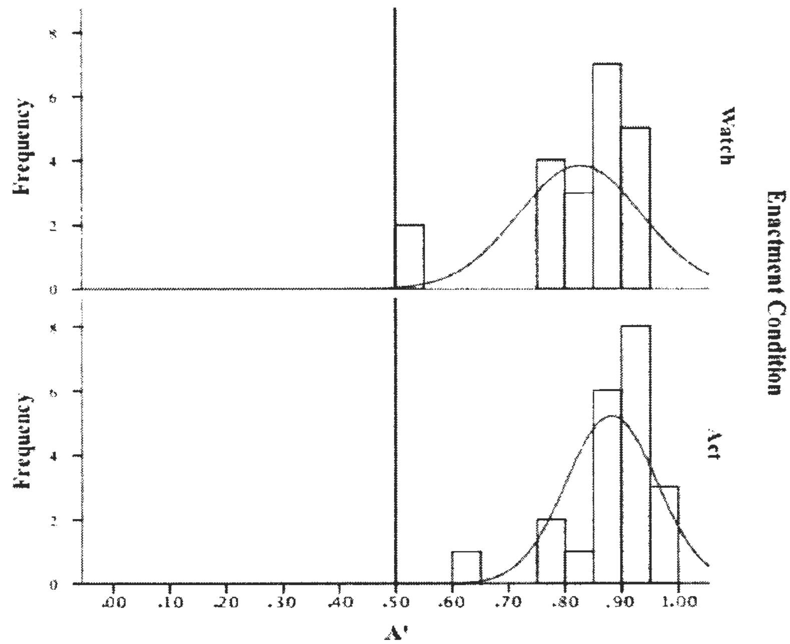


Figure 4.4: Frequency histograms of A' values given encoding condition. *Notes.* 1. $n = 21$. 2. Encoding condition was manipulated within-participants. 3. An A' of 1 indicates a hit rate of 1, with no false alarms, A' of .5 indicates chance performance, and an A' lower than .5 indicates that more false alarms than hits were made, a result most likely due to sampling error.

4.3.3 Confidence Ratings

A 2X2 repeated-measures ANOVA on confidence ratings for old stimuli was conducted with encoding condition (watch vs. act) and repetition condition (once vs. four times) as within-participants factors. Overall, participants were very confident in their answers ($M = 4.90$, $SE = .11$), and confidence did not vary as a function of the encoding condition, $F(1, 20) = 2.28$, $MSE = 0.347$, $p = .147$, $\eta_p^2 = .10$. Participants were as confident in their responses to the watch ($M = 4.80$, $SD = .58$) as to the act items ($M = 5.00$, $SD = .63$). Participants were more confident in the four times condition ($M = 5.14$, $SD = .66$) then they were in the once condition ($M = 4.66$, $SD = .63$), $F(1, 20) = 8.48$, $MSE = 0.554$, $p = .009$, $\eta_p^2 = .30$. There was no significant interaction between the repetition condition and the encoding condition, $F(1, 20) = 2.11$, $MSE = 0.105$, $p = .162$, $\eta_p^2 = .10$.

4.4 Discussion

Experiment 1 was designed to examine the hypothesis that an enactment effect would be obtained in an interaction with a conceptual processing manipulation, here, the repetition condition, or the number of times a given stimuli was seen. An overall enactment effect was detected, as well as a main effect of the repetition condition. There was no significant interaction of these two factors. In other words, contrary to predictions from the multimodal memory model (Engelkamp, 1998), the size of the enactment effect was the same regardless of whether or not participants had the opportunity to form action concepts for a subset of stimuli. Note that at test, the repetition condition thought to help conceptual processing had a positive impact on participant's confidence in their judgment. However, enacting did not affect confidence. These results indicate that at least in a recognition study, the implication of the multimodal memory model arguing for the necessity of pre-existing action concepts in the detection of an enactment effect was not supported. It seems that it is not necessary for action concepts to be present prior to enacting for motor information to be integrated in the memory trace. Experiment 2 was designed to generalize the findings of the recognition test of Experiment 1 to a recall test.

Chapter 5

Experiment 2

5.1 Rationale and Predictions

The multimodal memory theory predicts that pre-existing action concepts are necessary for motor encoding to be integrated to a memory trace, and hence no enactment effect should be obtained with novel abstract arm motion stimuli. However, Experiment 1 indicated that in a recognition test, pre-existing action concepts were unlikely to be mandatory for motor encoding. Indeed, the enactment effect was observed when stimuli were seen multiple times as well as when they were only seen once. Because the multimodal memory theory prediction is thought to hold true accross memory tests, results from the recognition test should be replicable with a recall test. Experiment 2 was created specifically to test whether or not an enactment effect would be obtained in the *absence* of pre-existing action concepts using a recall test. Experiment 2 mimicked a subset of the encoding situation of Experiment 1, where partipants were asked to recall stimuli seen only once. Contrary to the prediction of the multimodal memory theory, but in accordance with Experiment 1, an enactment effect is predicted to be obtained when participants are asked to recall abstract arm motions seen for the first time.

Enacting is thought to promote item-specific encoding, and under certain conditions, watching can promote relational encoding (Engelkamp & Dehn, 2000). Free recall and recognition are the memory tests most commonly used in typical enactment effect studies, but the choice of recall in Experiment 2 necessitates careful design considerations. Free recall relies on both item-specific and relational encoding (Nairne et al., 1991). If not designed properly, it could be possible to unwittingly mask an enactment effect, given that encoding under the act and the watch conditions could lead to memory improvement for entirely different reasons. The design of Experiment 2 was chosen to minimize potential differences in relational encoding by following Engelkamp and Dehn's recommendation to use a within-participants design.

Recall was performed through overt arm motions (Engelkamp, 1998; Watanabe, 2003). Participants replicated the stimuli seen at encoding to the best of their abilities. Their performance was assessed using a gist-based rating scale I created, presented in Section 5.2.4.3.

5.2 Method

5.2.1 Participants

Thirty participants ($M = 21.4$ years, $SD = 2.7$ years; 20 females, 10 males) from the Memorial University of Newfoundland originally took part in Experiment 2. Given the large effect size for the enactment effect obtained in Experiment 1 (equivalent to d = .65), it was determined that in Experiment 2 would yield an acheived power of .93 with 30 participants. Of the 30 participants, twenty-seven declared themselves students, and three declared other occupations. Because of non-compliance with the instructions, two participants were dropped from subsequent analyses (see Section 5.2.4.4). The final sample therefore included 28 participants ($M = 21.4$ years, $SD = 2.8$ years; 19 females, 9 males; 25 students, 3 with other occupations). As in the pilot study and Experiment 1, they were volunteers who had either originally responded to advertisements posted on the university campus or had been contacted from a participant pool contact list. The sessions were conducted individually and lasted approximately 50 minutes. Participants received a $10 stipend for their participation. None had participated in the pilot study or in Experiment 1.

5.2.2 Materials

The same material and stimulus set as in Experiment 1 were used. The only new material added was a video camera to record the session. Participants were filmed face-on, with the camera being mounted on the stand beneath the television screen.

5.2.3 Procedure

5.2.3.1 Preparation

The experimenter administered the informed consent form and emphasized the anonymous and voluntary nature of participation. Participants could leave at any time and still collect their stipend. The participants were aware that they were going to be filmed. All data collected up until that point would be destroyed if they chose to withdraw their participation. All participants completed the experiment. The experimenter gave the participants all necessary information for them to perform the memory test. After making sure that the participants understood the instructions, the experimenter started the experiment and sat out of participants' view. As in Experiment 1, participants stood up for the duration of the experiment. The memory test that followed was a free recall memory test. The design of Experiment 2 is illustrated in Figure 5.1.

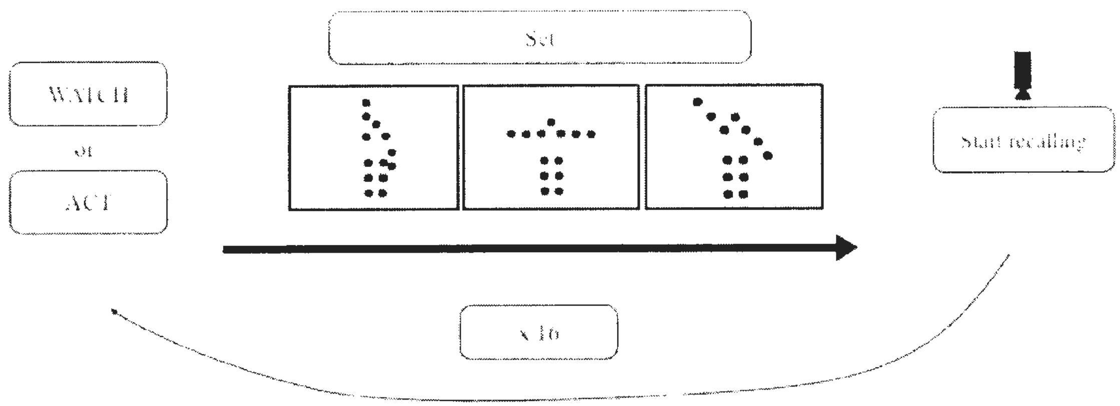


Figure 5.1: Design of Experiment 2. The instruction to watch or to act preceded presentation of a list of three stimuli. As the stimuli unfolded, participants complied with the instruction. They then performed the stimuli from memory to the best of their ability. Participants were filmed at all time.

5.2.3.2 Stimulus Setup

For each of the participants, the 48 stimuli from the set were randomly assigned to one of 16 three-stimuli lists. Half of the lists were randomly assigned to the act condition and half to the watch condition.

5.2.3.3 Free Recall

When participants were ready to start presentation of a to-be-recalled list, they gave the experimenter the command to initiate the computer program. The instruction to WATCH or to ACT came up on the screen for 4s, and the three list stimuli were shown sequentially at a 1s inter stimulus interval. This was followed by a written instruction to start recalling. Participants could recall stimuli in any order they liked, performing the actions as similar to the original stimuli as possible. They were encouraged to identify the stimulus they were recalling by saying its serial position out loud. Participants were aware that this was not crucial to the memory test. Also, if participants were unsure of a stimulus, they were encouraged to guess rather than skip it. When participants finished performing the list stimuli, they decided when to start the next list. This procedure was repeated until all 16 lists were seen and recalled.

5.2.4 Data Analysis

5.2.4.1 Video File Preparation

After the experimental session, a video file was created from the experimental session video footage for each participant. At this time, information regarding encoding condition was removed, keeping only the free recall portions of the movies. An in-movie tag identifying only the participant number and the list number preceded each list recall attempt.

Figure 5.2: Examples of acceptable position performances. The first black figure represents the position as performed in the stimulus. It is reproduced in grey in subsequent figures. The black lines overlayed on the grey figures represent various ways participants could execute the position. Each of these represent *acceptable position performance, as they are within 22° of the original action.*

5.2.4.2 Coding Performance

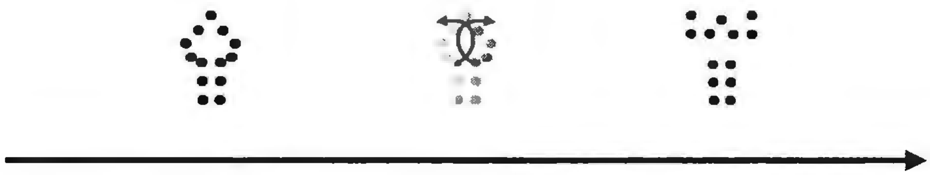
A research assistant and I viewed all the blinded video files, and transcribed participants' recall performance on a coding form similar to the schematic representation in Appendix B. The goal of this procedure was to provide an objective assessment of participants' memory accuracy. I then watched all movies again with both coding forms in hand, resolved discrepancies, and applied a gist-based rating scale to the coded performances.

Each stimulus was made up of a sequence of positions, and sometimes of transitions, represented on the coding form. Positions were instances in the presented stimuli where the figure paused in a specific manner. Execution of a given position is considered an *acceptable position performance* if both of the participant's arms were positioned within 22° of the original action (see Figure 5.2 for examples of acceptable position performances). Given that most participants could be expected to have never been involved in such activities, I thought this range would both minimize inaccuracies due to inexperience with the task, yet still be precise enough that it should represent the underlying memory trace representation.

