KATHERINE ANNE LEIGHTY
Joystick Acquisition in Tufted Capuchins (*Cebus apella*)
(Under the Direction of DOROTHY M. FRAGASZY)

I examined joystick acquisition in four tufted capuchins under two directional relationships of joystick movement and resultant cursor displacement. I also recorded the development of cursor tracking and body-tilting during skill acquisition. Rates of acquisition were comparable between the two conditions. After mastering the task in one condition, subjects re-mastered the task at an accelerated rate in the opposing condition. All subjects significantly increased or maintained high proportions of cursor tracking throughout acquisition. All subjects demonstrated a postural tilt upon task mastery that was found more often in the direction of goal location than that of required joystick movement. This suggests that body-tilting reflects attentional demands of this unique testing system and not the motoric requirements of the task.

INDEX WORDS: Skill acquisition, Motor skill, Joystick, Body-tilting, Tracking, Capuchin monkey, *Cebus apella*

JOYSTICK ACQUISITION IN TUFTED CAPUCHINS (*CEBUS APELLA*)

by

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CHAPTER 1: INTRODUCTION

Acquisition of perceptual motor skills became a topic of interest within psychology early in the last century (Schmidt, 1975). A large body of research addressing the development of motor control and assessment of motor performance arose over several decades. Although there was a large amount of experimental research being conducted, it was not until the 1970's that this field began to develop its own theoretical orientations that addressed the acquisition and development of motor skills (Dickinson, 1985). In the decades since the conception of these classic theories, such as those of Adams (1971) and Schmidt (1975), a wide array of new tasks has developed as a result of technological advances. These new skills are interesting because their nature is often quite different from those motor skills addressed by the traditional theories. Here I investigated the acquisition of one of these new skills (mastery of a joystick) by tufted capuchin monkeys (*Cebus apella*). I examined behaviors apparent during skill acquisition and manipulated the directional relationship between joystick movement and resultant cursor displacement. In addition, I attempted to fit the acquisition of this skill into traditional theories of motor skill acquisition to highlight the successes and failures of these models in accounting for a skill of this type.

The nature of a joystick task makes its mastery an interesting skill to address. Joystick systems, in which the subject controls cursor movement on a computer screen by manipulating a joystick, require the subject to be displaced spatially from the task goal. Subjects must manipulate the joystick in one physical area to cause movement of the cursor to a goal region in another area of the visual field (i.e. the monitor) (Rumbaugh, Richardson, Washburn, Savage-Rumbaugh & Hopkins, 1989). Therefore, unlike most tasks working in three dimensions, the subject never comes in physical contact with the goal region. Subjects encounter the additional difficulty of learning to make a motor movement of the hand upon the joystick, an action that occurs in three dimensions, while viewing the results of this movement on a two-dimensional computer monitor. Utilizing this three-dimensional/two-dimensional interface is not only a problem presenting multiple unusual relationships of action and outcome, but is one that is novel to these non-human subjects.

The question arises: how do subjects learn to manipulate a joystick to achieve a goal that is spatially displaced from them and present only in two dimensions when all life experiences have involved direct action on objects in three dimensions? To answer this question we must understand the nature of this motor skill by documenting its development. Although a body of research on joystick-mediated tasks has been developing in recent years (see Appendix A), there is still a key deficit in this literature. While performance on these tasks has been documented, acquisition of the motor skill of joystick control has been largely ignored.

Early theories of motor skill acquisition focused on discrete tasks in which the performer worked the task within the three-dimensional world and acted directly upon the target either with his or her body (pressing a lever) or with another object (hitting a baseball with a bat). Joystick mastery therefore poses interesting challenges to these early theories.

Perhaps the most pervasive of the early theories of motor skill acquisition was the Closed-Loop Theory, proposed by Adams (1971). This theory claimed that two memory states develop as movements are learned. The first of these memory states, the perceptual trace, indicates the correctness of movements as learned from feedback in early practice trials with particular tasks. Thus, the perceptual trace provides the subject with the knowledge of the requirements of the task. This perceptual trace is then compared to feedback during movements in order to allow for error adjustments to be made. It is this comparison and alteration of movements that gives the theory its name. The second memory state, known as the memory trace, is responsible for selecting the appropriate movement from a catalog of known movements and then initiating it. Therefore, the memory trace selects the movement appropriate for task completion and the perceptual trace monitors the progress of that movement in attaining the goal (Dickinson, 1985).

The problem with this notion of motor skill acquisition is that it supposes a single solution to the task. It is evident from casual observation of joystick users that manipulation of the joystick to direct the cursor can be accomplished in a wide variety of ways, and subjects may not be consistent in their approach over time. For example, the joystick can be manipulated with different parts of the body and the cursor can be directed to the goal along a number of equally effective and efficient paths. Another limitation in the application of this theory to the task of joystick manipulation is that it seems to ignore the early stages of the learning process. The theory does not address the early chain of associations that must take place to discover the goal of the task. In addition, acquisition of this task requires the discovery of the directional relationship that exists between joystick movement and cursor displacement. Thus, in order to select the appropriate joystick movement for task solution a complete understanding of this relationship must be present. Adams (1971) does not address this level of processing in his theory.

Seen as a follow up to Adams (1971) Closed-Loop Theory, Schmidt (1975) proposed his Schema Theory. The schema theory proposes the presence of two memory systems, a recall schema and a recognition schema. Schema are defined by Bartlett (1932) as storage mechanisms consisting of generalizations, and it is from these generalizations that fine detail can be reconstructed. The recall schema is responsible for the storage of aspects of movement. These aspects include initial conditions of the movement, the parameters of movement such as force and timing, knowledge of results provided following the movement, and the resulting sensory experiences of the movement. Schmidt argues that these four aspects of a movement are held in temporary store while relationships among them are learned. These relationships are then moved to permanent storage. Thus, the recall schema is comprised of the existing relationships among aspects of movement. The second schema involved in motor skill acquisition is the recognition schema. The recognition schema develops with continued exposure to a task. This schema allows for the prediction of outcomes of particular movements for particular tasks. One can then apply movement knowledge contained in a recognition schema to novel yet similar situations (Dickinson, 1985).

The ideas set forth by this theory explain many aspects of joystick acquisition. Unlike Adam's (1971) Closed-Loop Theory, Schmidt's (1975) theory describes the presence of knowledge of relationships between environmental cues, one's actions, and task outcome. The notion of attention to initial environmental cues is essential for acquisition of the joystick in that attention must be paid to the monitor and in order for subjects to gain knowledge of its contents (presentation of cursor displacement). The theory also addresses the process that may be present in the subject's learning of the joystick/cursor directional relationship. Once attention is being paid to the relevant environmental features of the task (tracking the cursor on the monitor and receiving proprioceptive feedback from manipulation of the joystick), each new movement of the joystick will create the memory of a new set of relationships among all aspects of the movement. Here, perhaps, the subject gains knowledge of the directional relationship between joystick manipulation and resultant movement of the cursor on the monitor. Once this relationship is understood, the subject then has control over cursor movement.

