

# Handshape Consistency in Spontaneous Gestural Systems

Michael Matessa & Martha Alibali

Carnegie Mellon University

## Handshape Consistency in Spontaneous Gestural Systems

How does the complexity of a communication system develop? For someone learning an established language, it could be argued that the complexity is contained in the language to be learned, and the person's communication gradually reflects this complexity. But what if there is no language to learn from, and so the person must create the complexity? This paper will focus on the grammatical complexity of gestural communication systems where there is no gestural language input, specifically spontaneous gestural systems. Spontaneous gestural systems are created by hearing individuals in experimental situations where they are instructed to describe events or recount stories using only gestures. Most of the spontaneous systems studied show grammatical properties of segmentation (breaking down information into parts) and combination (using these parts together in a consistent manner), but do not show the property of a system of contrasts (a systematic way of differentiating parts).

Singleton et al. (1993) studied the spontaneous gestural systems of 16 adults and 6 children using the Verbs of Motion Production test. In this test, subjects are shown various objects performing various actions and asked to gesturally describe these scenes. In order to determine if subjects used their gestures in an "internally consistent manner" (i.e., used a system of contrasts), Singleton et al. measured the number of handshapes used for a class of objects. As shown in Figure 2, it was found that adult novice gesturers used 3.2 different handshapes per category and child novice gesturers used 2.9, while native child gesturers used 1.9 handshapes per category. Since the difference between the novice and native gestures was significant, Singleton et al. concluded that "the native signers were more likely than the novice gesturers to use the same handshape to represent an object each time it occurred on the test". However, the novice gesturers may have used more handshapes per category in order to capture the individual differences of the objects in a category. For example, one of the child novice gesturers used different handshapes to represent a real airplane and a paper airplane in the airplane category. The data were not presented to differentiate repetitions of an object from different instances of a category.

Goldin-Meadow et al. (1996) also used the Verbs of Motion Production test on 16 hearing adults and found a consistent use of gesture ordering and the use of hand shapes to incorporate aspects of objects into action gestures, but stated that no system of contrasts was created. Gestures were categorized as representing moving objects (M), stationary objects (S), or actions (A), and SA, MA, and SMA gesture orderings were used consistently. Goldin-Meadow et al. gave less detailed information about the handshapes used by the subjects. The only example given was that a circle moving diagonally was represented as a circle hand shape combined with a diagonal movement. No data were given to describe the lack of a system of contrasts.

### What's a good way to determine if a gestural system has a system of contrasts?

Singleton et al. (1993) used the number of handshapes per object category to check for the consistent use of gestures, but there are two possible problems with this measure. First, it would not be able to determine if a handshape were being used overly generally. For example, a subject could use just one handshape to represent any object. Second, the measure penalizes subjects for not forming linguistic categories that agree with those of the experimenter. Should the same handshape be used to represent both a real and a paper airplane?

### What aspects of the task are important in producing a system of contrasts?

Linguistic properties of gesture systems can depend on the specific task. For example, American Sign Language generally uses an SVO gesture order for tasks like telling stories, but an OSV order is used for tasks like the Verbs of Motion Production task (Goldin-Meadow et al., 1996). The development of a system of contrasts in a task like VMP may depend on factors such as the contrastiveness of the stimulus objects. Would the spontaneous gestural systems of subjects describing a set of highly contrastive objects develop a system of contrasts? Results from Singleton et. al (1993) and Goldin-Meadow et al. (1996) suggest they would not, since it appears experimental subjects do not use handshapes consistently. However, a system of contrasts may develop because of subjects' intent to discriminate highly contrastive objects in their communication. This hypothesis is tested with Experiment 1. It uses a VMP-like task where subjects use gestures to describe scenes of moving objects. In order to determine if a gestural system developed by a subject has a system of contrasts, both the number of handshapes per

object and the number of objects per handshape are calculated. As Figure 1 shows, both measures are needed to determine a unique mapping between handshapes and objects. Objects are used in calculating the measures instead of categories because it is assumed subjects try to maximally discriminate between objects with their handshapes. Both the handshapes per object and objects per handshape measures are needed because one handshape could be used to represent several objects, or one object could be represented by several handshapes. If both of these measures are equal to one, a unique handshape represents each object, indicating a system of contrasts.

## EXPERIMENT 1

### Method

#### Participants

Three college graduates volunteered to participate in Experiment 1. All were male, ranged in age from 23-28, and were not familiar with sign language.

#### Procedure

Subjects were told they would see a scene and that they should describe the scene in gestures without words. The scenes consisted of one object that the experimenter moved in relation to another stationary object. The objects were selected to be easily distinguishable by one-handed gestures.