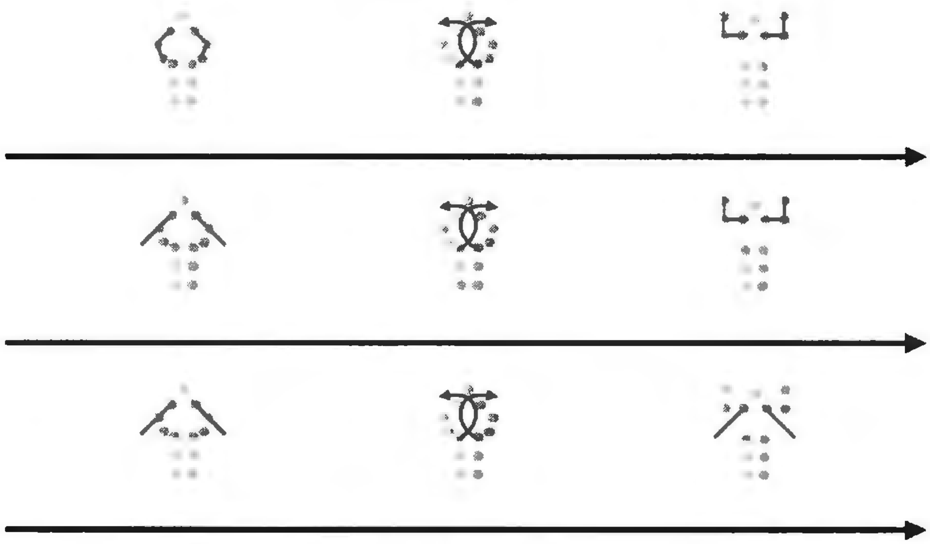
Salient transitions were defined as specific movements executed between two positions: For example, they could involve performing curved trajectories with one or more inflection points, spirals with arms, or large circle motions. For each of these transitions, important features, such as the type of trajectory and the initiated direction, when necessary, were identified and coded. A transition was considered an *acceptable transition performance* when the (or the two) features were correctly executed, regardless of the accuracy of the preceding and following positions. Examples of acceptable transition performances are illustrated in Figure 5.3.

5.2.4.3 Gist-Based Rating Scale

A 6-point rating scale, ranging from 0 to 5 points, was devised to take into account several sorts of errors. This *gist-based rating scale* was based on the performance of positions and transitions *within a stimulus* and therefore reflects the overall quality of the participant's performance as compared to the original stimulus. At the extremes, performance of a stimulus was assigned a 5-point value if only *acceptable positions and transitions* had been performed and is called a *perfect* performance because it maintained all of the important features of the presented stimulus. A 0-point value was assigned if the participant had either entirely failed to perform the action or if the recalled stimuli could not be identified as one of the three list stimuli. As a guide, the other points on the gist-based rating scale for recognizable actions can be interpreted as follow: a 4 was an almost perfect performance, a 3 reflected minor errors, and 1 or 2 were two levels of major errors. Table 5.1 describes the typical types of errors and the number of points that were to be subtracted. Stimuli containing repetitive elements required further error categories in order to maintain integrity of the rating scale. This is described in Table 5.2. Coders used both tables to determine the gist-based score of each stimulus.



(a) Presented stimulus.



(b) The black lines illustrated are the actual positions executed.

Figure 5.3: Examples of acceptable transition performances . Notice that acceptable *position* performance for those positions flanking the transition are not necessary for the *transition* to be acceptable. In the three examples depicted above, notice that the defining features of the transition, here, and inwards, circle-like motion, are all that matter for an *acceptable transition performance*. However, notice that on the first line below the presented stimulus line, the entire stimulus is recalled acceptably. On the second line, only the transition and the final position are acceptable. On the third and final line, only the transition is acceptable.

Table 5.1: *Replication Errors Applicable to All Stimuli*

Category	-	Description
Orphan Position	4	Of the list stimulus, the participant only attempted one position (not transition)
Position Substitution	1	A target position was not acceptably replicated, and the deduction is made regardless of if it was a one-arm or two- arm error. In the event that the list stimulus contained repetitions of the target position, if the position error remained constant across these repetitions, no further points were deducted. However, if the position errors were different, then 1 point per occurrence was subtracted.
Inexact Position Repetition	1	A position present in the list stimulus was performed an inexact number of time, but was at least performed once.
Position Insertion	1	Intrusive position was performed.
Position Deleted	1	When a position present in the list stimuli was neither performed nor substituted with a different one.
Transition Substitution	2	A transition other than the expected one was performed
Transition Deleted	3	When a transition present in the list stimuli was neither performed nor substituted with a different one.

Note. Each row identifies an error likely to occur, how many points should be deducted from the 5 point maximum, and gives additional descriptive information.

Table 5.2: *Additional Replication Errors Applicable to a Subset of Stimuli*

General Instructions		
All 48 stimuli from the set are identified by a number, 01 to 48. Identify the category to which it belongs & associated instructions. Stimulus structure is described with both symbols text. Subtract points as indicated. Switch to the general table for the remaining errors.		
Category	-	Description
Mirror (*bdb*)		Sequence of mirror image positions.
Instructions		Identify *the error* resulting in the largest subtraction.
Stimuli		11, 13, 16, 17, 30, 33, 38, 41, 43, and 48.
Repetitions	1	Too few or too many performance of b or d positions, with at least one b and d performed. Only count once.
Flank insertion	2	Intrusive position flanking bd pairs (e.g., xbdb). Count once.
Insertion within bd	3	Intrusive position inserted within otherwise intact bd pairs. (e.g., bdxb)
	2	For *stimuli 38 & 48 (Abdb*, if the first position, was repeated within otherwise intact bd pairs. (e.g., AbdAb)
Mirror+A (*AbAd*)		Sequences of mirror positions interleaved with a repeating position.
Instructions		Identify *the error* resulting in the largest subtraction.
Stimuli		07, 10, 19, 21, 34, 42, B44 and B46.
Amplitude error	1	For *stimulus 46 (AbAbA)* amplitude of the second b smaller than of the first, otherwise, subtract point.
No position A	2	When an A position was deleted and resulted in a bd pair.
Insertion within	2	Intrusive position performed within otherwise intact Ad or Ad pairs. (e.g., AxbAdA)
Position Substitution	2	Intrusive position was performed instead of the target. If the intrusion was constant across target repetitions count once. If the intrusive errors vary across target repetitions, count multiple times.
Repeated - no mirror (*ABCA*)		One or more positions are repeated later in the stimuli.
Instructions		Subtract points for *all* errors listed below.
Stimuli		12, 23, 29, 35, and 36.
No repeated	2	None of the repeated positions were performed.
	1	For *stimuli 29 and 35 (ABCBA)* amplitude of the second b smaller than of the first, otherwise, subtract point.]
Repetitions	1	Too few or too many performance of b or d positions, with at least one b and d performed. Count for all.
Insertion anywhere	1	Intrusive position performed. Subtract 1 point per repetition of the intrusion.

Note. This table is to be used with Table 5.1.

5.2.4.4 Compliance With Encoding Condition

After all video files were coded on the gist-based rating scale and the final scores obtained, I reviewed the preprocessed video files and coded whether or not, for each stimulus, participants had complied with the encoding condition instructions. Did participants watch and act when required to? In most cases, they did. However, lists in which a minimum of one stimulus was not performed in compliance with the encoding condition were removed from further analyses. Two participants were found non-compliant in more than two lists, and their data were removed from the dataset. Another step was added to make sure participants were contributing the same number of data points in all conditions. For those participants who performed all stimuli in accordance with the encoding condition, one of the lists was randomly selected for exclusion. The result of this procedure was that for each of the final 28 participants, 7 out of 8 lists per condition (ie., 14 out of all 16 lists) contributed to the final results, and within, all three stimuli had been performed in compliance with encoding instructions.

5.3 Results and Discussion

5.3.1 Overall Recall Performance

All results were analyzed at the critical two-tailed $\alpha = .05$ level. Overall recall performance was assessed using the 6-point gist-based recall scale (from 0 *omitted* to 5 *perfectly replicated*. Participants obtained on average 2.85 points ($SD = 1.83$) on the gist based measure, with a score of 3 points indicating minor performance error. Observation of the distribution of the gist-based rating in Figure 5.4 reveals that participants omitted .21 ($SD = .40$) of the stimuli at recall, and that there was a negative asymmetry for those

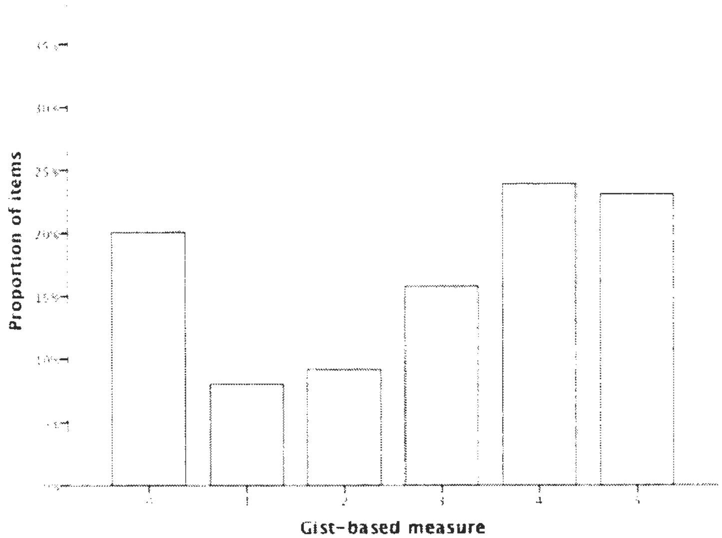


Figure 5.4: Distribution of the overall gist-based ratings for Experiment 2.

stimuli attempted and recognizable. Though there was much room for improvement, participants tended to replicate the stimuli at an adequate level.

A paired sample t-test revealed that participants performed at the same level in the watch condition ($M = 2.90$, $SD = .58$) as in the act condition ($M = 2.79$, $SD = .61$), $t(27) = .88$, $SE = .120$, $p = .386$. Results from the recognition test of Experiment 1 led to the expectation that an enactment effect would be obtained in Experiment 2 with a recall test. However, in accordance with the multimodal memory theory, the necessity of pre-existing action concept seemed to be verified. Indeed, no enactment effect was obtained in the absence of pre-existing action concepts.

This absence of an improvement in memory for enacted lists of stimuli cannot be explained by a ceiling effect, as the gist-based rating scale could allow for improvement to be detected. The opposite explanation did not hold either: Participants performed well enough that the explanation that they were not able to memorize stimuli well enough for recall can not be defended. It is possible that pre-existing action concepts are more important to the enactment effect in recall than they are in recognition studies, therefore lending support to at minimum, a weak form of the multimodal memory theory implication. Experiment 3 was designed to address this possibility. Its design was based on Experiment 2, except for one critical change: A manipulation was implemented to facilitate conceptual processing of the stimuli.

Chapter 6

Experiment 3

6.1 Rationale and Predictions

In Experiment 2, no enactment effect was found with recall of three-stimulus lists. This result was congruent with the multimodal memory theory prediction, but not with results from Experiment 1. In Experiment 3, therefore, I set out to examine the extent to which facilitating the formation of action concepts would allow the enactment effect to appear. In the case of recall studies specifically, if facilitating the formation of an action concept formation gives rise to an enactment effect, then it will appear that this form of conceptual processing can mediate *recall*.

In Experiment 3, *conceptual processing* was varied not as a repetition condition (see Chapter 4) but as a *labeling condition*. Indeed, had the three stimuli from each list been repeated more than once, the probability of obtaining ceiling-level performance at recall would have likely been too high. Instead, to facilitate conceptual processing of the stimuli, I created verbal labels associated semantically with the to-be-remembered abstract actions, and presented each label before their associated stimulus. With this additional information, participants were expected to form correct expectations of the pattern of motions they would view, and better integrate the motor information to the memory trace. The creation of the verbal labels is described in Section 6.2.2

The critical hypotheses were evaluated as between-experiment effects. First, in order to demonstrate the efficiency of the labeling conditing, verbal labeling had to be demonstrated to significantly increase recall performance across experiments. Second, the necessity of pre-existing action concepts was assessed as an interaction of encoding condition across experiments. If action concepts, as facilitated in Experiment 3, permited motor information to be integrated to the memory trace, then an enactment effect would be detected in Experiment 3, but not in Experiment 2.