In this examination of the development joystick mastery I investigated several behavioral markers present during acquisition in an attempt to relate this process to that proposed by Schmidt (1975). I recorded and examined the rate of skill acquisition by noting the number of trials faced prior to mastery of a number of criteria on the way to joystick proficiency. To address attention to environmental cues I recorded visual tracking of the cursor on the monitor by subjects during the acquisition process. To investigate how the subjects learned the parameters of their movements and the resultant action I used two different joystick/cursor directional relationships. The first condition was the isomorphic condition in which the direction of joystick movement and resultant cursor displacement is the same. In the inverted condition this relationship between joystick and cursor was 180 opposed. After mastering the task in the inverted condition, subjects underwent a reversal and were required to relearn the skill in the isomorphic condition. Finally, it has been observed previously that capuchin monkeys tilt their bodies while manipulating the joystick (Filion, Rogers, & Fragaszy, 1998). This body-tilt appears to be similar to that demonstrated by human children when playing videogames. I interpret body-tilting as an attempt to gain increased control over the situation on the screen, which is precipitated by the disjointed nature of these computerized tasks and is not a result of motoric demands of the joystick or video controller.

It is clear that at least one traditional view of motor skill acquisition can be applied to the development of this unique motor skill while another fails to address several key issues. Following from Schmidt's (1975) theory and other key findings in the motor learning literature, I made the following five predictions regarding joystick acquisition.

Hypothesis #1) Research on aviators use of controls in a flight simulator suggests that controls are easier to use when movements are directionally compatible with the corresponding display movements (Poulton, 1974). In addition to this observation, it has been noted by researchers utilizing joystick testing systems that learning is facilitated by a direct relationship between controller and display movement (Poulton, 1966). Therefore, I predicted that acquisition of the joystick would take place at a faster rate for subjects initially assigned to the isomorphic condition than those initially assigned to the inverted condition.

Hypothesis #2) Based on Schmidt's (1975) comments on the importance of gaining information from the environment during skill acquisition, I predicted that subjects' average duration of cursor tracking per trial would increase during acquisition in the initial condition. Visual tracking of the cursor is necessary to gain information provided by the display on the screen to learn the association between joystick manipulation and cursor position, and the directional relationship present between the two. Therefore, knowledge of the display's value should be manifested, at least initially, by visual tracking of the cursor.

Hypothesis #3) Knowledge that information is provided by the monitor was already to be in place when subjects underwent the reversal of the joystick/cursor relationship upon mastering the inverted condition. Therefore, I predicted that subjects would track significantly more following the reversal than they did initially in the inverted condition.

Hypothesis #4) In addition, because these subjects had learned the value of the monitor as well as the function of the joystick prior to reversal, they would be able to transfer knowledge of these two key components of the task under the new conditions. Therefore, I predicted that subjects that initially mastered the inverted condition would acquire the isomorphic condition following reversal more quickly than they did the inverted condition and more quickly than those initially assigned to the isomorphic condition.

Hypothesis #5) Finally, I predicted that as seen previously in tufted capuchins using joysticks (Filion, Rogers, & Fragaszy, 1998) and in human children, these subjects will demonstrate a pronounced body-tilt during the course of joystick mastery. I believe body-tilts reflect attentional/control aspects of the task, therefore I expect that significantly more tilts will occur in the direction of the goal location than in the direction of required joystick movement in all conditions. If instead body-tilts are merely the result of the motor demands of the task then tilts will occur significantly more in the direction of required joystick movement than in the direction of goal location on the monitor.

CHAPTER 2: METHOD

Subjects and Housing

The subjects of this study were four male tufted capuchins (*Cebus apella*): Leo, Nick, Mickey, and Solo (aged 5 - 7 years). Subjects were pair-housed in indoor cages at the University of Georgia. They were fed Lab Diet monkey chow twice daily and various fruits once a day. Water is available ad libitum. Testing took place outside of the homecage in a separate testing room. Video and computer equipment was controlled from a room adjacent to this testing room.

Apparatus

The testing room contained two testing stations. Each station consisted of a clear Plexiglas and metal testing cage (64 cm x 47 cm x 78 cm) placed in front of a Plexiglas-covered computer monitor, joystick, sugar pellet dispenser, and speaker. An armhole (5.84 cm in diameter), providing full range of motion, was centered in the front Plexiglas panel of the cage, and set up approximately 8 cm from the joystick. A perch in front of the armhole permitted animals to sit or stand while manipulating the joystick. A Panasonic video camera (model XL - CL700) mounted above the computer monitor provided images of the subject's face and body during testing (see Figure 1). Additional cameras in the computer room recorded the images presented on the monitor of each testing station. Signals from these four cameras were routed through a Panasonic QuadPlex to allow them to record simultaneously to a single VHS tape.

Subjects were presented with the SIDES task; the first in a series of joystick-mediated tasks developed at the Language Research Center of Georgia State University

Figure 1. Joystick testing station.

(Richardson, Washburn, Hopkins, Savage-Rumbaugh & Rumbaugh, 1990; Rumbaugh, Richardson & Washburn, 1989). The goal of the SIDES task was to manipulate the joystick to bring a cursor in contact with a highlighted region at the margin of the computer monitor. It began with all four margins of the monitor being highlighted. The task was self-paced, such that the subject's performance controlled progress through the task. After successfully completing five trials with four highlighted margins, the goal area titrated down to three highlighted sides. The program randomized the position of these highlighted sides across trials. With increasing mastery of the joystick, the goal region continued to reduce to 2 sides, 1 side, 1A (approximately 2/3 of a margin), 1B (approximately 1/3 of a margin), and 1C (an area slightly larger than the cursor itself) (see Figure 2). The program returned to the previous titration of the goal region when the subject experienced difficulty on a particular titration (i.e. exceeds 20 second time limit for average trial completion for the titration block and/or drops out of trials by not contacting the joystick for 45 seconds).

Procedure

Subjects were given the opportunity to work on the SIDES task twice a week for approximately 15 to 30 minutes each session. Pairmates were tested simultaneously, with one experiencing an isomorphic relationship between joystick movement and resultant displacement of the cursor on the monitor, and the other initially experiencing an inverted relationship. Leo and Mickey were initially assigned to the isomorphic condition. In this condition, manipulation of the joystick in a particular direction resulted in movement of the cursor in that same direction. Thus, when the joystick was manipulated to the left, the cursor moved to the left on the monitor. Nick and Solo were initially assigned to the