#### Materials /Stimuli

The following is a list of the objects used in Experiment 1:

##### Round Group

Small cylinder	8cm tall	7cm diameter
Big cylinder	8cm tall	10cm diameter
Small ring	3cm tall	7cm diameter
Big ring	3cm tall	10cm diameter

##### Thin Group

Thin rod	14cm long	1cm diameter
Medium paper	18cm long	3cm wide
Wide paper	18cm long	12cm wide

##### Animate Group

Plane	10cm long
Scissors	14cm tall
Man	5cm tall
Horse	7cm tall

For the first half of the experiment, scenes were created by selecting all combinations of 2 objects from different groups. One object was randomly assigned as the moving object and an action was randomly chosen from the set (on, over, past, up-to). For example, the small cylinder could move past the thin rod. The second half of the experiment was the same, except objects were chosen within a group. For example, the plane could move up to the man.

### Coding

The experiment was videotaped, and handshapes used for representing objects were identified by examining this tape. For example, one subject represented a big cylinder with a C-4 handshape (creating a C with a curved thumb and four fingers together and curved) while a small cylinder was represented with an O-4 handshape.

### Results

The goal of this experiment was to look for evidence of a system of contrasts in the gestural systems created to describe simple events. Since the objects in these events of this experiment were selected to be contrasting, if subjects used unique handshapes to refer to these objects, the gestural system would then be contrasting. As a measure of uniqueness, handshapes per stimulus object and stimulus objects per handshape were calculated for each subject. Both of these measures are needed because one handshape could be used to represent several objects, or one object could be represented by several handshapes. If both of these measures are one, a unique handshape will represent each object.

Table 1 shows the average number of handshapes per object and objects per handshape in Experiment 1. In the first half of the experiment, more handshapes per object were used ( $t(32)=4.14$ ,  $p<.0001$ ) and more objects per handshape were represented ( $t(25)=3.35$ ,  $p<.01$ ) than the second half, showing that this is a developmental process. In the second half of the experiment, both measures were near one (handshapes per object = 1.12, objects per handshape = 1.23), indicating a system of contrasts had developed (unique handshapes were being used to represent each object).

## Examples

Subject MD developed the following consistent hierarchy for round objects:

	Big	Small
Ring	C-2	O-2
Cylinder	C-4	O-4

Subject FL developed the following consistent hierarchy for animate objects:

thumb up	=	animate object
thumb up higher	=	man
thumb up lower	=	horse

## Discussion

Although subjects reported they were conscious of comparing the gestures that they created (a true sign of producing a system of contrasts), the creation of their gestural systems was no doubt highly influenced by the contrasting nature of the stimulus objects, especially in the second half of the experiment where the simultaneous presentation of within-group objects emphasized different dimensions. For example, showing the small cylinder move past the big cylinder might suggest that the dimension of height may be important to incorporate into handshapes representing the objects. Would subjects still be able to develop a system of contrasts if the objects were not as contrastive? Or if the same object was shown in different configurations? Or if within-group objects were never seen in the same scene? Experiment 2 was designed to answer these questions.

## EXPERIMENT 2

### Method

#### Participants

Three graduate students volunteered to participate in Experiment 2. Two were male and one was female, and they ranged in age from 22-25. None were familiar with sign language.

#### Procedure

Subjects were told they would see a scene and that they should describe the scene in gestures without words. The scenes consisted of one object that the experimenter moved in relation to another stationary

object. The objects were selected to be harder to distinguish by one-handed gestures than the objects of Experiment 1, and some objects were shown in two positions, open and closed.

### Materials /Stimuli

The following is a list of the objects used in Experiment 2:

#### Round Group

Small cylinder	8cm tall	7cm diameter
Small ring	3cm tall	7cm diameter
Slinky (open,closed)	10cm,5cm tall	7cm diameter
Lei	3cm tall	13cm diameter

#### Two Group

Scissors (open,closed)	14cm tall
Compass (open,closed)	13cm tall
Salad fork (open,closed)	28cm tall

#### Animate Group

Man	5cm tall
Gumby	15cm tall

For the first half of the experiment, scenes were created by selecting all combinations of 2 objects from different groups. One object was randomly assigned as the moving object and an action was randomly chosen from the set (on, over, past, up-to). For example, the small ring could move over the open scissors. The second half of the experiment showed the exact same scenes as the first half.

### Coding

As in Experiment 1, the experiment was videotaped, and handshapes used for representing objects were identified by examining this tape.