6.2 Method

6.2.1 Participants

As in Experiment 2, thirty participants ($M = 20.2$ years, $SD = 2.1$ years; 24 females, 6 males) from Memorial University of Newfoundland originally took part in Experiment 3. Two participants were dropped from subsequent analyses because of non-compliance with the encoding condition instructions. Refer to Section 5.2.4.4 for the exclusion procedure followed. The final sample therefore included 28 participants ($M = 20.4$ years, $SD = 2.1$ years; 22 females, 6 males; 28 students). As in previous experiments, they were volunteers who had either originally responded to advertisements posted on the university campus or had been contacted from a participant pool contact list. The sessions were conducted individually and lasted approximately 50 minutes. Participants received a $10 stipend for their participation. None had participated in the pilot study, in Experiment 1 or Experiment 2.

6.2.2 Stimuli

The same stimuli from Experiments 1 and 2 were used, but a set of evocative, relevant verbal labels was created in a separate *labeling study* to reflect important aspects of the stimuli. Eight students from Memorial University of Newfoundland, some of whom had taken part in Experiment 2, sat down in front of the computer for this 'labeling' study. Taking part in previous experiments was desirable, because previous contact with the stimuli increased the possibility that participants would report valid labels. None of the participants took part in Experiment 3.

In the labeling study, participants took part in a self-paced session. The 48 stimuli used in Experiments 1 and 2 were randomized in a different order for each participant. Each stimulus was presented in a loop until the participant decided on a label and wrote it down on the appropriate line of a printed booklet. Participants pressed the space bar when they were ready to see the next stimulus. When all stimuli had been presented, participants received a new booklet and the set was represented in a new random order. As they saw each stimulus, they tried to remember which label they had originally written. Participants were not allowed to look back to the first booklet (for the specific instructions used, see Appendix C).

To create the labels, I followed three guidelines. First, I identifed the most frequent theme for each stimulus, from the most commonly used keywords. Second, when there were several theme options for a label, I chose the one that was the most stable from one viewing to the next. Finally, in the event of a tie between specific labels, I chose the label option that I felt was most evocative of the action. The result of this procedure can be found in Table 6.1. Of the final label selected, on average, 2.85 participants (SD = 1.78) had selected the same theme for a given stimulus, and 2.63 participants (SD = 2.63) had produced this same theme on second viewing.

Table 6.1: *Labels Associated With Each Stimulus*

Stimulus	Label	Stimulus	Label
01	scoop	25	criss cross
02	attack	26	X
03	lift weights	27	robot dance
04	chicken dance	28	waterfall
05	horizontal wave	29	clock
06	clap	30	puppet
07	hug	31	half circle
08	fitness	32	zombie
09	wave down	33	disco
10	don't know	34	bring-separate
11	LL	35	for you
12	hold backpack	36	stretch
13	boot straps	37	go team!
14	0	38	punch
15	L to W	39	elbow circles
16	smell	40	plane
17	up-down	41	flap wings
18	defeat	42	low cross
19	reverse stairs	43	blocking
20	bounce back	44	hello
21	swim	45	spiral
22	all around	46	slash
23	cold	47	love
24	top-down	48	tug of war

6.2.3 Procedure

6.2.3.1 Preparation

Preparation was identical to Experiment 2. All participants completed the experiment. The design of Experiment 3 is summarized in Figure 6.1.

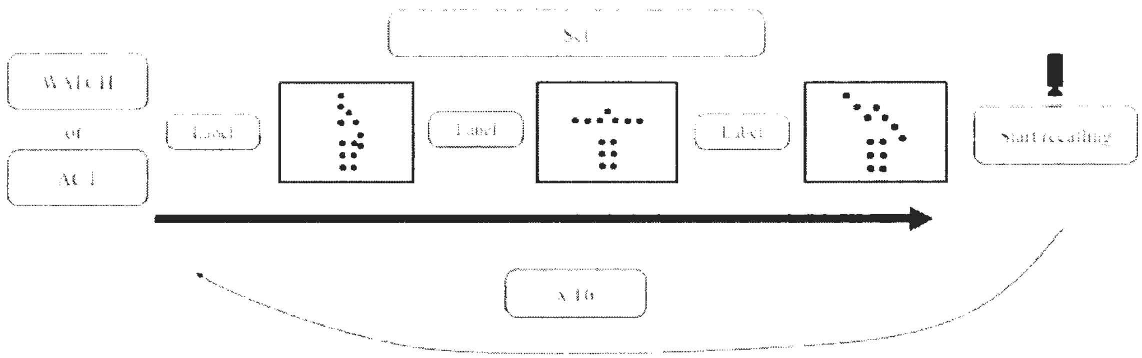


Figure 6.1: Design of Experiment 3. The instruction to watch or to act preceded presentation of a list of three stimuli. An evocative verbal label preceded each stimuli. As the stimuli unfolded, participants complied with the instruction. They then performed the actions from memory to the best of their ability. Participants were filmed at all times.

6.2.3.2 Stimulus Setup

As in Experiment 2, for each of the participants, the 48 stimuli from the set were randomly assigned to one of 16 three-stimulus lists. Half of the lists were randomly assigned to the act or watch condition. Remember that the stimulus labels were fixed: The same words were associated to the same stimuli across participants.

6.2.3.3 Free Recall

The stimulus presentation and free recall test unfolded exactly as in Experiment 2, save for two aspects. The first difference was that after the list instruction to WATCH or to ACT was presented, the first stimulus label was shown in lower case letters for four seconds. Participants read the label silently. The label was followed by a 1s interstimulus interval and its associated movie. The second and third label-stimulus pair were shown similarly. The other difference was that participants announced the stimulus label, rather than the presentation order, out loud, prior to executing them from memory.

6.3 Results and Discussion

All results were analyzed at the critical two-tailed $\alpha = .05$ level. As in Experiment 2, overall recall performance was assessed using the 6-point gist-based recall scale (from 0 *omitted* to 5 *perfectly replicated*. Participants obtained on average 3.28 points ($SD =$ 1.70) on the gist based measure. Observation of the distribution of the gist-based rating in Figure 6.2 reveals that there was a negative asymmetry for those stimuli attempted and recognized as such. Participants omitted .12 ($SD = .32$) of the stimuli at recall, revealed by independent t-test to be fewer than omissions in Experiement 2, $t(58) = 4.11$, $SE =$ .021, $p < .001$. A paired sample t-test revealed that gist-based performance of the watch

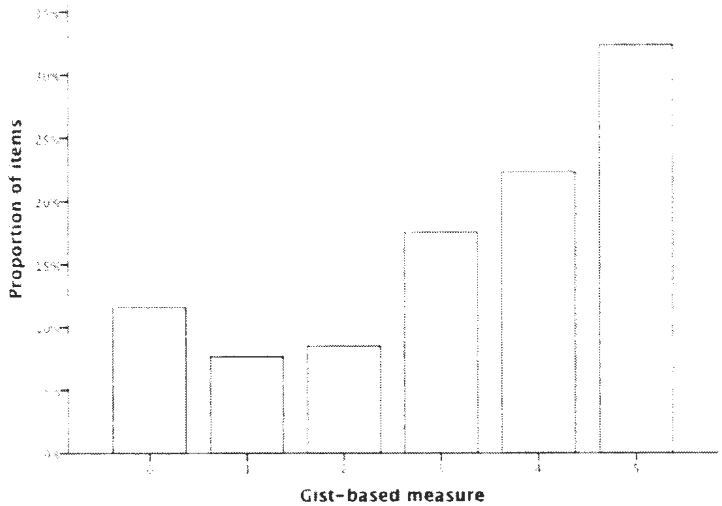


Figure 6.2: Distribution of the overall gist-based ratings for Experiment 3.

condition ($M = 2.83$, $SD = .52$) was not significately different than performance in the act condition ($M = 2.79$, $SD = .60$), $t(27) = -.347$, $SE = .098$, $p = .732$.

Labeling in Experiment 3 was expected to enhance conceptual processing compared to no labeling of stimuli in Experiment 2, and result in better memory in Experiment 3 than in Experiment 2. This labeling condition was also expected to interact with the encoding condition. The necessity of pre-existing action concepts for motor encoding was assessed as a between-experiment condition, where an enactment effect was predicted to be detected in Experiment 3, but not in Experiment 2. In case there could be a practice effect, and predicted effects would only be detectable after participants became accustomed to the memory test, a third factor was investigated. The analysis therefore includes a Halves variable, the *first* half denoting performance on the first 8 lists of the test, and the *second* half, on the last 8 lists.

A 2x2x2 mixed-measures ANOVA on recall performance on the gist-based rating scale with Experiment (Experiment 2 vs. Experiment 3) as a between-participants condition and encoding condition (watch vs. act) and Halves (first vs. second) as within-participants conditions was therefore conducted. See Figure 6.3 for the associated graph, and Table 6.2 for the results of the analyses. As foreshadowed earlier, there was no overall main effect of enactment: Participants recalled stimuli in the act condition (M = 2.96, SD = 1.74) as well as in the watch condition (M = 3.01, SD = 1.67). However, there was a main effect of experiment. Participants recalled stimuli better in Experiment 3, when the stimuli were presented with a verbal label (M =3.19, SD = 1.64) than in Experiment 2, when they were presented alone (M = 2.77, SD = 1.76). There was no interaction between enactment and experimental condition.

With the absence of an enactment effect in both Experiments 2 and 3, and no interaction based on conceptual processing, it seems that conceptual processing does not directly affect the obtention of an enactment effect in recall. Interestingly, there was a practice effect whereas participants performed better in the second (M =3.09, SD = 1.71) than in the first half (M = 2.87, SD = 1.70) of the lists, but Halves did not interact with any factor. No other interaction was significant.

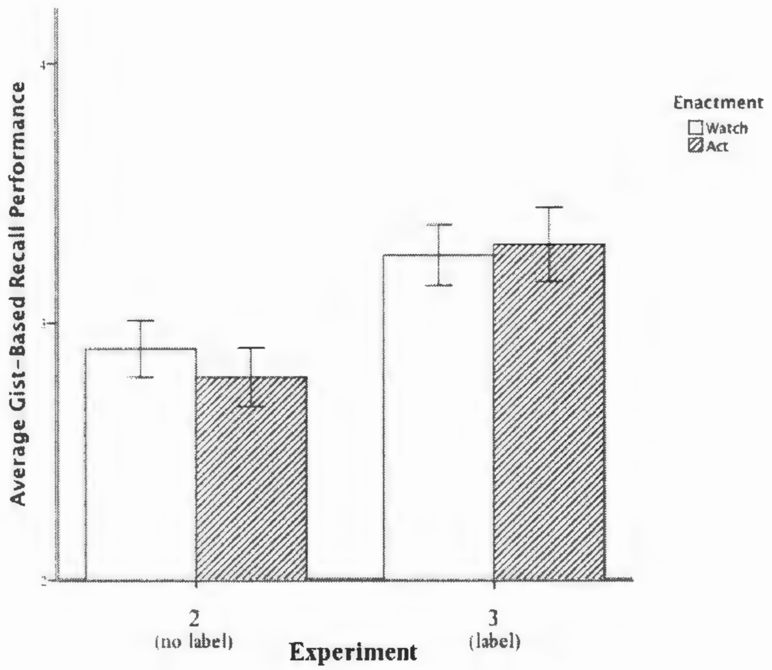


Figure 6.3: Gist-based recall performance in Experiments 2 and 3 given encoding condition.

Table 6.2: *Mixed-Measures ANOVA of Recall Performance With Experiments, Encoding Condition, and Halves As Factors*

Source	df	Mean Square	F	η_p^2	p
Labeling	1	9.00	7.29	.12	.009
Error(Labeling)	54	1.23			
Encoding	1	0.001	0.00	.00	.967
Encoding * Labeling	1	0.336	0.95	.02	.334
Error(Encoding)	54	0.353			
Halves	1	2.14	8.51	.14	.005
Halves * Labeling	1	0.140	0.56	.01	.459
Error(Halves)	54	0.252			
Encoding * Halves	1	0.038	0.10	.00	.748
Labeling * Encoding * Halves	1	0.493	1.36	.03	.249
Error(Encoding * Halves)	54	0.362			

Note. Labeling = Experiments 2 and 3; Encoding = watch and act encoding conditions; Halves = first and second halves of lists. The * indicates assessment of an interaction.