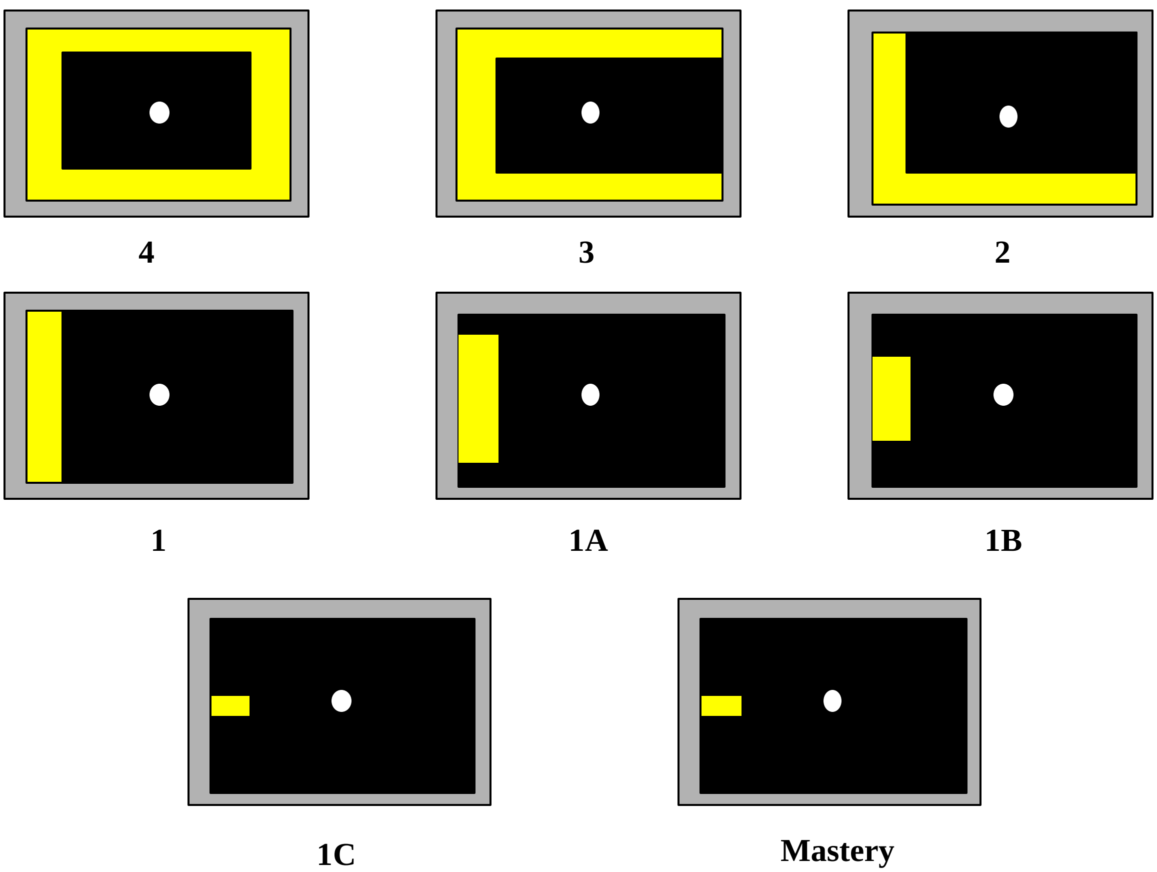

Figure 2. Titrations of the SIDES task.

inverted condition. In this condition, manipulation of the joystick resulted in movement of the cursor on the monitor in a direction 180° opposed to that of joystick manipulation. Thus, movement of the joystick to the left displaced the cursor to the right side of the monitor. Upon achieving mastery of the inverted condition, Nick and Solo were presented with the isomorphic condition and trained on the SIDES task following the same procedures as above. Successful completion of a trial by placing the cursor in the highlighted region resulted in a tone sounding, presentation of a green sunburst display on the computer monitor, and the delivery of a Noyes® sugar pellet and/or hand delivery of a piece of nut or dried fruit by the experimenter.

Training with the joystick took place over an 18-month period. Data from each trial was recorded by the computer and saved to disk by the experimenter at the end of each testing session. VHS recordings of the testing sessions were then digitized using the Broadway® software package and selected trials were burned to CDs. Data were collected from these CDs using the Observer Video-Pro (®Noldus Corp.), a software package for the analysis of observational data.

Data Scoring

Video records were scored for three elements of joystick acquisition; rate of acquisition, cursor tracking and body-tilting as judged by two observers. The percentage agreement for these two observers examining rate of acquisition for two subjects was 100%. The percentage agreement over 30 trials for two subjects was 100% for cursor tracking data with a maximum time discrepancy of +/- .1 seconds, and 100% for frequency and direction of body-tilts.

Rate of acquisition was determined by recording the number of total trials presented prior to first achieving specific criteria at each titration. I defined this criterion to be successful completion of nine out of 10 consecutive trials for the particular titration. Criterion for joystick acquisition, or mastery of the SIDES task, was defined as successful completion of 18 out of 20 consecutive trials at the 1C titration following attainment of mastery on all prior titrations. In these 18 trials, the goal region was present on each margin at least two times and the subject could not bring the cursor in contact with the margin of the monitor outside of the highlighted goal region on more than one occasion per trial.

I defined cursor tracking as the proportion of total trial duration in which the subject's pupils followed movement of the cursor on the monitor. Because the images from the computer monitor and frontal view of the subject were recorded simultaneously, they could be compared side by side to determine the duration of this behavior. For each subject in each condition, the first 25 completed trials at mastery of each titration and upon joystick acquisition (including the 10 in which mastery was achieved) were scored for cursor tracking using frame-by-frame analysis of digitized images.

I defined body-tilting as movement of the body such that the ear opposite the direction of body movement passed over the midline of the subject's body. Total tilts in the left and right direction were scored for each trial by placing a vertical line overlay on the video screen and aligning it with the body midline. The body midline was determined by using the forward facing image of the subject prior to the beginning of each trial and placing the line on the subject's nose and between the hips. Each pass of the opposite ear over the midline in both the left and right direction was recorded. Movements of the ear over the midline when not facing the screen, or occurring during characteristic head bobs (typical of these monkeys in this test situation), were not counted as tilts. Location of the goal was recorded concurrently to permit for analysis of the direction of tilt as a function of goal location and joystick/cursor relationship.

Using the digitized images and the Observer Video-Pro software, a frequency of body-tilting behavior was determined for each subject by scoring the total number of tilts per trial for 25 trials upon attainment of the 4-sided criterion, 1-sided criterion, and criterion for joystick mastery. Thirty trials (15 trials with the goal located on either side of the monitor) were then scored at joystick mastery to examine direction of tilt distribution. Frequency of tilts and direction (left, right) of each tilt was recorded.

Data Analysis

To examine hypothesis #1 (that joystick acquisition would occur more quickly in the subjects initially exposed to the isomorphic than those in the inverted condition) the number of trials presented prior to first achieving each criterion for each subject were compared graphically. Having only two subjects in each condition and apparent individual differences precluded the use of inferential statistics to compare the two conditions. The graph provides a means to examine individual trends in acquisition across the criteria as well as differences between individuals within and between the conditions.

To test hypothesis #2 (that cursor tracking would increase during acquisition for all subjects under the initial conditions) I calculated the average proportion of trial spent tracking for the first 25 trials faced upon attainment of each criterion. Next, for each subject I conducted a sign test comparing the 25 trials from the 4-sided criterion and 25 trials at criterion for joystick mastery. This was a one-tailed test and alpha was set at .05. The same procedure was used to test hypothesis #3 (that subjects initially experiencing the inverted condition would track significantly more at criterion for the 4-sided titration in the isomorphic condition following reversal than they did in initial inverted condition).

To test hypothesis #4 (that subjects that underwent reversal would master the isomorphic condition more quickly than they did the initial inverted condition and that they would master the post-reversal isomorphic condition more quickly than the subjects initially placed in the isomorphic condition) trials to each criterion of joystick mastery were presented graphically for each subject. This allowed for a comparison within each reversal subject of their pre and post-reversal performance as well as allowed for a comparison of the performance of both subjects post-reversal to the performance of the two subjects that initially experienced the isomorphic condition.