### Results

Again, the goal of this experiment was to look for evidence of a system of contrasts in the gestural systems created to describe simple events. A gestural system would have a system of contrasts if unique handshapes were used to represent objects. As a measure of uniqueness, handshapes per stimulus object and stimulus objects per handshape were calculated for each subject. Both of these measures are needed because one handshape could be used to represent several objects, or one object could be represented by

several handshapes. If both of these measures are one, a unique handshake will represent each object. In these calculations, open and closed objects are considered independent objects and separate objects are not grouped into categories.

Table 1 shows the number of handshapes per object and number of objects per handshake. In the first half of the experiment, more handshapes per object were used ( $t(38)=5.75, p<.0001$ ) and more objects per handshake were represented ( $t(34)=1.96, p<.06$ ) than the second half. In the second half of the experiment, both measures were near one (handshapes per object = 1.49, objects per handshake = 1.55), indicating a system of contrasts may be developing. Although these values are higher than those of Experiment 1 (handshapes per object = 1.12, objects per handshake = 1.16), they are not significantly different for handshapes per object ( $t(2)=3.60, p>.05$ ) or objects per handshake ( $t(2)=1.42, p>.10$ ). Also, the values are less than the 1.9 handshapes per category used by the native signers in Singleton et al. (1993). The handshapes per object results for Experiment 1 & 2 are shown in Figure 3.

The objects per handshake value of 1.55 for the second half of Experiment 2 can be further understood by looking at the most common final handshapes. These handshapes can be seen for individual subjects in Appendix C (a handshake like C-4 means a C was formed with one hand with a thumb and four fingers). Subjects are using the same handshake to represent more than one object, but in a systematic way. Some use the same handshake for an object whether it is open or closed (thumb+index for the salad fork), and some use the same handshake for different but similar objects (O-4 for the small cylinder and the slinky), suggesting they are including the objects into one category.

### Examples

Subject IB practiced contrasting handshapes between trials. (self-babbling?)

Subject NH used the same handshake (2 fingers pointed down and open) for the open scissors and the open compass and the same handshake (2 fingers pointed down and closed) for the closed scissors and the closed compass. In contrast, subject IB made a distinction between the scissors and the compass by

using the same handshapes as NH, but orienting the hand to the front for the scissors and to side for the compass.

### Discussion

These results were found for individual objects in specific states (open or closed). Different analyses could be done looking at the objects independent of state or looking at categories of different objects. For example, since subjects CH and IB used the same handshape for the salad fork whether it was open or closed, their objects per handshape measure could be decreased by considering the open or closed fork as one object. Likewise, since NH used the same handshape for the small cylinder and the slinky, her objects per handshape score could be decreased by having those two objects in one category.

In order to investigate how category definition can influence the measure of the number of handshapes per category, Experiment 3 was designed with a hierarchical categorization of objects (from the experimenter's point of view) and included a session at the end where subjects defined their own object categories. A level of the experimenter's hierarchy (Person, Animal, Vehicle, Plane, Round-thing, Flat-thing) was chosen to be similar to categories used by Singleton et al. (People, Animals, Vehicles, Airplanes, Trees ).

## EXPERIMENT 3

### Method

#### Participants

Six undergraduate students from the Carnegie Mellon University subject pool participated in Experiment 3. None were familiar with sign language. One subject was removed from analyses for making only one "blob" gesture resulting in a high categories per handshape score (the subject later reported he thought the experiment was testing his memory of object movements). This extreme example shows the usefulness of using a categories per handshape measure in addition to a handshapes per category measure.

## Procedure

Subjects were told they would see a scene and that they should describe the scene in gestures without words. The scenes consisted of one object that the experimenter moved in relation to another stationary object. At the end of the experiment, subjects were asked to place the objects into different groups, and these groups were used as subject categories.

## Materials /Stimuli

The following is a list of the objects used in Experiment 3:

Living thing		
Person		
baby	5cm tall	
man	9cm tall	
Animal		
frog	5cm tall	
horse	7cm tall	
Means of transportation		
Vehicle		
tractor	5cm tall	
truck	3cm tall	
Plane		
paper glider	24cm long	
jet airplane	7cm long	
Household object		
Round thing		
roll of tape	12cm diameter	
metal washer	2cm diameter	
Flat thing		
ruler	15cm long, 3cm wide	
book	15cm long, 10cm wide	

## Coding

As in Experiment 1 & 2, the experiment was videotaped, and handshapes used for representing objects were identified by examining this tape.