Chapter 7

General Discussion

As described by Engelkamp (1998), the multimodal memory theory is a comprehensive account of the enactment effect. The multimodal memory theory distinguishes two modality-specific input and output systems, one dedicated to verbal information, the other, to nonverbal information. Information processed through these systems is made available for encoding in a memory trace specific to the to-be-remembered item. When viewing and performing actions, the nonverbal system processes both visual information and motor information. The enactment effect is thought to arise when the critical motor information is integrated in the memory trace in addition to the visual information. However, Engelkamp (1998), as well as Zimmer and Engelkamp (2003) specified a limiting factor for the possibility of motor encoding: Motor encoding can only occur in the context of conceptual encoding, where an action concept can be drawn upon at the time of encoding. Based on this idea, I proposed that if to-be-remembered actions were entirely new to participants, no motor information could be encoded in addition to visuo-spatial information, and no enactment effect would be obtained. This test was made possible by manipulating encoding conditions of novel abstract arm motion stimuli.

To test this hypothesis, I varied encoding conditions of abstract arm motion stimuli as a within-participants variable in three experiments: Experiment 1 used a recognition test, and Experiments 2 and 3, a recall test. According to the multimodal memory theory, results obtained from both memory tests should have been congruent, as enacting is hypothesized to enhance item-specific encoding, and care was taken in Experiments 2 and 3, that no other factor would mask the enactment effect.

The evidence for the necessity of pre-existing action concepts for motor encoding was mixed. On one hand, results from Experiment 1 provided strong evidence against it. In this recognition study, the enactment effect was obtained whether a stimulus had only been shown once, or four times. There was no interaction between the two conditions. In other words, despite the improbability of having pre-existing action concepts at encoding for stimuli seen once, enacting improved memory compared to watching. On the other hand, results from Experiment 2 seemed to support the multimodal memory theory. Participants recalled lists of stimuli for which they had no pre-existing action concepts at the same level whether they enacted or watched. As it was possible that pre-existing action concepts played a more critical role in recall than in recognition, a third experiment was necessary to assess interaction of conceptual processing and encoding condition. Experiment 3 was designed to provide conceptual information for the stimuli prior to enacting in the form of evocative verbal labels. Results from Experiment 3 did not support the theory. Indeed, although this conceptual processing manipulation was effective in generally improving performance compared with Experiment 2, it did not result in detection of an enactment effect either. Overall, it seems the multimodal memory theory was wrong on that point, and that pre-existing action concepts do not mediate motor encoding.

It should be noted that adding the verbal label in Experiment 3 certainly helped participants recall items in this condition to a greater extent than in Experiment 2, where this information was not available. However, a confound precludes interpretation of conceptual processing as the sole explanation for improvement. Indeed, introducing a verbal label led to an increased interstimulus interval between each of the video presentation. It has been pointed out that this longer time increasing from 1 s in Experiment 2 to 4 s in Experiment 3 could have been repurposed by the participants for additional rehearsing. I acknowledge that this is an important limitation to drawing firm conclusions. I propose that in further replications, the interstimulus interval of Experiment 2 should be lengthened to that of Experiment 3, and that results of both these conditions should be compared to control conditions where participants are explicitely told to engage in rehearsal. In this case, a main effect of experiment, or of verbal labeling, with participants performing better with verbal label than without, would indicate that conceptual processing has an effect independent of interstimulus interval lenght. As for the explicit rehearsal control condition, a main effect of explicit rehearsal would indicate that participants do not spontaneously engage in this process, even with long list lenghts. If no main effect of explicit rehearsal could be found, one could turn to the interaction of both factors to further qualify the effect of interstimulus length.

7.1 Recognition, Recall and the Enactment Effect: Rethinking the Role of Action Concepts

In light of contradictory findings in the recall and recognition experiments, it becomes critical to answer a different question: Why was the enactment effect dependent on the memory test? When studied as a contrast between the act and the listen condition, the enactment effect is stable, but as described in Section 1.2.1.2, trade-offs between relational and item-specific encoding when comparing the act and watch conditions make the enactment effect sensitive to the memory test. Dissociations in memory performance for recall and recognition tests have been documented for other experimental memory effects (for e.g., Eagle & Leiter, 1964; Kinsbourne & George, 1974).

In the *generation effect* (Slamecka & Graf, 1978), memory performance is contrasted between a condition in which participants simply read a word associate with a condition where they generate this word (for e.g., Generate the opposite of COLD: H _ _). This generation effect was found to be stable only when memory performance was tested in recognition (Begg & Snider, 1987; Hirshman & Bjork, 1988; Slamecka & Katsaiti, 1987; Watkins & Sechler, 1988) or, in free-recall, with a mixed-list design (Begg & Snider, 1987; Hirshman & Bjork, 1988; McDaniel, Waddill, & Einstein, 1988; Nairne et al., 1991; Slamecka & Katsaiti, 1987). In the *word frequency effect* (Greg, 1976), low-frequency words are better recognized than high-frequency words (Gorman, 1961; Mandler, Goodman, & Wilkes-Gibbs, 1982; Shepard, 1967; Underwood & Freund, 1970), but high-frequency words are better recalled if pure lists of high- and low-frequency words were used (e.g., Duncan, 1974; Gregg, 1976; May & Tryk, 1970). In the *bizarreness effect* (e.g., MacDaniel & Einstein, 1986), bizarre imagery enhances memory when it makes the encoded item distinctive. With free recall, it appears in mixed-lists, within-participants designs (e.g., McDaniel & Einstein, 1986,1989; Merry, 1980; Pra Baldi, de Beni, Cornoldi, & Cavedon, 1985; Wollen & Cox, 1981); but not in pure lists, between-participants designs (e.g., Cox & Wollen, 1981; McDaniel & Einstein, 1986; Wollen, Weber, & Lowry, 1972). In the *perceptual interference effect* (Hirshman & Mulligan, 1991), interfering with the perceptual processing by immediately masking an item upon presentation improves memory for that item at test. However, its appearance in free recall depends on whether type of encoding is manipulated in pure or mixed study lists (Mulligan, 1999).

Engelkamp and Dehn (2000) applied the item-order hypothesis to the enactment effect in an act versus watch contrast. They assumed that enactment leads to better item-specific encoding than watching, but that watching leads to better relational information than enacting. They believed that memory tests did not rely on the same type of information for motor performance. A recognition test captures item-specific information, but not relational information. Therefore, the better encoding for enacted than for viewed actions should always be detected in such tests. A free recall test, however, captures both item and order information. While enacting leads to better memory via an increase in item-specific information, watching does the same via relational information. However, this is only true for within-participants designs, where order information is constant across the encoding conditions.

Unfortunately, we thus see that the commonly accepted explanation for the disappearance of the enactment effect when a watch condition is used does not manage to explain the experimental results. Indeed, both recognition and free recall experiments studies were conducted in a within-participants design, yet the enactment effect was not detectable in the free recall test. I believe that the absence of pre-existing action concepts with abstract arm motions played a key role, but in a way different from that specified by the multimodal memory theory. In a recognition study, the item-specific information encoded under the act condition might have sufficed for the relatively easy task of identifying the old stimuli at test. However, free recall is much more difficult. Participants saw the abstract arm motions for the first time before performing them back. It is entirely possible that in this memory test involving generation, a reconstruction of the memory trace, that the information provided by enactment may not have been sufficient to increase performance at a level great enough to be helpful.

To test this hypothesis, Experiments 2 and 3 should be replicated, but with a key design change: Participants should be trained extensively on the stimuli set. Perhaps, with proper knowledge of the motions depicted in the abstract arm motion can the richer encoding from enacting produce the enactment effect. This would essentially be an examination of the enactment effect in a recall study where participants have fully formed action concepts. Generation at recall would be from a more stable memory trace, and perhaps here will motor information be able to boost memory performance. Note that this replication was not part of the original research plan because it did not allow to directly test the necessity of pre-existing action concepts. If it had been run directly, without the previous experiments, it would have been nothing more than a generalization of the enactment effect to a new class of actions. The theoretical value of this thesis would have been lessened.

7.2 Conclusion

Although the multimodal memory theory's claim that pre-existing action concepts are necessary for motor encoding to occur was neither strongly supported nor disconfirmed by the experiments, an interesting conclusion can still be drawn: It appears that pre-existing action concepts do not play the critical role specified by Engelkamp (1998) in his theory. Indeed, performing actions resulted in better recognition memory performance than watching actions, even for the subset of stimuli that was only seen once. For these, it was impossible for participants to have had an action concepts. Perhaps all that mattered was an a posteriori ability to match the motor sensations to the newly formed action concepts. This would be efficient in recognition because of the easy memory test, but not in recall, where the whole trace must be reconstructed at test.

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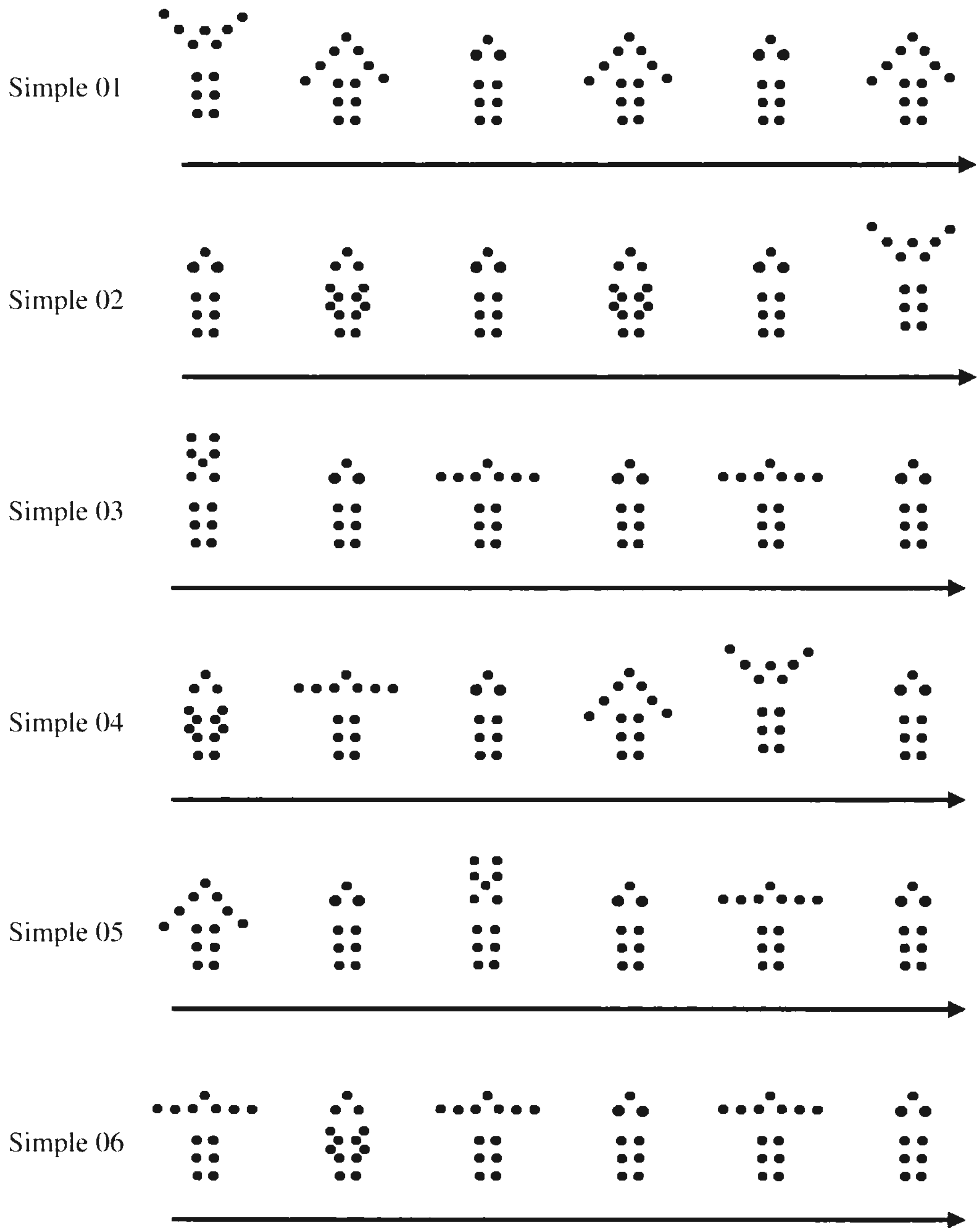
Appendix A