To examine hypothesis #5 (that subjects would demonstrate body-tilting during acquisition of the joystick) the frequency of tilts per trial for 25 trials for each subject at the 4-sided titration, 1-sided titration, and joystick mastery were examined. If a frequency of body-tilts was found to be greater than zero then I concluded that tilting was present. If tilting was determined to be present at criterion for joystick mastery I examined the direction of tilts demonstrated when the goal was located right and left of the monitor. This analysis was conducted using a one-tailed binomial test with alpha set at .05 to test the hypothesis that tilting would occur in the direction of goal location and not in the direction of required hand movements. The critical analysis of this hypothesis was the examination of the tilting behavior of subjects in the inverted condition. Direction of goal location and direction of required hand movement are the same in the isomorphic condition but 180° opposed in the inverted condition. Thus, it is in the inverted condition that it can be determined if subjects tilt in accord with the direction of required hand movement or with goal location.

CHAPTER 3: RESULTS

All subjects reached criterion for joystick mastery in the initial condition. There did not appear to be a difference in number of trials to overall joystick mastery between subjects in the isomorphic and inverted condition (see Figure 3). Initially experiencing the isomorphic condition, Leo acquired the task in 2237 trials and Mickey did so in 3195 trials. Nick and Solo initially experienced the inverted condition and they acquired the task in 2483 and 3364 trials respectively.

Average proportion of trial spent tracking was calculated for each subject at each titration criterion (see Figure 4). Three of four subjects significantly increased their visual tracking of the cursor from criterion at the 4-sided titration to that of joystick mastery. Initially experiencing the isomorphic condition, Leo maintained a fairly consistent level of tracking throughout acquisition (.778 at 4-sided titration and .791 at mastery). Also in the isomorphic condition, Mickey demonstrated a significant increase from .029 at the 4-sided titration to .673 at mastery ($p<.05$). Initially experiencing the inverted condition, Nick demonstrated a significant increase in cursor tracking from .000 at the 4-sided titration to .900 at mastery ($p<.05$). Solo, also initially in the inverted condition, increased cursor tracking significantly from .108 at the 4-sided titration to .535 at mastery ($p<.05$). Nick was tracking at .969 and Solo at .630 at criterion of the 4-sided titration in the post-reversal isomorphic condition (see Figure 5). Therefore both tracked significantly more at criterion for the 4-sided titration of the post-reversal isomorphic condition than they did in the initial inverted condition ($p<.05$).

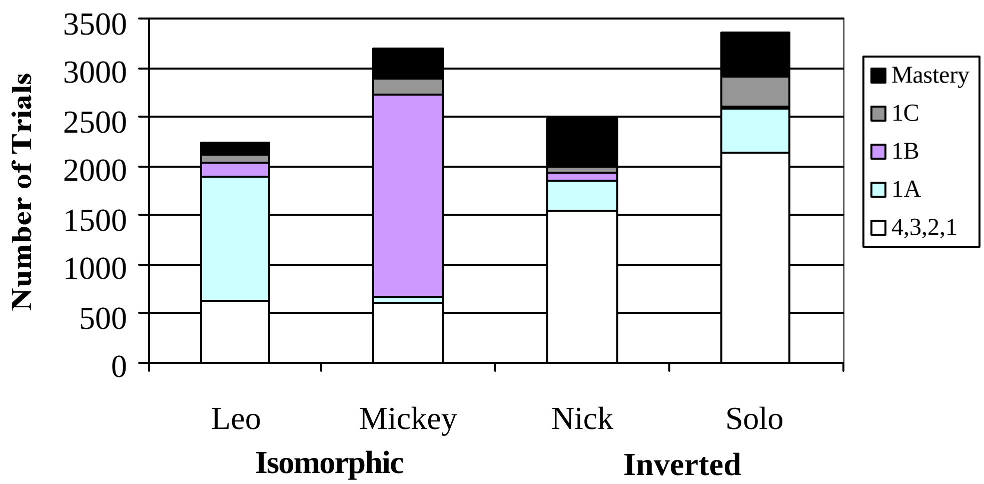

Figure 3. Trials to criterion (isomorphic versus inverted) in the initial condition

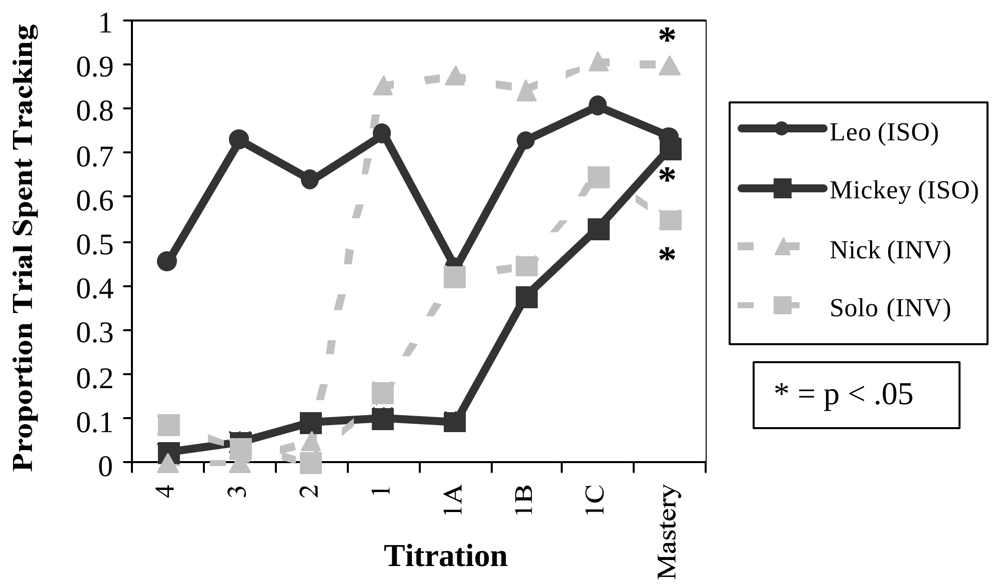

Figure 4. Cursor tracking per trial (isomorphic versus inverted) in the initial condition.

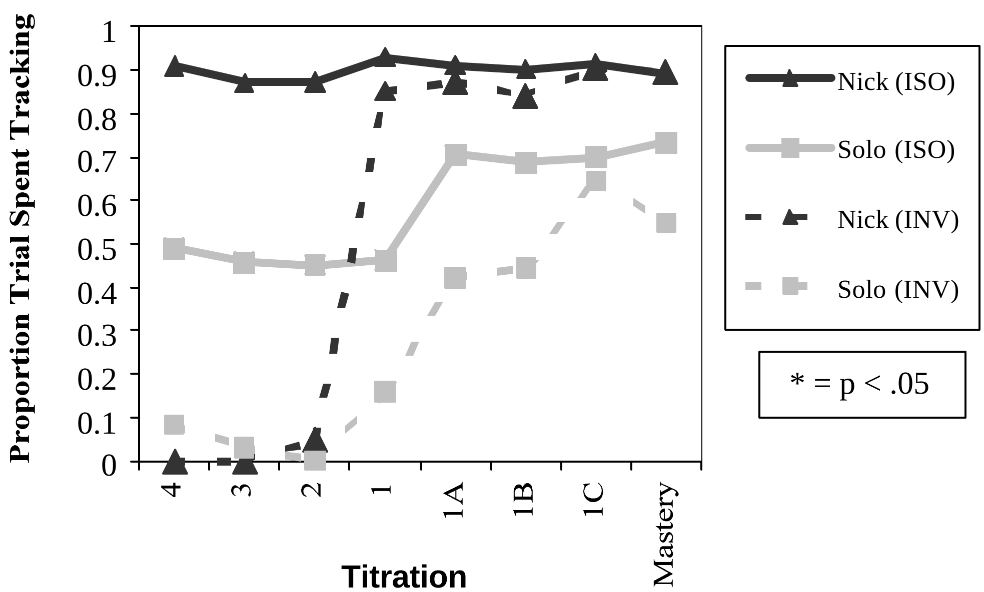

Figure 5. Cursor tracking per trial (post-reversal isomorphic condition versus pre-reversal inverted condition).