## Results

Again, the goal of this experiment was to look for evidence of a system of contrasts. A gestural system would have a system of contrasts if unique handshapes were used to represent object categories. As a measure of uniqueness, handshapes per category and stimulus objects per handshape were calculated for each subject. In addition to categories defined by the experimenter (Person, Animal, Vehicle, Plane,

Round-thing, Flat-thing), subjects also demonstrated their own categories by sorting the objects into groups, and so measures using both experimenter and subject categories are reported.

As seen in Table 1, subjects show fewer handshapes per category when the categories are defined by themselves than when the categories are defined by the experimenter in both the first half ( $t(4)=7.84$ ,  $p<.01$ ) and second half ( $t(4)=9.31$ ,  $p<.001$ ) of the experiment. This shows the importance of considering how the subject views categories when using a handshapes per category measure. There is a significant decrease in handshapes per category from the first half of the experiment to the second half both when categories are defined by the experimenter ( $t(4)=4.56$ ,  $p<.05$ ), and when categories are defined by subjects ( $t(4)=3.23$ ,  $p<.05$ ), indicating a developmental process.

In the second half of the experiment, measures of handshapes per subject category (1.68) and objects per handshape (1.93) were both low, indicating a system of contrasts was developing. The measure of handshapes per category was significantly higher for categories defined by the experimenter (2.37) compared to categories defined by the subjects (1.68), so this system of contrasts may not have been noticed if only experimenter-defined categories were considered.

### Examples

Subject OL showed the following development:

#### 1st half

Handshapes per experimenter category (Person): 4  
fist-down, palm-out, 2-down-straight, 2-down-curved  
Handshapes per subject category (Man): 2  
palm-out, 2-down-straight

#### 2nd half

Handshapes per experimenter category (Person): 2  
2-down-straight, 2-down-curved  
Handshapes per subject category (Man): 1  
2-down-straight

## GENERAL DISCUSSION

Unlike the subjects in the Singleton et al. (1993) and Goldin-Meadow et al. (1996) experiments, subjects in all of the Experiments appear to be developing spontaneous gestural systems having a system of

contrasts. Their handshapes per category and objects per handshape measures were near one, indicating unique handshapes were being used to represent objects. These measures could be made even closer to one if objects were grouped into categories.

Handshapes per object and objects per handshape turned out to be useful in evaluating unique handshape representations of objects. Objects per handshape can be thought of as a measure of generalization and can vary depending on how categories are defined.

Subjects appeared able to produce a gesture system with a system of contrasts for both contrastive objects and objects that were similar to each other and changed in form. In addition subjects, did not need specific simultaneous presentation of objects to highlight relevant dimensions in order to produce a system of contrasts.

One limitation of the study is that the degree to which the handshapes would generalize to other objects was not tested. The issue of generalization may be thought of in terms of memory limitation. Native signers use specific handshapes for a limited number of categories (allowing generalization), presumably because memory limitations do not allow the creation of a large number of handshape to category mappings. Spontaneous gesturers may be able to create a unique handshape for each instance of an object in an experiment if the number of objects does not tax their memory and so they might not show signs of generalization. By increasing the number of objects in an experiment, subjects may be forced to create a limited number of categories and generalize handshapes to different objects in the same category.

Another aspect of memory limitation could be where the attention of the subject is focused. In the VMP test used by Singleton et. al (1993), the path and manner of motions were varied and were presumably more complex than the four simple movements of this study. This complexity may have focused the subjects' attention on accurately representing the motion of the scenes rather than the shapes of the objects. This issue should be addressed in further studies.

Singleton et al. (1993) concluded that although spontaneous gesturers successfully represented some information, "it is the organization of information into contrastive and productive categories that appears to be difficult to achieve on the spot and that may require the benefit of gradual development over a longer timespan". The results of this study show that a longer timespan is not necessarily needed to develop a system of contrasts.

#### REFERENCES

Goldin-Meadow, S., McNeill, D., & Singleton, J. (1996). Silence is liberating: Removing the handcuffs on grammatical expression in the manual modality. *Psychological Review*, *103*(1), 34-55.

Singleton, J. L., Morford, J. P., & Goldin-Meadow, S. (1993). Once is not enough: Standards of well-formedness in manual communication created over three different timespans. *Language*, *69*, 683-715.