Stimulus Set Used in the Pilot Study



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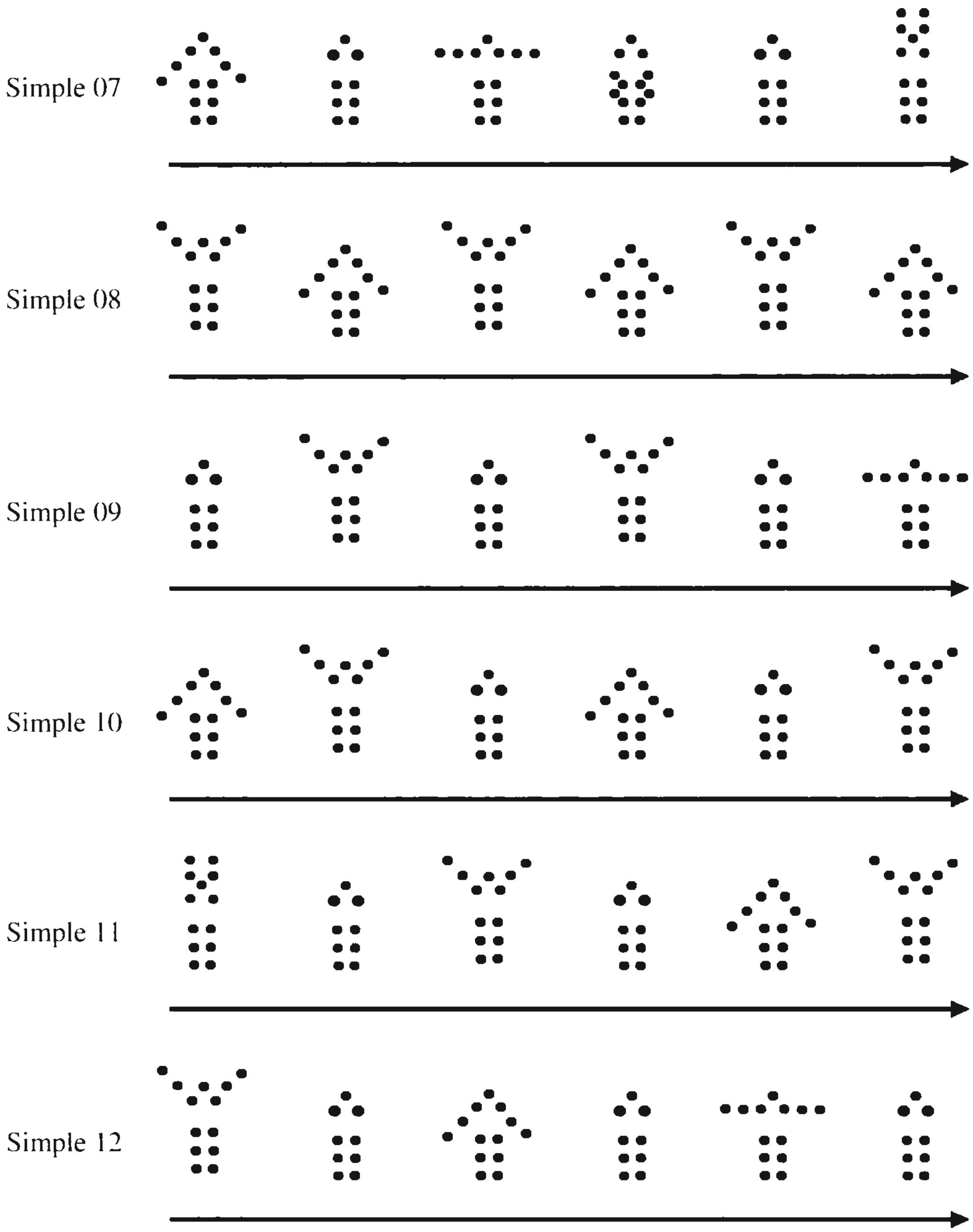
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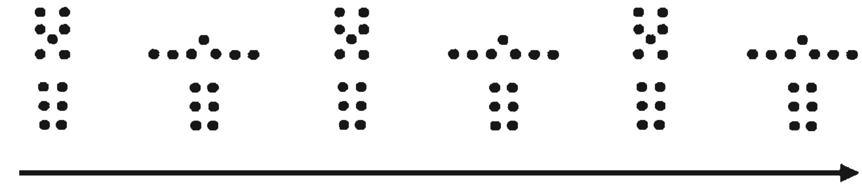

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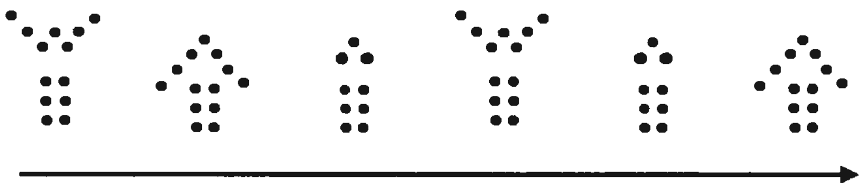

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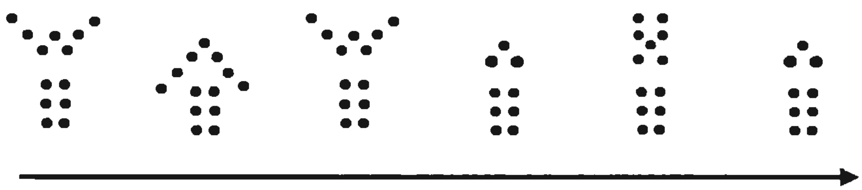

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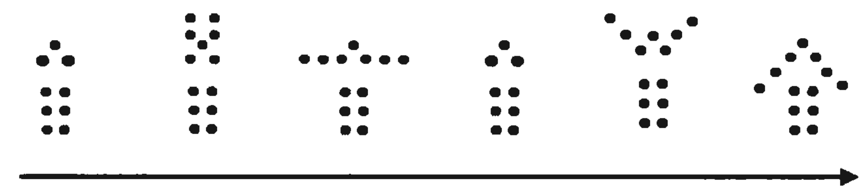

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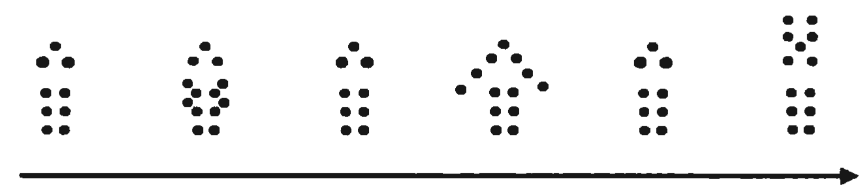

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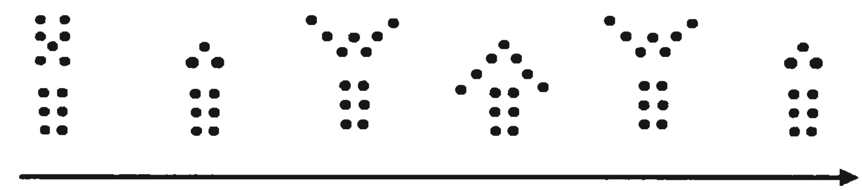