Following reversal, Nick remastered the task in the isomorphic condition in 843 trials and Solo did so in 327 trials. Therefore, both subjects that underwent reversal from the initial inverted condition to the isomorphic condition mastered the task more quickly after the reversal. Additionally, both of these subjects mastered the post-reversal isomorphic condition in fewer trials than did Leo and Mickey who initially experienced this condition (see Figure 6).

All subjects in all conditions were found to demonstrate body-tilting (see Table 1). All subjects while in the isomorphic condition were observed to tilt significantly more in the direction of goal location than in the opposite direction ($p<.05$). In the inverted condition Nick tilted significantly more in the direction of goal location than in the opposite direction for both directions ($p<.05$). Solo while in the inverted condition tilted significantly more in the direction of goal location when the goal region was located on the right side of the monitor ($p<.05$) but not when it was on the left side of the monitor ($p>.05$). Therefore, in three of the four series of tilting that were scored for subjects in the inverted condition, tilting occurred significantly more often toward the direction of goal location rather than the direction of required hand movement (see Table 2).

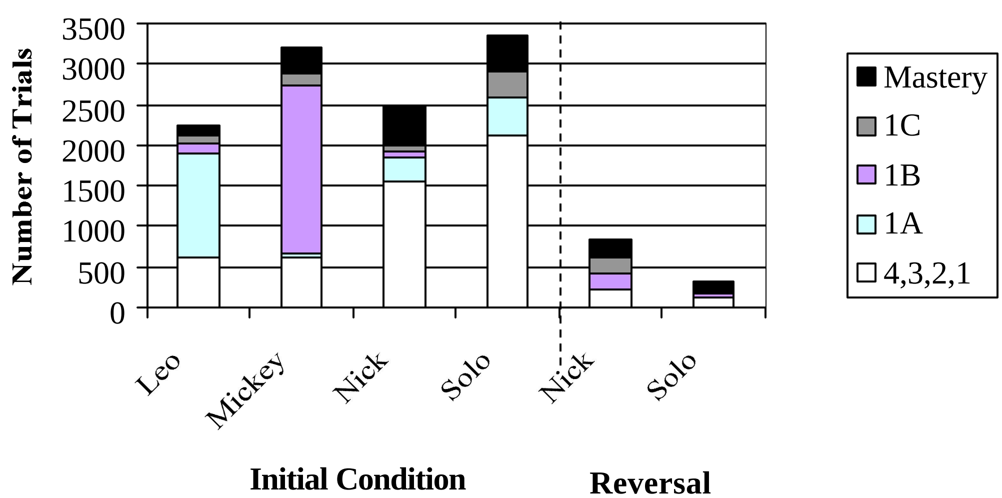

Figure 6. Trials to criterion (post-reversal isomorphic condition versus pre-reversal inverted condition).

Table 1

<u>Frequency of Body-Tilts per Trial</u>

Subject	Condition	4-Sided Titration	1-Sided Titration	Mastery
Leo	Iso	0	0.24	0.64
Mickey	Iso	0	0.08	1.4
Nick	Inv	0	0.48	0.88
Solo	Inv	0	0.36	0.64
Nick	Iso	0.44	0.28	1.04
Solo	Iso	0.2	1.2	0.8

Table 2

Direction of Body-Tilts at Joystick Mastery

Subject	Condition	Goal Location	Total Tilts (in 15 trials)	Tilts To Goal
Leo	ISO	R L	15 22	15 * 19 *
Mickey	ISO	R L	23 15	20 * 15 *
Nick	INV	R L	24 33	21 * 30 *
Solo	INV	R L	16 16	16 * 8
Nick	ISO	R L	19 12	19 * 10 *
Solo	ISO	R L	22 13	22 * 12 *

* = $p < .05$

CHAPTER 4: DISCUSSION

All four subjects achieved criterion for mastery of the joystick. Thus, these tufted capuchins can learn to manipulate a joystick to direct a cursor on a video screen. This confirms previous findings that capuchins can utilize joystick-testing systems (Filion & Fragaszy, 1997; Jorgenson, Hopkins, Washburn, & Suomi, 1993). Mastery of this skill is an impressive feat due to the complex nature of this testing system. First, the animals must overcome the disjointed setup of the testing system. Subjects must learn to manipulate a joystick in one region of space while monitoring the resultant displacement of a cursor on a video screen that is spatially displaced from the joystick. This lack of a visual connection or direct contact between the joystick and cursor makes this task quite unlike that of any faced during the daily routine. A second complex feature of the joystick testing system is that the subject must learn to manipulate a joystick that exists in three-dimensional space while monitoring the resultant cursor displacement on a two-dimensional computer screen. Again, this setup is unlike any situation faced in their daily lives.

Despite these complexities, these animals can acquire this task. Additionally, not only do they master the task in the isomorphic condition in which joystick movement and cursor displacement are directionally locked, but these animals can also master the task when the joystick is rotated 180° (resulting in cursor displacement in the opposite direction of joystick movement). Contrary to my hypothesis, the animals that initially experienced this inverted condition mastered the task in a comparable number of trials as the animals in the isomorphic condition. This suggests that the directional relationship between joystick movement and cursor displacement does not affect rate of acquisition. This finding is contrary to work done with both human aviators and that of researchers utilizing joystick-testing systems that suggest that an isomorphic relationship facilitates learning (Poulton, 1966, 1974). These findings therefore lend support to an associative viewpoint of the learning of directional relationship between physical action and resultant object movement. In other words, all directional relationships between action and resultant motion should be learned in comparable numbers of trials. This could be tested directly in these subjects by again altering the joystick/cursor directional relationship by rotating the joystick 45 or 90°.

Visual tracking of the cursor was found to covary with skill development. Consistent with my hypothesis, three of four subjects demonstrated a significant increase in cursor tracking from mastery of the 4-sided titration to joystick mastery. The fourth subject was observed to track at a rate comparable to that of the other subjects at joystick mastery when attaining criterion for mastery of the 4-sided titration. This subject maintained this level of tracking throughout skill development. Therefore, this subject was tracking at a high rate beginning from attainment of criterion at the 4-sided titration and across acquisition. These results support Schmidt's (1975) emphasis on the importance of bringing in information from one's environment while learning a skill. By tracking the cursor's movement on the screen, subjects could learn of the control of the cursor by the joystick and the directional link between them.

The two subjects initially exposed to the inverted condition underwent a reversal following their mastery of the task in the inverted condition and were made to re-master the task in the isomorphic condition. Since knowledge of the joystick/cursor relationship was already in place prior to the reversal, I expected these animals to track significantly more at mastery of the 4-sided titration post-reversal than they did initially in the inverted condition. My findings supported this hypothesis. Thus, once an animal learned to use the information provided by the computer screen he continued to do so, even if critical task parameters where altered.