## TABLES

Table 1 - Comparison of Experiments

Handshapes per category			
	Category	1st half	2nd half
Exp 1	object	1.79	1.12
Exp 2	object	2.28	1.49
Exp 3	exprmnt	3.50	2.37
Exp 3	subject	2.51	1.68

Stimulus objects per handshape			
	1st half	2nd half	
Exp 1	1.62	1.16	
Exp 2	1.87	1.55	
Exp 3	1.91	1.93	

Results from Singleton et al. (1993)

Handshapes per category	
Adult novice	3.2
Child novice	2.9
Child signer	1.9

## FIGURES

Figure 1 - Handshapes per Object and Objects per Handshape

Figure 2 - Results from Singleton et al. (1993)

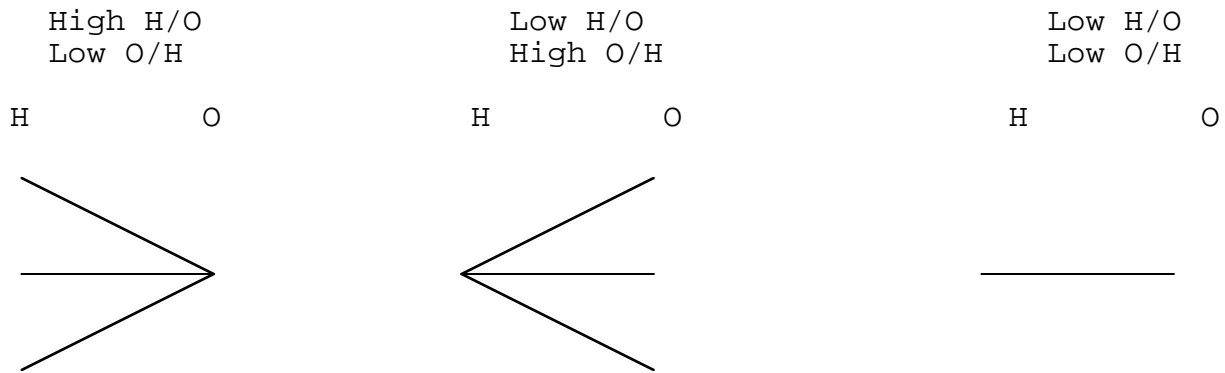
Figure 3 - Performance in Experiments 1 and 2

Figure 4 - Performance in Experiment 3

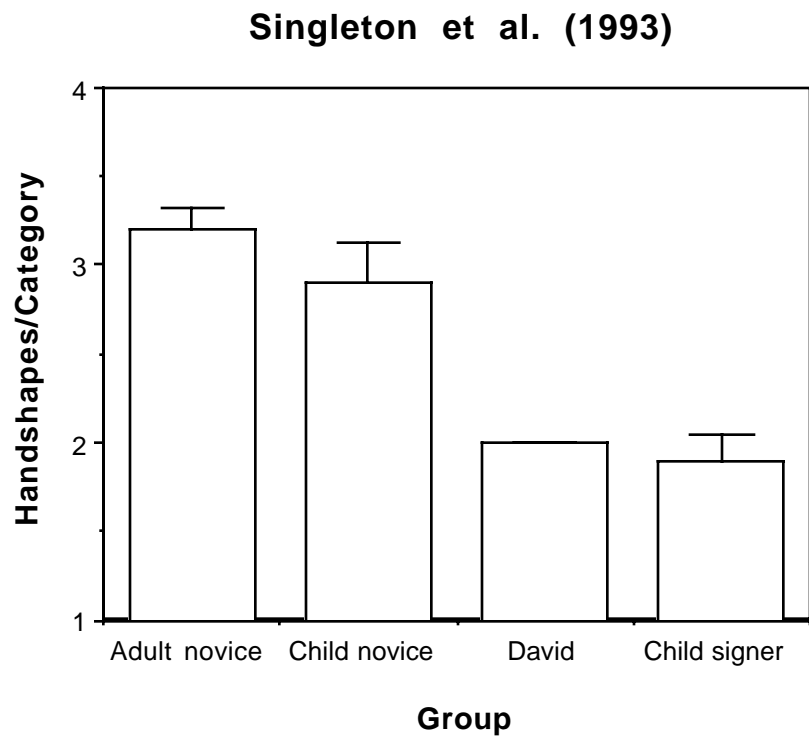
Figure 5 - Final performance from all experiments