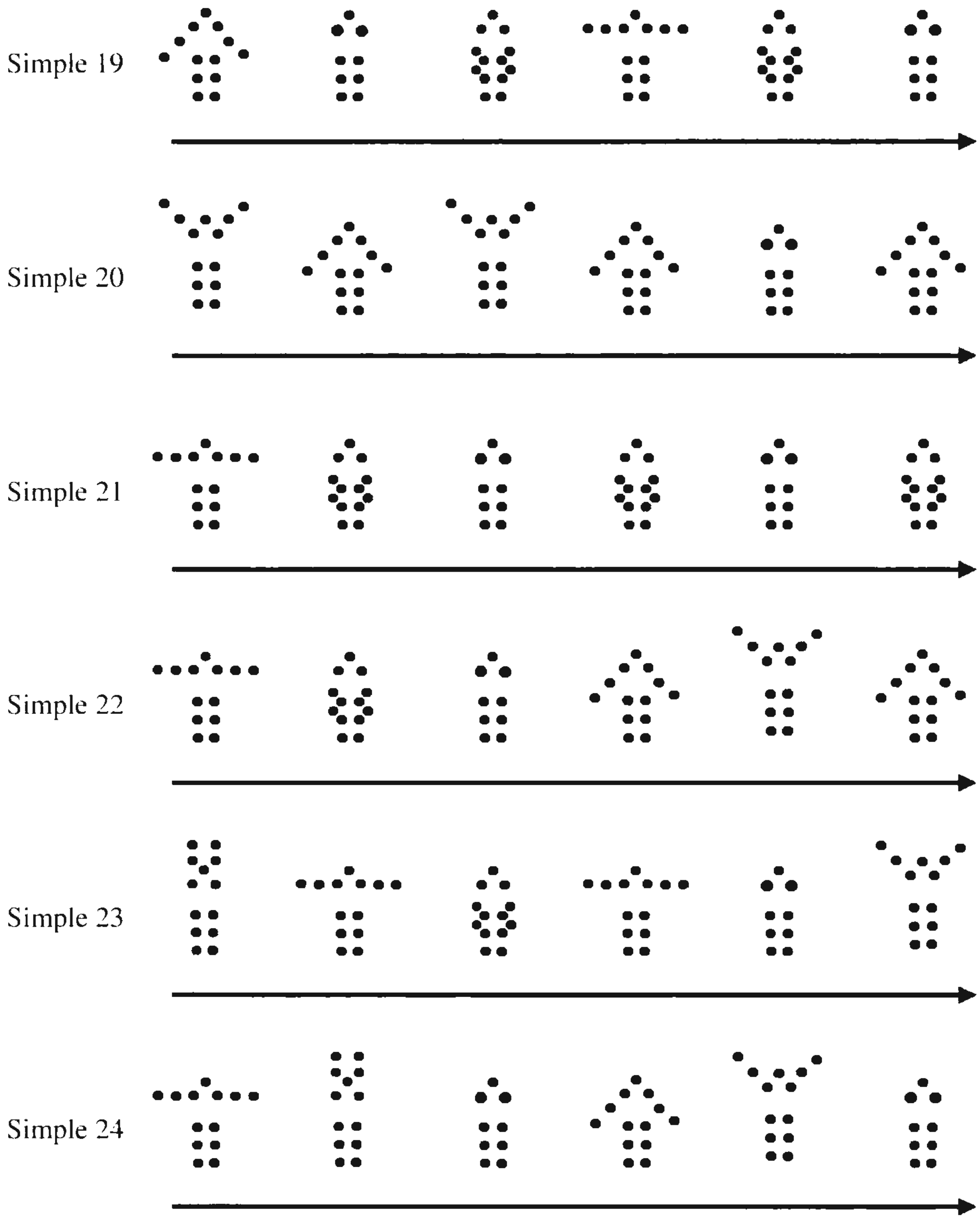
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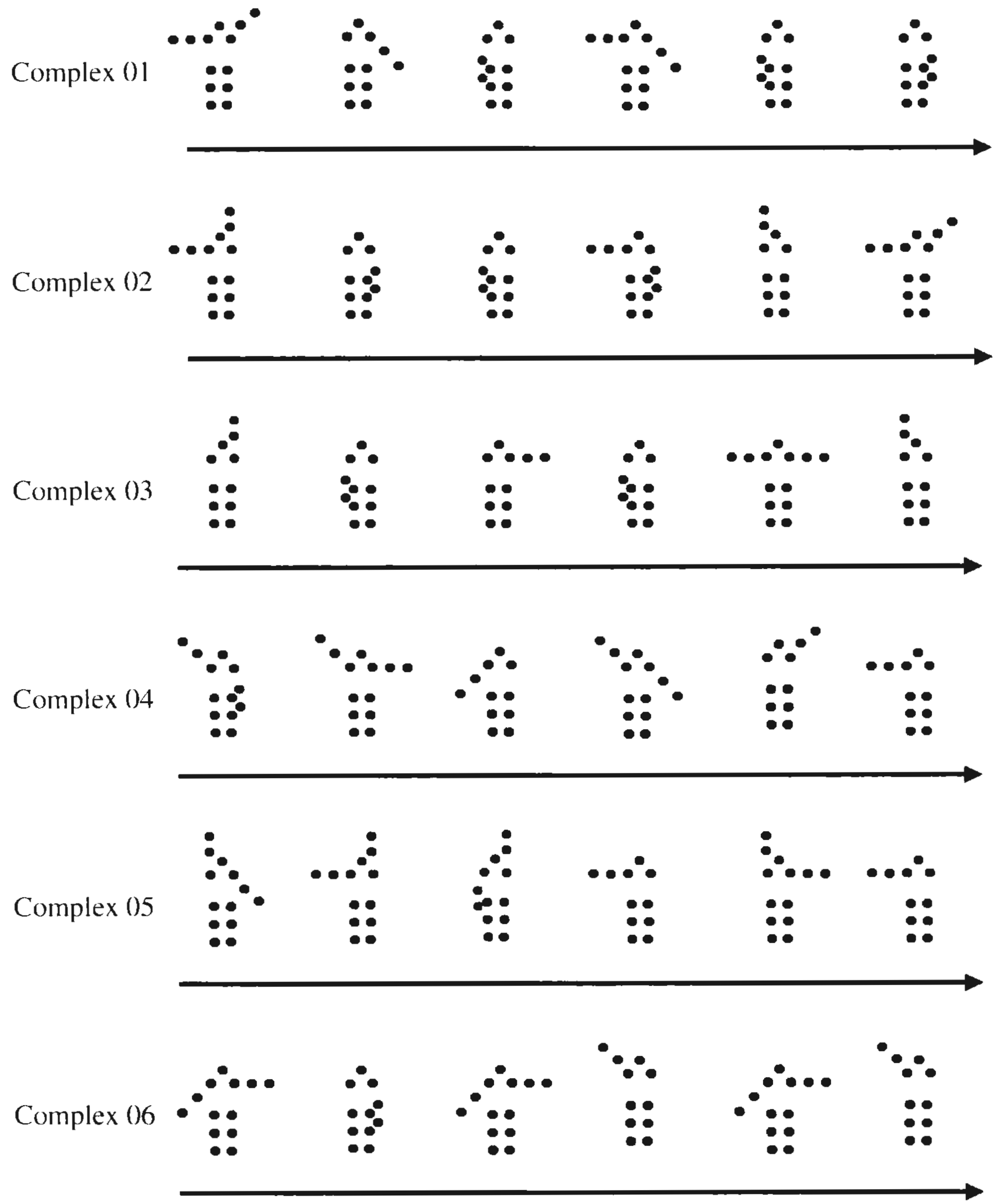
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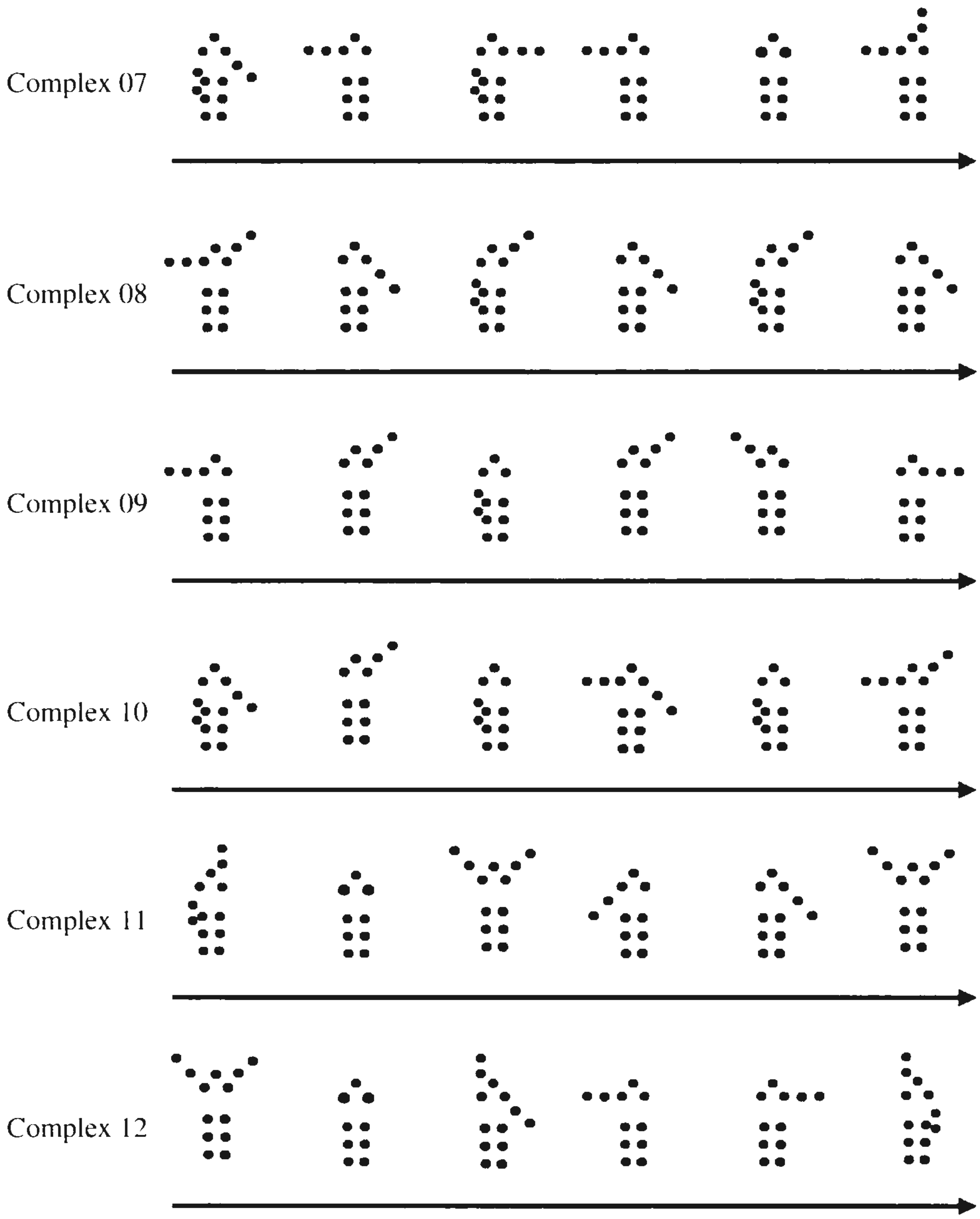

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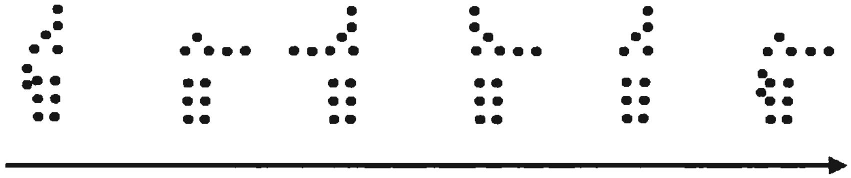
Complex 12

Complex 13



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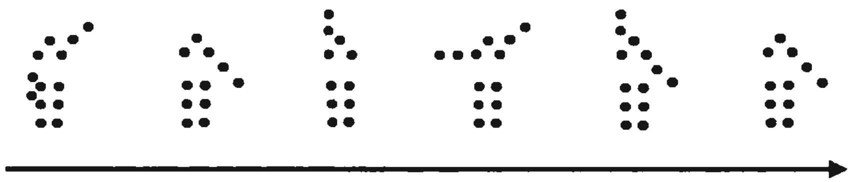

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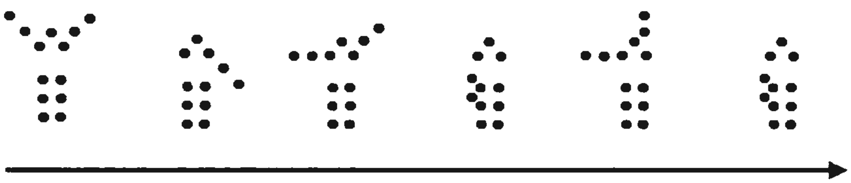

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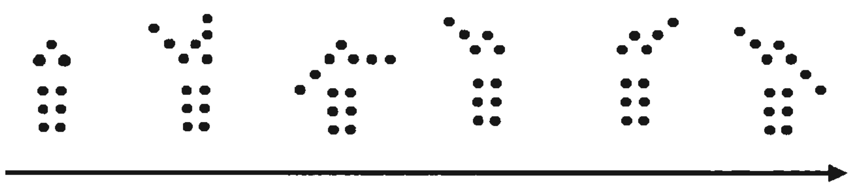

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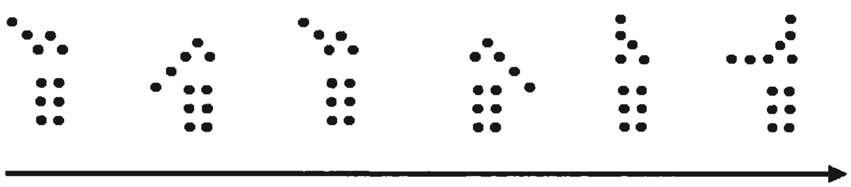

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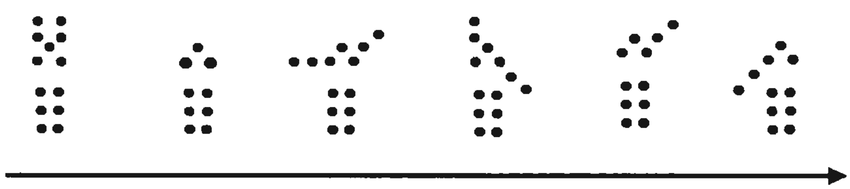

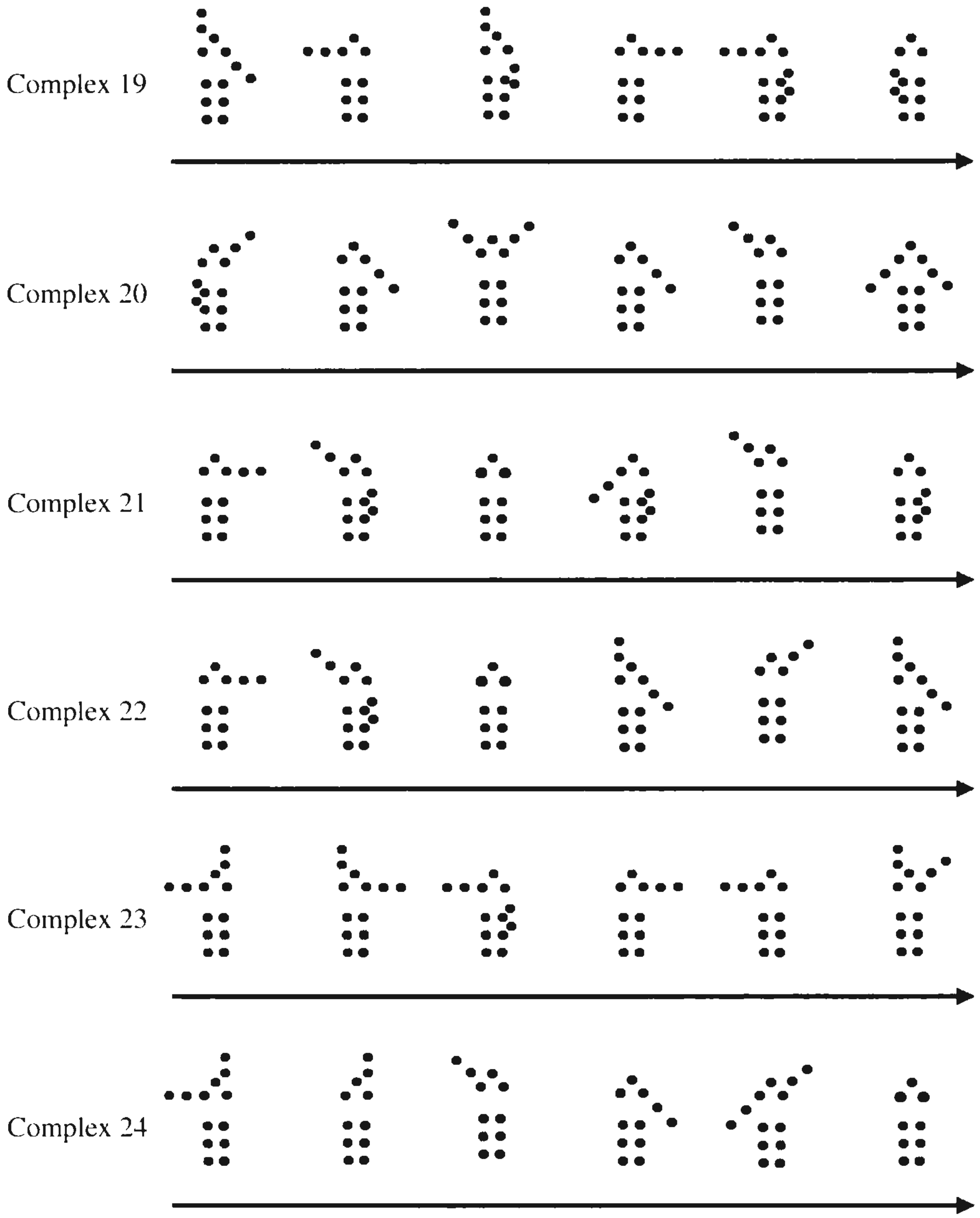
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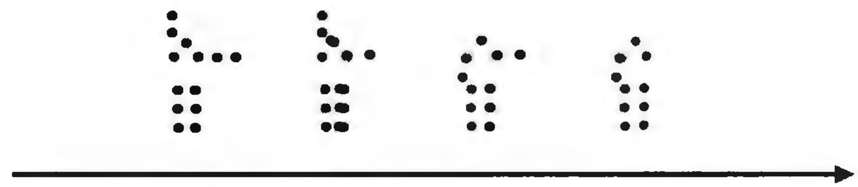
Complex 20
Complex 21
Complex 22
Complex 23
Complex 24