Following the same line of reasoning, I hypothesized that subjects that underwent the reversal would master the isomorphic condition in fewer trials than they did the inverted condition and in fewer trials than it took the subjects initially assigned to the isomorphic condition. My findings supported this hypothesis. Subjects that underwent the reversal mastered the isomorphic condition in fewer trials than it took them to master the inverted condition and fewer trials than it took those animals exposed only to the isomorphic condition. Therefore, not only are these animals retaining the behavior of cursor tracking when task parameters are changed but they are also retaining other knowledge previously gained about the task. By retaining this knowledge post-reversal, the animals are able to re-master the task in fewer trials than their initial mastery of the inverted condition and than that of subjects facing only the isomorphic condition.

A more complete view of the retention of key task components following alteration of task parameters would have been provided if I had not only reversed the directional relationship between joystick and cursor for those animals initially in the inverted condition to the isomorphic condition, but also made those animals that initially mastered the isomorphic condition re-master the task in the inverted condition. This second reversal was not conducted because of the fact that these animals were to be used in a number of studies using the joystick-testing system and it was thought that this reversal to the inverted condition and subsequent return and re-mastery of the isomorphic condition would significantly delay the participation of these animals in these other studies for quite some time.

Consistent with the findings of Filion, Rogers, & Fragaszy (1998), all subjects demonstrated a postural tilt of the body while mastering the use of the joystick. I then wanted to determine which factor of the task (goal location or direction of joystick movement) governs the direction of the tilt. The critical test to distinguish between these two factors was made by examining the tilts of subjects in the inverted condition. In this case a goal located on the right of the monitor would require a hand movement on the joystick to the left. Thus, these two factors would lead to prediction of tilts in opposite directions. In three of the four cases (2 inverted animals x 2 directions of goal location) the subjects tilted significantly more in the direction of goal location than direction of required joystick movement.

Literature on postural body-tilts in skill acquisition or performance appears to be minimal even though this behavior can be observed in a number of everyday situations. For example, consider the body-tilt that occurs when a bowler watches the ball traverse the lane, when a golfer strikes a putt and watches it move to the cup, after a tennis player strikes a shot that is approaching the boundary lines, or even when a child is playing a video game. All of these situations, as well as the one I addressed here, share one key commonality: that the tilt occurs when the actor is out of direct physical contact with the object that he or she is acting upon. In the case of the bowler, the tilt occurs after the ball has left the hands and as it is approaching the pins. It appears that the tilt occurs in an attempt to steer the ball away from the gutters and toward the center pin. For the golfer, the tilt occurs after the club strikes the ball and as it is moving to the cup. In this case, it seems that the tilt occurs in a manner consistent with an attempt to steer the ball into the cup. A similar situation occurs with the tennis player. The tilt occurs after striking the ball with the racket as it is moving out of bounds, thus appearing that the player is attempting to direct the ball to drop inside the line and not sail beyond. Finally, in the case of children playing video games and monkeys learning to utilize a joystick to control a cursor on a screen, I believe the tilt is an attempt to control a situation in which they do not see a direct physical connection between action and target object. Just as in the sporting examples in which the tilt is observed to occur after contact with the object but while waiting for the final outcome, the same appears to occur in tilting with video systems. The subjects or players can act upon the joystick to control movement on the screen but are not directly displacing the cursor physically (by placing their hand or joystick directly on it). Therefore, I believe that body-tilting in skill development and performance is a reflection of the spatially disjointed nature of the tasks. The tilt occurs when the object receiving the action is out of direct physical contact of the actor and prior to movement outcome.

To test the notion that tilting reflects a lack of direct physical control of the object acted upon at the time of outcome, one might examine skill acquisition using three versions of computer-mediated testing systems. I would first want to replicate my results in naive animals using the joystick-mediated system. Second, I would want to see if tilting is also present in animals learning to control a cursor on a screen using a rollerball interface. This system would present the subject with the same form of spatial displacement of action from outcome that is present in the joystick-mediated system.

Because of the similar nature of the joystick and rollerball systems, I would expect tilting to be present in subjects mastering and utilizing the rollerball system. Finally, to test that it is the disjointed nature of the system setup that governs tilting behavior, I propose to train naive subjects to use a touch screen system to bring a cursor in contact with a goal region. Since this system would allow for direct action upon the target object as well as direct physical control at time of outcome, I believe that body-tilting would be absent in subjects mastering this paradigm.

The joystick-mediated testing system provides a unique and interesting paradigm with which to study skill acquisition. Although the nature of the system is unlike that of skill traditionally addressed by theories of motor skill acquisition we do see that key concepts of theories, such as Schmidt's (1975) Schema Theory, can be applied to the development of this skill. I have confirmed the finding that tufted capuchins can master use of the joystick-mediated system. Additionally, I have found that contrary to previous joystick research and studies on human aviators, the directional relationship between joystick movement and resultant cursor displacement does not affect the overall rate of skill acquisition. I also determined visual monitoring of the cursor on the computer screen to be essential for skill mastery. Once this aspect of the skill is acquired, subjects continue to utilize it, even if key parameters of the task are altered. Along the same lines, those animals that underwent a reversal in the joystick/cursor relationship were observed to re-master the task in a greatly reduced number of trials than their initial performance in the inverted condition and than the performance of animals that only experienced the isomorphic condition. Thus, these subjects retained knowledge of key task components and utilized them following reversal. These examples of being able to use experience with a task to solve new problems is consistent with Schmidt's (1975) theory. Finally, I found that when performing this task, these animals demonstrate a pronounced tilt of their bodies. This tilt was observed to occur more often in the direction of goal location and is not necessarily related to the motoric demands of joystick manipulation. I propose that the presence of this body-tilt in skill acquisition and performance is due to the spatially disjointed nature of the testing system. Thus, the tilt is a reflection of the subject's lack of direct physical contact with the object and target at time of outcome. I propose to investigate this hypothesis with further research using both this joystick-mediated testing system as well as other interface systems such as the rollerball and touchscreen.

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APPENDIX A: A REVIEW OF THE LITERATURE

Part I: In recent years, the rise of technology has seen the utilization of computerized testing systems as a means of assessing cognitive abilities in both humans and non-humans. Specifically, computerized systems in which the subject controls task outcome through the use of a joystick have been used to determine psychomotor functioning. A body of research is currently emerging which supports the use of these computerized testing systems, and emphasizes their advantages over the previously widely accepted testing paradigms used to assess this type of functioning. Here, I address the benefits of joystick-mediated computer testing systems in assessing psychomotor functioning and discuss a number of tasks completed by non-human primates utilizing this testing paradigm.

The computerized test system (CTS) used in this study was developed at the Language Research Center (LRC) of Georgia State University (Richardson, Washburn, Hopkins, Savage-Rumbaugh & Rumbaugh, 1990). The system presented to the subject consists of a monitor and joystick. The system's software allows for the presentation of a wide variety of tasks to the subject. Non-human primates can be tested using this system in their homecages or while contained in a testing cage positioned in front of the apparatus. Manipulation of the joystick by the subject provides the sole control of task outcome therefore task progression is dependent on the subject. Thus, while the experimenter has a great deal of control over the testing parameters, the subjects' control of the rate of testing helps to avoid fatigue effects and bias on the part of the experimenter. Data from each trial are automatically recorded by the computer, preventing countless hours of data transcription as well as ease in monitoring subjects' progress (Richardson et al., 1990).

