Objective

The objective of my research is to test whether there is an advantage of ipsilateral transfer (the transfer within the same side of the body) versus bilateral transfer (the transfer to the opposite side of the body) of motor learning. Motor learning can take several forms depending on the characteristics of the task. This research will focus on learning of spatial sequences produced by either the hand or the arm. I predict that there is a transfer advantage of motor learning within the same side of the body compared to the opposite side of the body.

Literature Review

The cortex of the brain is divided from front to back into two approximately symmetrical hemispheric structures (Temple, 1993). They are interconnected by several fiber tracts, the largest of which is the corpus callosum, a channel to convey information from one hemisphere to the other (Temple, 1993). It is well known that the two hemispheres function differently. Of particular interest here, is that the left hemisphere controls movements of the right side of the body, and the right hemisphere controls movements of the left side of the body (Temple, 1993). There are various methods to study specialization of the brain (Archibald & Kimura, 1974; Benoit-Dubrocard & Velay, 1999; Carmon & Muram, 1972; Halsband, 1992). In my research, I will study the transfer between the two hemispheres as well as in the same hemisphere in terms of motor learning.

Previous research focusing on motor learning suggests that, for most people, the left hemisphere plays a primary role in learning movement of trajectories (Halsband, 1992), e.g., tracing a target figure within your visual field. The right hemisphere has a special role in the programming spatial movements (Benoit-Dubrocard & Velay, 1999), e.g., directing your hand to targets in a spatially defined sequence. On the other hand, the two hemispheres interact with each other in circumstances that require cooperation from both sides of the body. One situation that involves the transfer of a motor skill mastered by one side of the body to the other side of the body is called the *Bilateral Transfer of Learning*.

Research has been done on bilateral transfer of motor learning, including movements of hands, arms, and legs. (Ammons & Ammons, 1958; Baguley, Bairstow & Laszlo, 1970; Baker, Foster & Gagne, 1950; Byrd, & Gibson, 1986; Dunham, 1977; Heilman & Taylor, 1980; Hicks, 1974; Kinsbourne & Parlow, 1989; Puretz, 1983; Teixeira, 2000; Uehara, 1998; Verwey, 2003). These studies focused on the asymmetry of the transfer from left to the right body side, or vice versa. However, none of this literature addresses the issue of transfer within the same side of the body. My goal in this research is to compare bilateral transfer of learning with *ipsilateral transfer* of learning, in which the learning is transferred between different movement effectors (different part of the body that can conduct movements) on the same side of the body and thus controlled by the same hemisphere. One might expect ipsilateral transfer to be better than the bilateral transfer because of more direct connections within the same hemisphere. However, it is also possible that ipsilateral transfer is worse, or not better, than bilateral transfer. To achieve my goal, I will study transfer of learning between movements of the hand and the arm either on the same (ipsilateral) or opposite (contralateral) side of the body.

There are at least three kinds of motor learning tasks involving hand and arm movements: sequential learning, trajectory learning, and drawing. Within the realm of sequential learning, there is a further possible distinction between learning of abstractly-specified sequences, in which the task is to learn a sequence defined by abstract symbols, and learning of sequences of spatial-locations, in which the task is defined by a sequence of relative spatial locations.

Each of these motor learning tasks can take two different forms: explicit learning and implicit learning. In explicit learning, participants are informed of the exact, consistent routine of the movement that he/she is going to learn. In implicit learning, the same consistent routine is embedded randomly in other distracter routines so that the participants are unlikely to detect the consistency of the consistent routine. The reason to study the implicit task as well as the explicit task is that, previous studies suggest that explicit and implicit learning have different properties and take place in different areas of the brain. However, it is expected that transfer will happen in the two forms of learning in the three motor movement tasks.

Previous research studying bilateral transfer using different motor tasks has arrived at conflicting results. Some research suggests that the transfer is greater from the left hand to the right hand (Ammons & Ammons, 1958; Hicks, 1974). Other research suggests that the transfer is greater from the right hand to the left hand (Archibald & Kimura, 1974; Baguley, Bairstow & Laszlo, 1970;). One possibility of reaching difference results in these studies is due to the different tasks that they have been used in different experiments. Another possibility is that, they focused only on the tasks that they studied, but did not take into account other effects that might have existed in their experiments and therefore might have affected their results. Thus, to answer the general question whether there is a learning advantage for ipsilateral transfer versus bilateral transfer, it is essential to study the full variety of movement tasks. At the same time, to increase the validity of the experiment, it is essential to consider those effects and exclude them in the procedure of data analysis.

To start out this big project, my research will focus on just one of these tasks, the learning of explicit, spatially defined movement sequences.

Analytical Model

The methodology to analyze the data in this research is different from those in previous research. There are six transfer conditions/groups in the experiment (Table 1.), in each of which at least three possible effects are considered in the data analysis. The duration of the movement and errors will be measured. Based on the value of the duration, two contrasts that compare performance in all transfer conditions were established. The goal of computing these contrasts is to estimate the advantage of learning for ipsilateral over bilateral transfer, isolating it from other effects that might be operating in this task.
Left column: the six conditions in the experiment. (L-left; R-right; H-hand; A-arm; → - transfer).
Right column: effects that exist in each condition.