# Figure 1

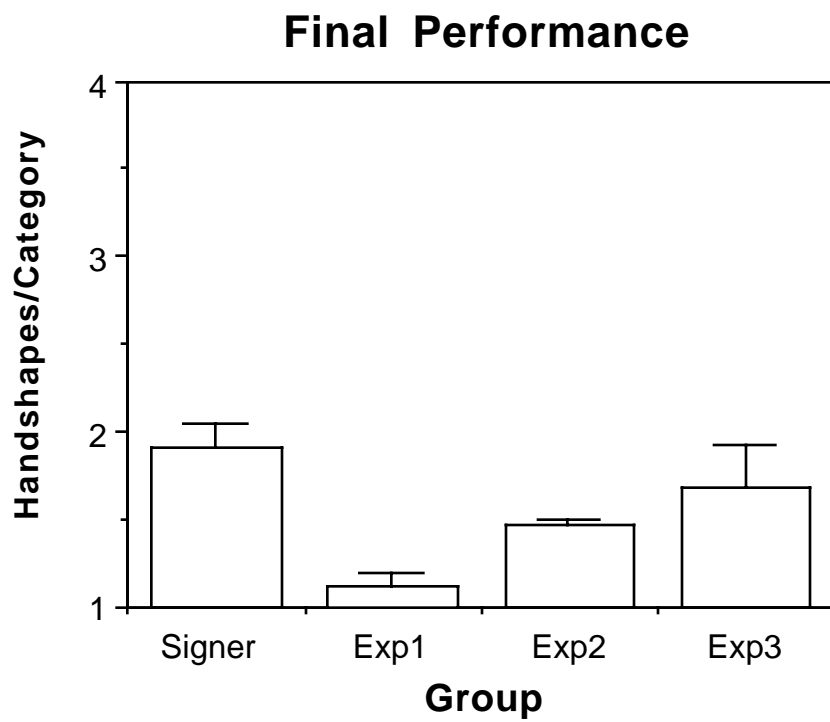
Figure 1 - Handshapes per Object and Objects per Handshape