One important benefit of the CTS is that it can be used to test psychomotor functioning in a wide variety of species. This characteristic of the system provides the opportunity for comparative research on the development and performance of these skills. It has been demonstrated that humans, chimpanzees, orangutans, bonnet macaques, rhesus macaques, baboons, squirrel monkeys, and tufted capuchins can utilize this testing system (Andrews, 1993; Andrews & Rosenblum, 1993; Filion & Fragaszy, 1997; Hopkins, 1991, Jorgensen, Hopkins, Washburn, & Suomi, 1993; Richardson et al. 1990; Vauclair & Fagot, 1993).

Another benefit of CTS is that it offers enrichment to captive animals while providing this valuable data on psychomotor skill ability (Rumbaugh, Washburn, & Savage-Rumbaugh, 1989). The tasks provide complex problems to be solved in an environment that typically does not afford such cognitive challenges. Animals have been seen to utilize the CTS in their homecages when experimenters are not present and have been observed to continue testing after food rewards have run out. Thus, animals may find the tasks to be inherently rewarding and therefore may gain enrichment from their availability (Washburn, Hopkins, & Rumbaugh, 1989).

CTS also provides a means by which many skills can be tested in the laboratory that otherwise might not be tested and avoids biases discovered in performance with traditional testing systems. Specifically, the CTS has been used to address trajectory prediction, tracking behavior, planning, and relational and conceptual learning (Filion, Washburn, & Gulledge, 1996; Washburn & Rumbaugh, 1991; Fragaszy, Johnson-Pynn, Murnane, Menzel, Brakke, 2001). Unlike three-dimensional testing paradigms such as the WGTA, CTS presents the subject with two-dimensional representations of stimuli. The substitution of three-dimensional stimuli with those of two dimensions may help to avoid object preference bias that has been noted in subjects' performance on WGTA (Filion, Johnson, Fragaszy, & Johnson, 1994). Taken together, these points demonstrate that the CTS has proven to be a beneficial and efficient method of addressing psychomotor functioning, specifically in the non-human primates.

The first task of the CTS system is a joystick acquisition task known as SIDES (Rumbaugh, Washburn, & Savage-Rumbaugh, 1989). The SIDES task provides a means by which to monitor the development of this skill while allowing the subject to progress at its own pace. The task consists of an area on the margin of the monitor that is highlighted which represents the goal region. The subject must manipulate the joystick to bring the cursor in contact with the highlighted region. Successful completion of a trial results in the presentation of a food reward. The task begins with all four margins of the screen being highlighted. After the subject successfully completes five trials the goal area titrates down to three highlighted margins of the monitor. With increasing mastery, the titration continues with two margins, one margin, and three goal regions consisting of a decreasing length of a single margin of the monitor, known as 1A, 1B and 1C. Goal regions are randomized for position on the margins so as to prevent the development of directional biases. When a subject experiences difficulty with a particular titration, the program adds an additional margin in the next block of trials. Thus, the program titrates the area of the goal region dependent upon the success rate of the subject (Rumbaugh, Richardson, Washburn, Savage-Rumbaugh, & Hopkins, 1989).

Following mastery of the joystick via the SIDES task, subjects are then run through the remainder of the CTS battery of tasks (Richardson et al., 1990). The next task is known as CHASE. The CHASE task requires the subject to bring the cursor in contact with a moving target, therefore assessing the subject's capacity for trajectory prediction. After attaining mastery of the CHASE task subjects are presented with a task known as PURSUIT. PURSUIT is similar to CHASE in that the subject must bring the cursor in contact with a moving target, but the PURSUIT task requires the subject to keep the cursor in contact with the target for an extended period. Thus, the PURSUIT task requires not only the skill of trajectory prediction but also develops the subject's ability to track the target. Following completion of these tasks, subjects can be presented with a wide array of tasks testing a variety of skills. One such task is known as LASER (Richardson, 1990). In the LASER task the subject has to shoot projectiles from a stationary turret at the moving target. The subject can control the trajectory of their shots with the joystick and can also abort faulty shots before they miss the target. Subjects have also been tested on a number of maze tasks where the goal region is blocked from the cursor by an increasing number of walls (Fragaszy, Johnson-Pynn, Murnane, Menzel, & Brakke, 2001). The subject must therefore navigate the cursor through alleyways to bring it in contact with the goal region. Finally, subjects have also been presented with discrimination tasks, learning set tests, and match to sample problems and comparable if not improved success rates over traditional three-dimensional testing paradigm of WGTA have been demonstrated (Washburn, Hopkins & Rumbaugh, 1989; Washburn, Hopkins & Rumbaugh, 1991; Washburn & Rumbaugh, 1991). Thus, this testing system provides a successful alternative to traditional three-dimension testing procedures for assessment of these psychomotor and cognitive abilities.

The manipulation of a joystick to control task outcome by human and non-human subjects is an impressive motor skill. Unlike working these problems in three dimensions as with the traditional WGTA, the joystick system adds another level of complexity to these tasks. The nature of the CTS system is such that the subject is displaced from the task goal. Subjects must manipulate the joystick in one physical area to cause movement of the cursor to a goal region in another area of the visual field (i.e. the monitor) (Rumbaugh, Richardson, Washburn, Savage-Rumbaugh & Hopkins, 1989). Therefore, unlike working in three dimensions as in the WGTA, the subject never comes in physical contact with the goal region. Subjects encounter the additional trouble of learning to make a motor movement of the hand on the joystick, an action that occurs in three dimensions, while monitoring the results of this movement on a two-dimensional computer monitor. Utilizing this three-dimensional/two-dimensional interface is not only a complex problem, but is one that is quite novel to these subjects.

The question subsequently arises: how do subjects learn to manipulate a joystick to achieve a goal that is displaced from them and present only in two dimensions when all life experiences have involved direct action on objects in three dimensions? To answer this question we must come to understand the nature of this motor skill by documenting its development. Although a body of research on joystick-mediated tasks has been developing in recent years, there is still a key deficit in this literature. While performance on these tasks has been documented, acquisition of the motor skill of joystick control has been largely ignored. The purpose of this experiment conducted with tufted capuchins is to track the development of joystick proficiency (rate of acquisition) between two joystick/cursor relationships (isomorphic and inverted) and to examine the development of two behaviors with increasing mastery (visual tracking of the cursor and body-tilting).

In sum, the use of computerized testing systems to address psychomotor functioning has risen in popularity in recent years due to its numerous benefits over more traditional testing systems. These benefits include the possibility for comparative analysis between species on a wide variety of tasks, cognitive enrichment for laboratory animals, subject-paced task administration, as well as ease of data recording and progress monitoring. Research conducted using these systems has demonstrated a number of abilities in non-human primates including joystick proficiency, trajectory prediction, manual tracking, object discrimination, learning set formation, and maze completion. Examining the acquisition of psychomotor skills such as joystick proficiency, as that necessary to utilize a computerized testing system, offers investigators an opportunity to determine key aspects of the task which must be attended to as well as behavioral markers which develop with increasing proficiency. Documenting the acquisition of this unique skill of joystick proficiency will serve in the determination of a theory of skill development that addresses the acquisition of such multi-component skills.