Condition	Effects (See Above)							
1. LH → LA	a				e		g	
2. LH → RH		b		d	e	f	g	
3. LH → RA		b			e		g	
4. RH → RA	a	b	c		e		g	h
5. RH → LH			c	d	e	f	g	h
6. RH → LA			c		e		g	h

Table 1. Conditions and the Mapping Effects onto Them.

Explanation of Analytical Model

a effect

This is the transfer of learning advantage ipsilateral versus bilateral transfer. It is the primary effect to be tested in my experiment. My goal is to isolate this effect from other effects that might exist in the experiment.

b effect

This is an advantage of performance after transfer on the preferred side of the body (Kinsbourne & Parlow, 1989). For example, right handers might gain a greater transfer on their right hands compared to the transfer to their left hands.

c effect

Initial learning may be better on the dominant side of the body (Kinsbourne & Parlow, 1989). For example, the right handers tap out the sequence better with their right hands than with their left hands the first time they learn the sequence. This better performance could produce better initial learning and thus better transfer of learning.

d effect

There may be an advantage when transfer is from hand to hand versus from hand to arm.

e effect

The initial learning may be better with hands than arms. This effect should be general across all conditions because, currently, we propose to use only the hands for initial training.

f effect

The transfer learning may be larger between homologous body parts (Hick, 1974; Kinsbourne & Parlow, 1989; Teixeira, 2000). For example, transfer from hand to hand will be greater than transfer from hand to arm. This effect differs from the *d effect* in also admitting the possibility that transfer from arm to arm may be greater than transfer from arm to hand.

g effect

The existence of *effector-independent* learning (Verwey, 2003). This captures any sources of learning and transfer that occur in all conditions and thus are independent of the particular effectors used for learning and transfer. It includes any general, abstract learning about how to do the task. In addition, however, a possibility that continues to be considered within the motor control literature is that the representations during motor skill learning in at least some situations is effector independent. (Wright, 1990, 1993; Lindemann & Wright, 1998). Thus, it is plausible to suppose that some of the learning that occurs during training is independent of the particular effector used in the initial training. This component of the learning would thus be expected to transfer fully from any effector to any other effector.

h effect

It is also possible that *effector-independent learning* may be increased when the initial learning is on the dominant side of the body (Verwey, 2003).

Among the effects that might exist in the experiment, the "a Effect" can be isolated based on contrasts of the data from the six conditions. The contrasts are based on a no-interaction assumption that the size of each effect is the same for each condition. The two possible contrasts to isolate the "a" effect are (C1+C4)-(C3+C6)=2a, and (C1+C4)-(C2+2*C6-C5)=2a (the rest of the effects cancel each other). If the "a" is a positive value, then there is a transfer advantage within the same side of the body. If it is negative, then there is a disadvantage of transfer within the same side of the body.

Methods

90 UCI students will be recruited to participate in the experiment. All of them are required to be right hand dominant, with normal or corrected-to-normal vision, and able to perform normal hand movements. Participants will be compensated $8/hour with a maximum learning duration of 1 hour. They will be randomly assigned to one of the 6 conditions/groups.

A display screen and 6-button keyboard will be provided to them. Participants are required to learn a consistent sequence of tapping responses cued by flashing lights shown on the display screen. In the hand response task, they will produce the sequence by taping on the keyboard using three fingers. In the arm task, they will use a hand-held stylus to tap out the sequence displayed on a computer monitor in the same spatial arrangement as the keyboard. There are 6 different conditions of transfer that will be studied: the transfer from LH-RH, LH-LA, LH-RA, RH-LH, RH-RA, and RH-LA (L=left, R=right, H=hand, A=arm). The letters on the left of the dash represent the learning hands, and the letters on the right of the dash represent the transfer hands/arms.

There are three phases in each task: pre-learning phase, learning phase, and transfer phase. In the pre-learning phase, participants are required to use their transfer hands/arms to produce the sequence for 3 trials; in the learning phase, their learning hands to practice the sequence for 40 trials; in the transfer phase, their transfer hands/arms to produce the same sequence for 3 trials. The total time to produce the sequence, which is from the onset of the flashing lights to when the movement is complete, and errors that they make on each trial will be recorded.

Timeline

Fall:

1. Complete experimental design with details.
2. Beginning writing introduction (including literal review), hypothesis, and research methodology.
3. Begin building programs that to be used in the experiment. Run pilot testing.

Winter:

1. Prepare instructions for the experiment.
2. Begin to recruit students from UCI by advertising.
3. Collect data.
4. Analyze data using SPSS.

Spring:

1. Begin writing result and discussion of the result
2. Prepare PowerPoint presentation.

Itemized Budget

Total Amount Request: $750.00

1. Compensation for participants: $720.00

Explanation: Each of the 90 participants will be paid $8/ hour for participating in the experiment. By compensating the participants, I expect to increase the validity of the experiment.

2. Print Outs and Photo Copies: $30.00

Explanation: This is for printing out on-line journal articles and copying bound journal articles.

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