Appendix B

Stimulus Set Used in Experiments 1, 2, and 3

01

02



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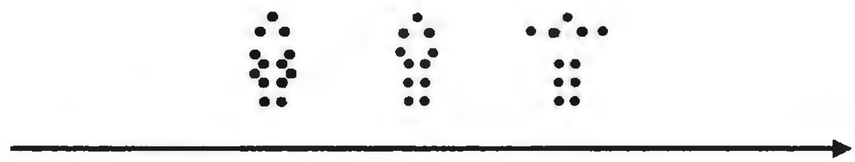

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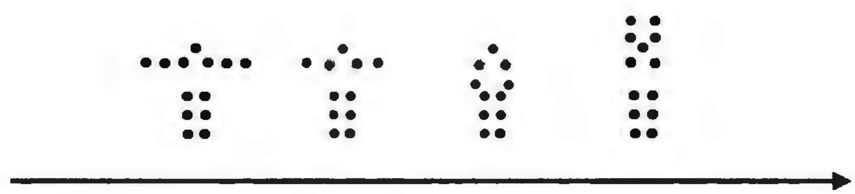

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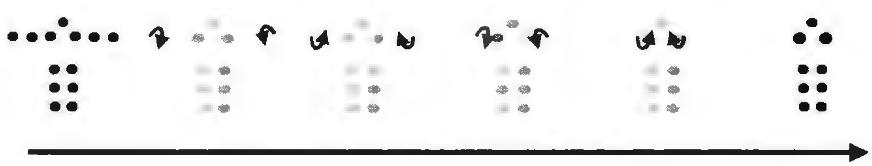

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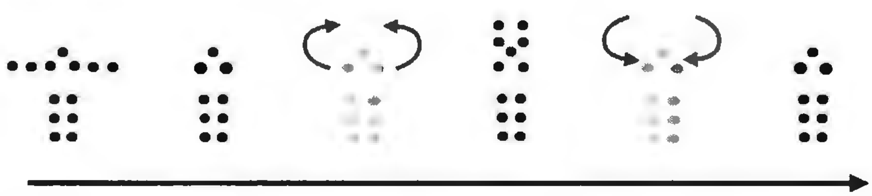

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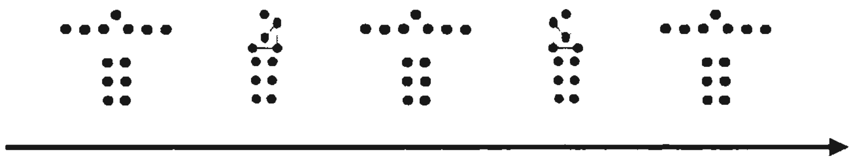

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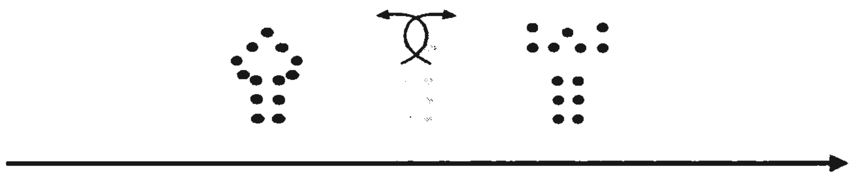

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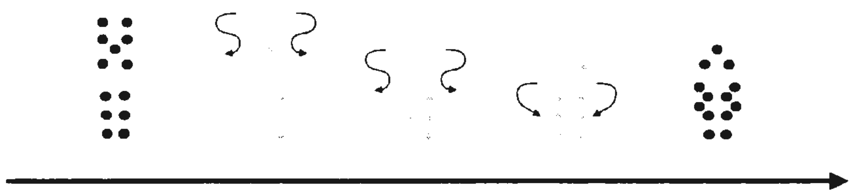

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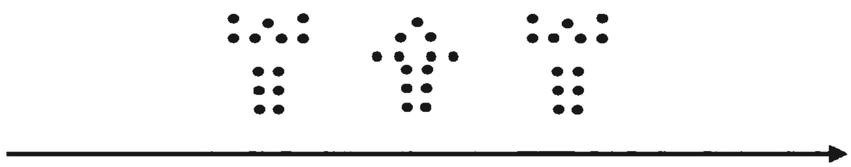

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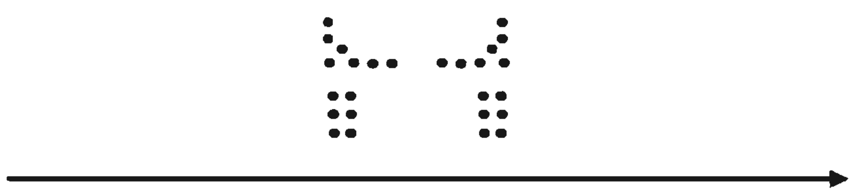

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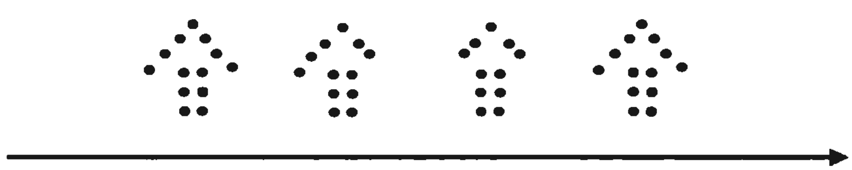

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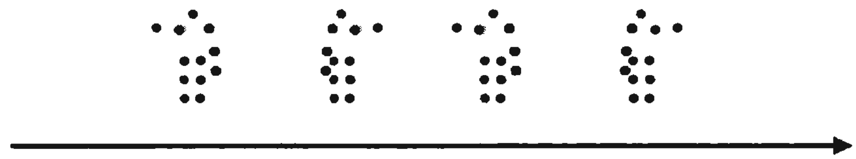

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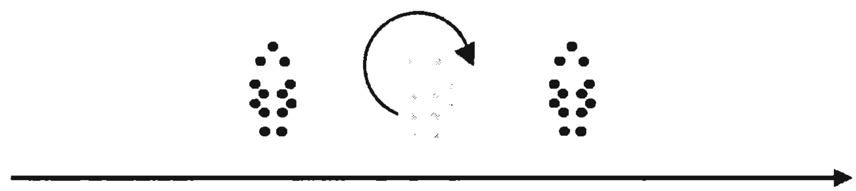

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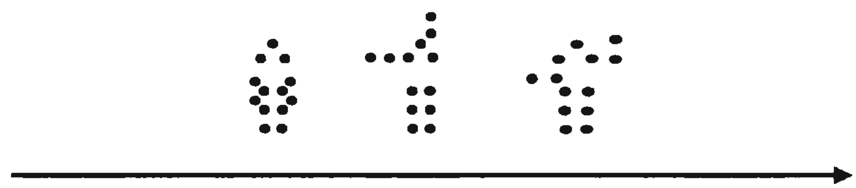

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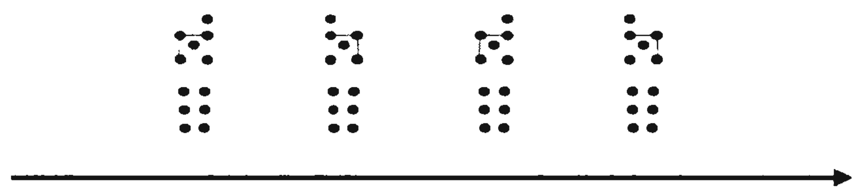

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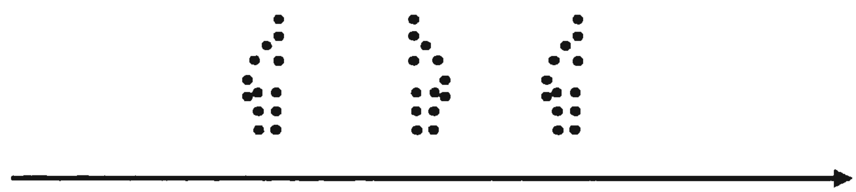

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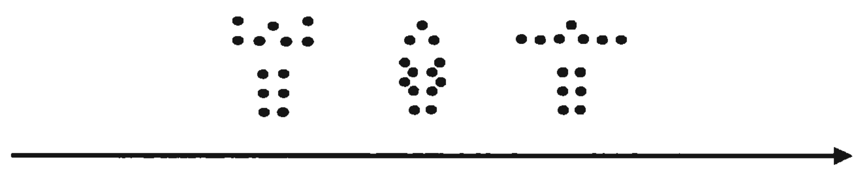

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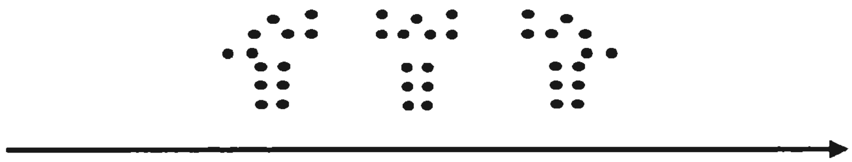

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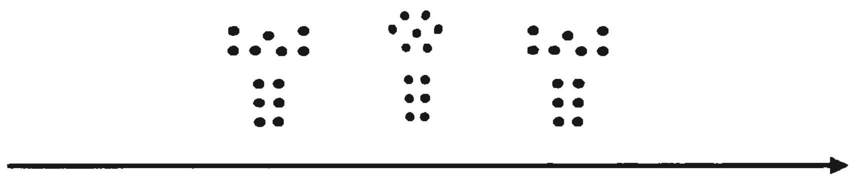

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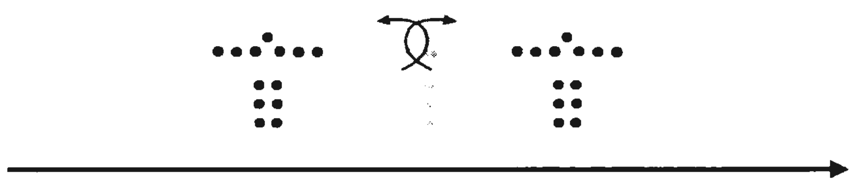

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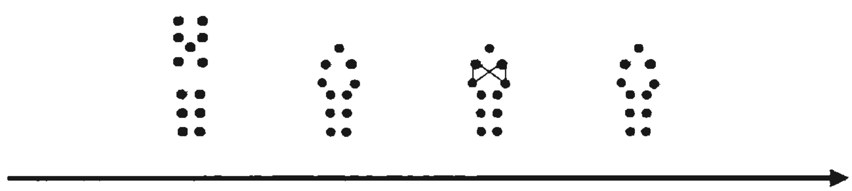

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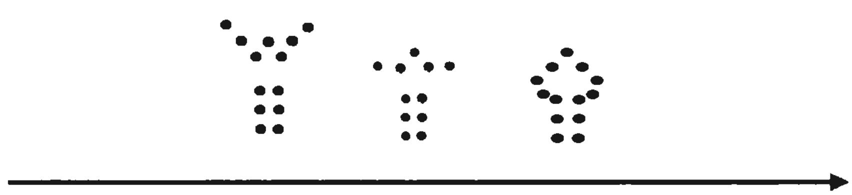