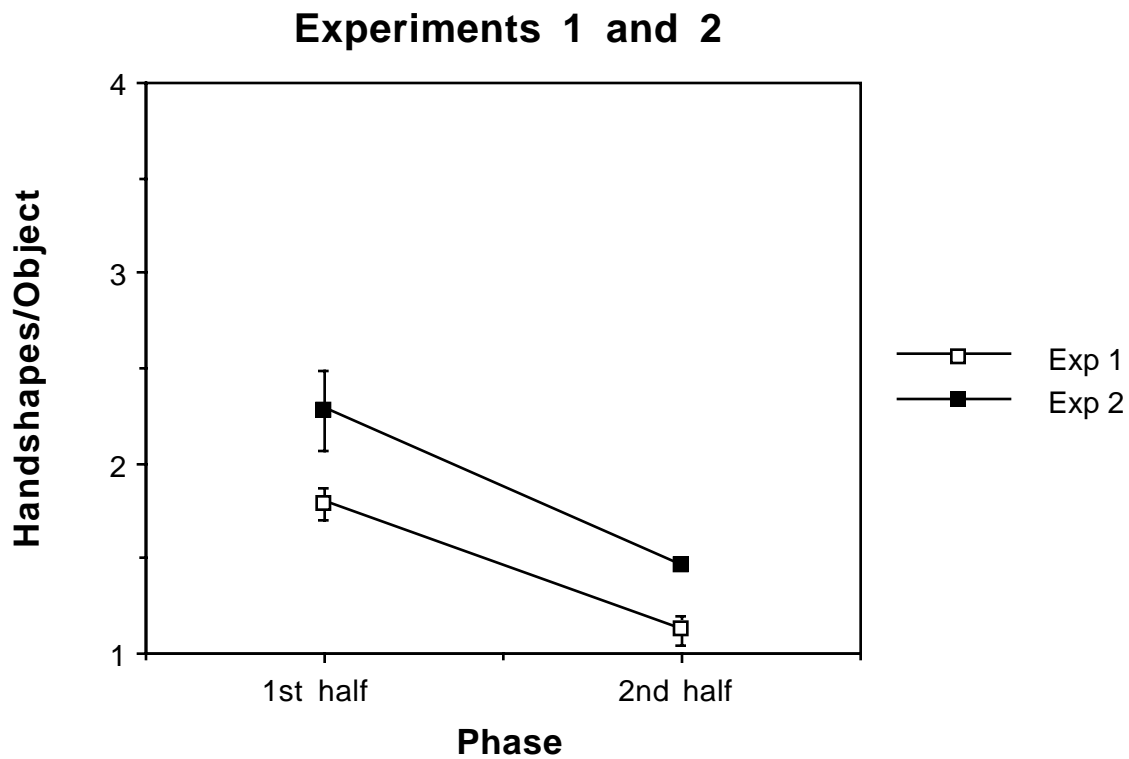
**Figure 2**



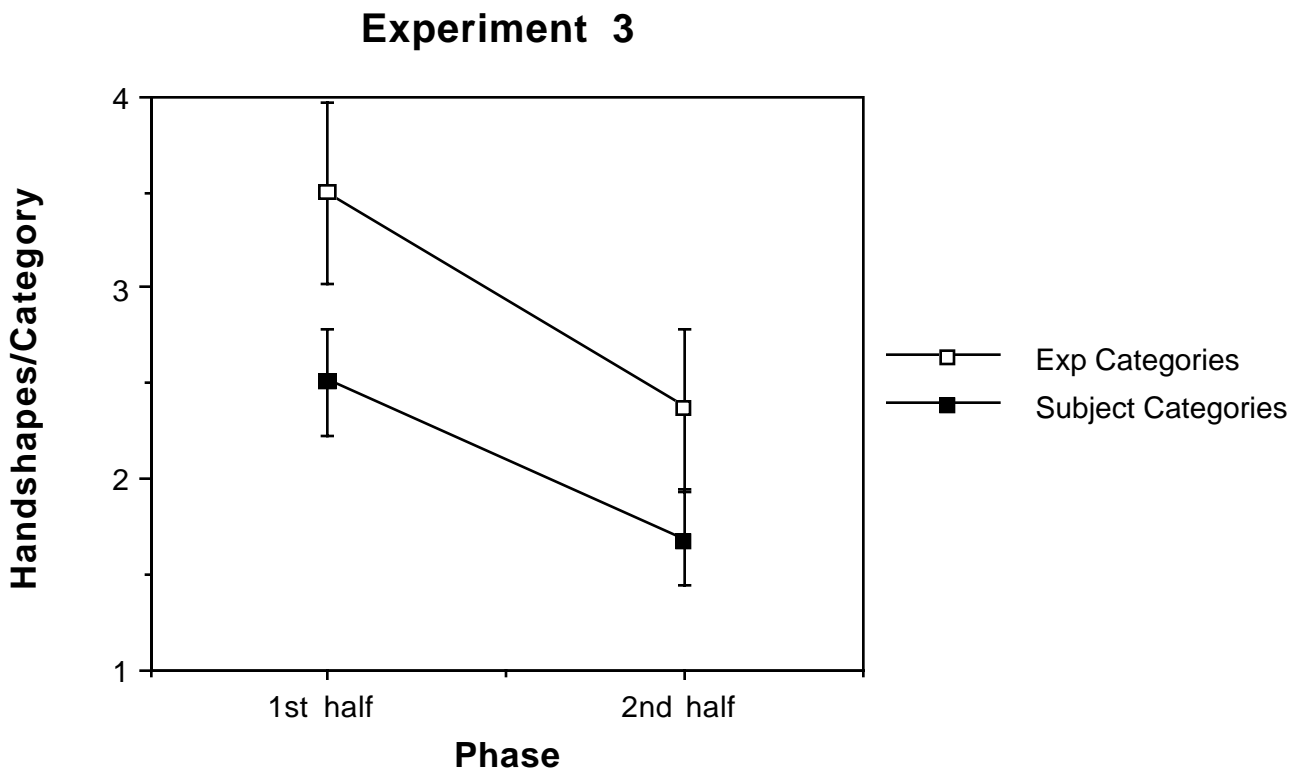
**Figure 5**



**Figure 3**



**Figure 4**



## APPENDICES

Appendix A: Measures of uniqueness for objects in Experiment 1

Appendix B: Measures of uniqueness for objects in Experiment 2

Appendix C: Most common final handshapes for subjects in Experiment 3

Appendix D: Individual scores for all three experiments

Appendix E: Subject categories for Experiment 3

Appendix F: Subject OL handshapes in Experiment 3

Appendix A: Measures of uniqueness for objects in Experiment 1

	Handshapes per stimulus object		(35 scences per half)
	1st half	2nd half	
Small cylinder	1.33	1.33	
Big cylinder	1.33	1	
Small ring	3.33	1	
Big ring	3.00	1.33	
Thin	1.67	1	
Medium	2.00	1.67	
Wide	1	1	
Plane	1.33	1	
Scissors	1	1	
Man	2.00	1	
Horse	1.67	1	
average	1.79	1.12	
	Stimulus objects per handshape		
	1st half	2nd half	
average	1.62	1.16	

Appendix B: Measures of uniqueness for objects in Experiment 2

	Handshapes per stimulus object		(35 scences per half)
	1st half	2nd half	
Small cylinder	1.33	1.33	
Small ring	2.66	1.67	
Slinky (open)	1.67	1.33	
Slinky (closed)	1.67	1.67	
Lei	3.00	2.33	
Scissors (open)	1.33	1.33	
Scissors (closed)	2.00	1	
Compass (open)	2.67	1.33	
Compass (closed)	2.67	1	
Salad fork (opn)	2.00	1.33	
Salad fork (csd)	2.67	2.00	
Man	3.00	1	
Gumby	3.00	2.00	
average	2.28	1.49	
	Stimulus objects per handshape		
	1st half	2nd half	
average	1.87	1.55	

---

Appendix C: Most common final handshapes for subjects in Experiment 2

	CH	IB	NH
Small cylinder	O-4	O-4	C-4
Small ring	O-2	O-1	O-2
Slinky (open)	O-4-open	C-4	C-4
Slinky (closed)	O-4	C-4	C-4
Lei	O-2	C-1	C-2
Scissors (open)	2-open-side	2-open	2-open
Scissors (closed)	2-closed	2-closed	2-closed
Compass (open)	2-open	2-open-side	2-open
Compass (closed)	2-closed	2-closed-side	2-closed
Salad fork (opn)	thumb+index	open-at-wrists	2-arms-open
Salad fork (csd)	thumb+index	open-at-wrists	arm-down
Man	pinch	pinch-small	2-bent
Gumby	2-closed	pinch-big	2-closed

---

Appendix D: Individual scores for all three experiments

Experiment 1

Subject	Handshapes per stimulus object	
	1st half	2nd half
BB	1.91	1.27
FL	1.82	1.10
MD	1.64	1.00

Subject	Stimulus objects per handshape	
	1st half	2nd half
BB	1.90	1.27
FL	1.78	1.20
MD	1.17	1.00

Experiment 2

Subject	Handshapes per stimulus object	
	1st half	2nd half
CH	2.62	1.46
IB	2.31	1.46
NH	1.92	1.54

Subject	Stimulus objects per handshape	
	1st half	2nd half
CH	2.00	1.58
IB	1.42	1.16
NH	2.18	1.91

Experiment 3

Subject	Handshapes per subject category	
	1st half	2nd half
DD	3.55	2.55
DJ	1.38	1.38
JB	3.40	1.80
OL	2.00	1.25
SR	2.20	1.40

---

Appendix E: Subject categories for Experiment 3

	Category	Common Handshape
JB:	girl	2-up-straight
	tape	O4-big
	hoop	O4-med
	washer	O4-small
	ruler, glider	2-out-straight
	man+baby+car+jet+	
	truck+frog+horse+	
	lego+tractor+dog	fist-down, palm-down-touch
	book+map	palm-down
OL:	ruler	1-out
	truck	straight-fist-back
	tractor	curved-fist-back
	car	palm-down-under-table
	book	palm-down-under-air
	glider	scribble-palm-down
	jet+lego	palm-down
	man	2-down-straight-plus
	girl	2-down-straight
	baby	2-down-curved
	frog	5-down-curved
	horse	4-down-nose
	tape	O4
	washer	O1
	hoop	O1-mid
	dog	4-down-short-nose
	map	scribble-pinch
DD:	man+baby+girl	2-grasp-open
	frog	grasp-open-wide
	horse+dog	1-grasp-closed
	tape	C4
	hoop	C1
	map+washer	thumb-grasp-closed
	glider+jet+lego	4-grasp-open
	tractor+truck	1-grasp-open
	car+book	thumb-grasp-open
	ruler	thumb-grasp-curved
DJ:	man+baby+girl	thumb-index-3
	horse+frog+dog+	
	tractor+truck	5-down-small
	tape	5-down-big
	hoop	5-down-small
	washer	5-down-very-small
	jet lego	1-3-1
	ruler map	palm-down
	book car	palm-down-curved
	glider	throw

SR:	man	2-down-straight
	baby	2-down-curved
	girl	2-down-1-behind
	horse	4-down-straight
	frog	fist-down
	dog+tractor+truck	5-down-curved
	tape	C4
	hoop	O1
	washer	O4-small
	glider+jet+lego	1-3-1
	ruler	2-side-straight
	map	palm-thumb-under
	book	palm-down
	car	4-down-angle

---

Appendix F: Subject OL handshapes in Experiment 3

PHASE 1

```

person: 4
        fist-down palm-out 2-down-straight 2-down-curved
animal: 3
        5-down-curved fist-down-nose 5-down-curved-touch
vehicle: 2
        fist-down fist-down 5-down-curved
plane: 1
        palm-down
round: 5
        palm-down fist-down O1 O4 O4-small
flat: 4
        palm-down-curved palm-side 1-out palm-down

```

Handshapes per category: 3.17

PHASE 2

```

person: 2
        2-down-curved 2-down-straight
animal: 2
        5-down-curved fist-down
vehicle: 2
        5-down-curved fist-down
plane: 2
        palm-down scribble-palm-down
round: 2
        O4 O1
flat: 2
        1-out palm-down-under

```

Handshapes per category: 2.00