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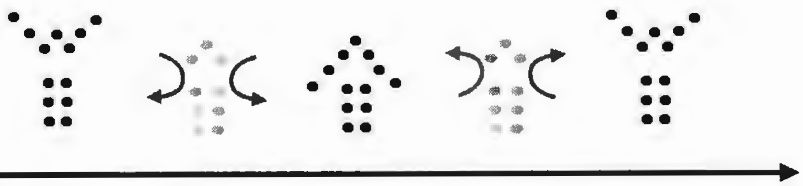

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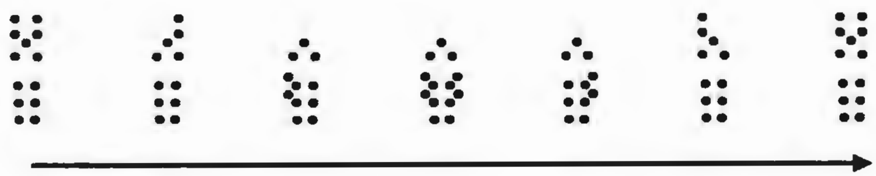

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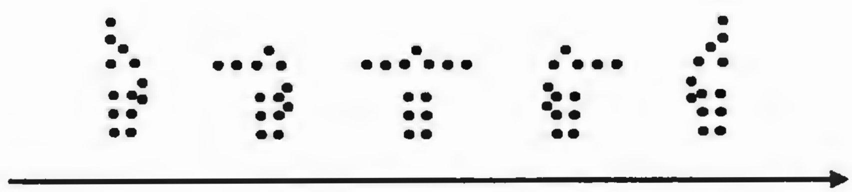

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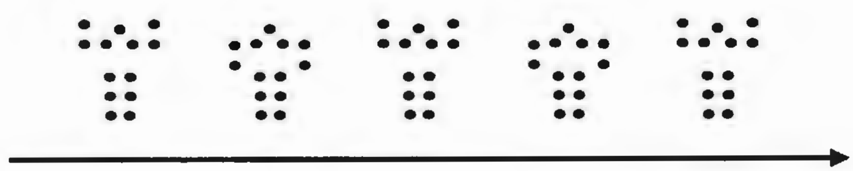

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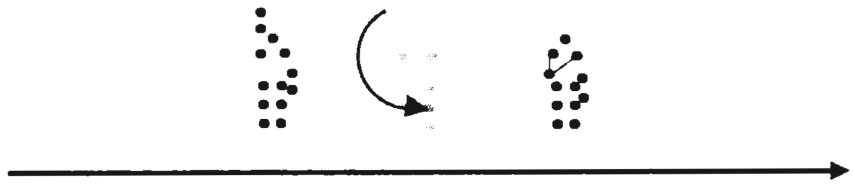

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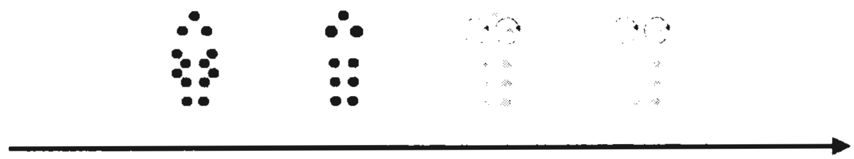

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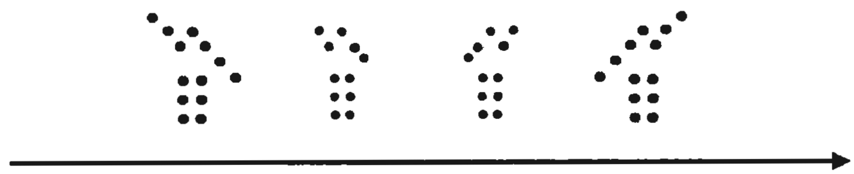

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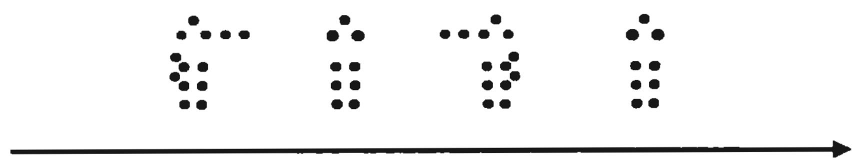

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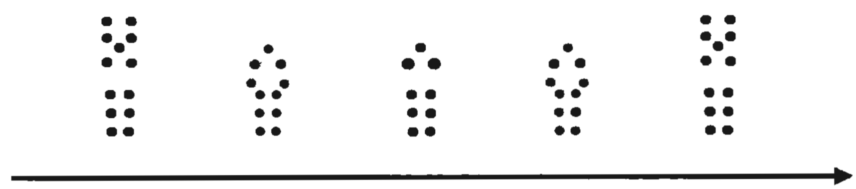

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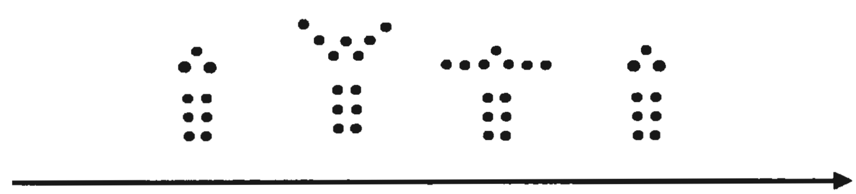
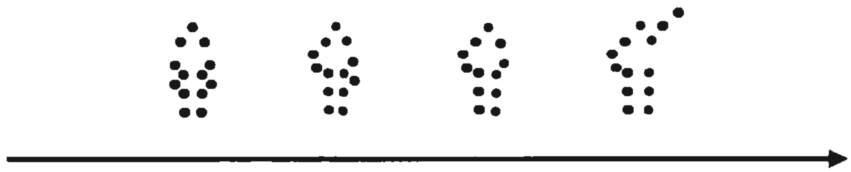
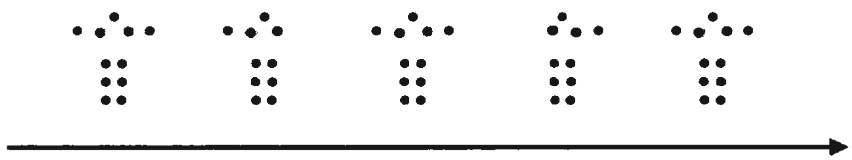
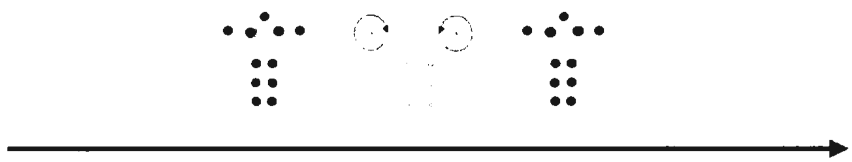
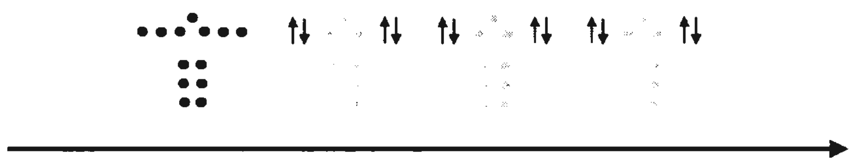
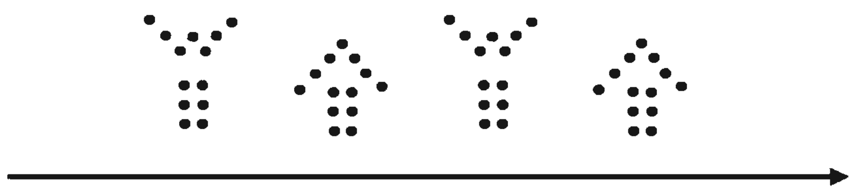


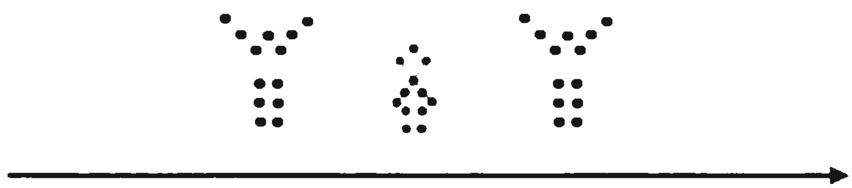
37 

38 

39 

40 

41 

42 

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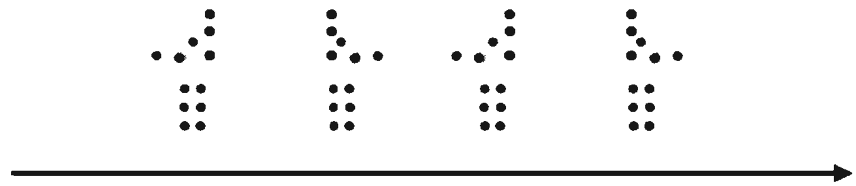

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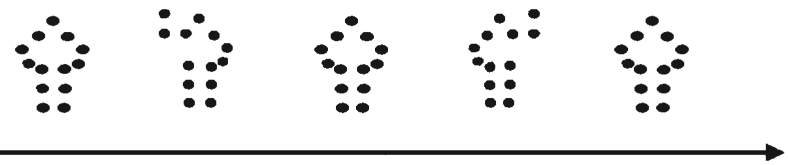

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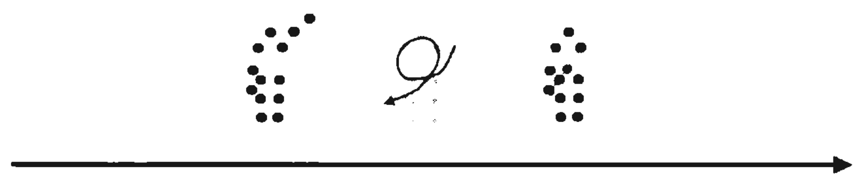

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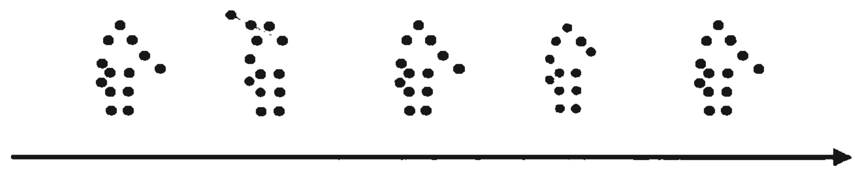

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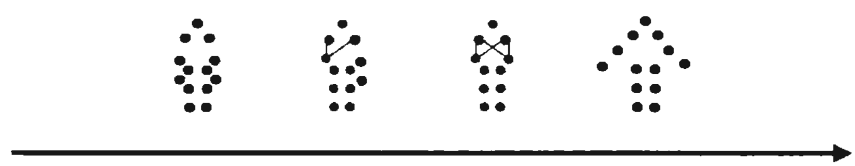

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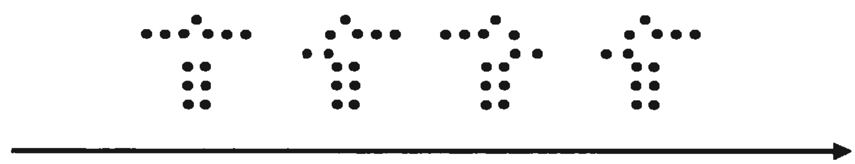

Appendix C

Labeling Instructions for Labeling Study of Experiment 3

During the next thirty to fourty-five minutes, you will see movies of arm motions. Your goal is to come up with labels, or words that you feel are associated with the action being performed. There will be two phases to this experiment, each associated with one of the two booklets that you will have received. The following sections will detail your tasks in each of these.

Booklet 1

General instructions

During the first phase, which we will call Booklet 1, you will see 48 movies of arm motion being depicted on a computer screen, one at the time. A number, which corresponds to the line on which your label should be written, will preceed presentation of a single movie. Press the SPACE BAR to start the movie's presentation. The movie will then be shown in a loop. When you have decided on a label, write it down in Booklet 1, on the appropriate line. Press the ESCAPE button to see the next movie.

Labeling instructions

Your goal is to come up with labels, or words that you feel are associated with the action being performed. You should write the first thing that comes to mind. This label should ideally be a single word, either a noun or a verb. If you struggle with writing a signle word, you could either write a short phrase, or a sentence to describe what comes to mind. Try to keep each label unique, but do not look back to your previous answers.

Booklet 2

When all of the movies have been shown, put Booklet 1 aside and take out Booklet 2. All of the movies you have seen before will be shown in a new order. Your goal is to try to reassign labels imagined in Booklet 1 to the same movies. Do not look back to Booklet 1. If you forgot a label, you should guess or come up with a new one.