Part II: Perceptual motor skills became a topic of interest within the field of psychology early last century (Schmidt, 1975), but it was not until the 1970's that the first theoretical claims were being made by researchers of motor learning as to the acquisition of such skills (Dickinson, 1985). These early theories of motor skill acquisition focused on discrete tasks in which the performer worked the task within the three-dimensional world and acted directly upon the target either with their body (pressing a lever) or with another object (hitting a baseball with a bat). In the decades since the conception of these classic theories a wide array of new tasks have developed due to human technological advances. For example, humans now interact daily with a number of computerized pieces of equipment that require new motor skills, such as using a television remote control, operating a computer mouse, typing on a keyboard, dialing a cell phone, or even using a joystick to play a video game. These new skills are quite interesting in that their nature is quite different from those motor skills addressed by the traditional theories.

Perhaps the most pervasive of the early theories of motor skill acquisition was the Closed-Loop Theory, proposed by Adams (1971). This theory made claim for the presence of two memory states that develop as movements are learned. The first of these memory states is the perceptual trace that indicates the correctness of movements as learned from feedback in early practice trials with particular tasks. Thus, the perceptual trace provides the subject with the knowledge of the requirements of the task. This perceptual trace is then compared to feedback during movements in order to allow for error adjustments to be made. It is this comparison and alteration of movements that gives the theory its name. The second memory state, known as the memory trace, is responsible for selecting the appropriate movement from an infinite catalog of known movements and then initiating it. Therefore, the memory trace selects the movement appropriate for task completion and the perceptual trace monitors the progress of that movement in attaining the goal (Dickinson, 1985).

The problem with this notion of motor skill acquisition is that it supposes a single solution to the task. It is evident from just casual observation of joystick users that manipulation of the joystick to direct the cursor can be accomplished in a wide variety of ways, and subjects may not be consistent in their methodology over time. For example, the joystick can be manipulated with different parts of the body and/or the cursor can be directed to the goal along a number of equally effective and efficient paths. Another key flaw in the application of this theory to the task of joystick manipulation is that it seems to ignore the early stages of the learning process. The theory does not address the early chain of associations that must take place to discover the goal of the task. In addition, acquisition of this task requires the discovery of the directional relationship that exists between joystick movement and cursor displacement. Thus, in order to select the appropriate joystick movement for task solution a complete understanding of this relationship must be present. Adams (1971) does not address this level of processing in his theory.

Seen as a follow up to Adams (1971) Closed-Loop Theory, Schmidt (1975) proposed his Schema Theory. The schema theory proposes the presence of two memory systems, a recall schema and a recognition schema. Schema are defined by Bartlett (1932) to be storage mechanisms consisting of generalizations, and it is from these generalizations that fine detail can be reconstructed. The recall schema is the system that stores aspects of a movement. Schmidt claims that there are four key aspects of a movement. The first of these movement aspects are the initial conditions. The initial conditions of a movement are stored before the start of the movement and include information on the pre-response state of the muscles and the other sensory information present within the environment. In the case of joystick usage, the animal would store the state of their muscles as they hold the joystick as well as the visual information present on the screen prior to movement initiation such as position of cursor and target. The second aspect of movement that must be stored are the response specifications. This aspect is stored at the very start of a movement and includes information regarding the command that was sent to the muscles about the angle and force of muscle movements. When beginning a joystick movement the animals will store the muscle command of hand movement used to manipulate the joystick to record the angle and force of the movement. The third aspect of movement in the recall schema is the sensory consequences. This information is received during the movement. This is the direct sensory feedback from the eyes, ears, proprioceptors, etc., that is received while the movement takes place. In joystick manipulation, the subject would store such information as the images of the cursor moving on the screen, the noises of the testing procedure, and the position of the body. The final movement aspect deals with response outcome. This is when the actual outcome of the movement is determined and compared to the desired outcome. With the joystick task, this information would come in the form of actual location of the cursor in relation to the target versus desired location of the cursor in the target.

These four aspects of movement are held in temporary store by the recall schema while relationships among them are learned. Each movement or trial in a joystick task provides slight modifications to the relationship between these aspects. Schmidt claims that by slightly changing the requirements of the task on a trial (put target in new location) that this variability in the task will create a more generalized relationship between these factors that can be more effectively applied to new situations. As these relationships are learned, they are transferred from temporary to permanent store.

The second system of this theory is the recognition schema. It is this schema that pulls information from permanent store to be used in the prediction of object movement and to solve novel problems. This schema also plays a vital role in that it is in charge of monitoring progress while movements are being made. The recognition schema compares the movement's outcome with the desired outcome in a feedback process and will command alterations to the movement as necessary. Therefore, it is this schema that in joystick testing allows subjects to monitor their progress within a trial as well as to deal with target/cursor configurations that they have never seen before.

There are several assumptions of theory. The first of these assumptions is that animals have the mechanisms of temporary and permanent storage. It also assumes that these storage mechanisms are available for use in feedback systems. A final and perhaps key assumption of this theory is that relationships once formed can be modified. Unlike previous motor models that claimed that each movement and result is stored independently, Schmidt (1975) emphasized a relationship between aspects of movement and believed that this relationship can be altered with experience.

There are a number of strengths of Schmidt's (1975) theory that made great advances to the way researchers think about motor learning. One of these key successes is his solution to the novelty problem. As previously stated, prior researchers such as Adams (1971) believed in the storage of individual movements. Schmidt's idea of a relationship between movement aspects provided an explanation of success on novel trials. A related problem solved by this theory dealt with storage. Schmidt's theory removed the problems of potential overload due to storage of individual movements as suggested by Adams (1971), by storing the relationships among movement aspects this decreased the demand on storage. This theory also dealt with the problem faced by earlier theorists with "errors". Adams (1971) believed that all errors were detrimental to learning. Schmidt's theory on the other hand allows errors to occur and to provide information that is critical to the establishment of boundaries within the feedback system as well as provide information for the relationship of movement aspects in the recall schema.

Perhaps the areas of Schmidt's theory that have triggered the most empirical testing are the ideas of variable practice and positive transfer. Schmidt claims that practice of a motor movement under variable conditions creates a more generalized relationship of movement aspects in the recall schema and that this generalized relationship can be used to solve new problems. Researchers have demonstrated that under variable practice you will perform better at the test (even if you have never performed under the conditions of the test in the past) than if you had only trained at the conditions of the test. Research on positive transfer also supports Schmidt's theory in that performance is better on related tasks due to prior experience; in other words, the subject is transferring knowledge of movement from one situation to another. Overall, I feel that Schmidt's theory made huge steps for the field of motor learning and its applications are far reaching including providing a framework for the acquisition of the joystick.

One contemporary theory of skill acquisition that frames the mastery of the joystick quite well was proposed by Daniel Willingham (1999). He states that there are four processes supporting the development of motor skills. First, the subject must determine the goal of the movement; this is known as the strategic process. This is a complex process for non-human subjects first presented with the CTS system. Unlike presenting a human child with a joystick and telling them to move the cursor to the highlighted area of the screen, the non-human subject has a large number of task parameters to discover before reaching this phase. First the subject must become accustomed to the mere presence of the system. Next, the subject must determine that manipulation of the joystick results in reward delivery. The subject then must learn to attend to movement taking place on the monitor. What appears to be the most difficult step in acquisition for non-humans is developing the connection between physical movements of the joystick and resultant movements on the monitor. Thus, the subject must learn the features of control. After these connections have been made, only then can the subject learn the goal of the task presented, to move the cursor to the highlighted region. Therefore, this first process of motor skill acquisition for joystick proficiency can serve to be quite difficult for non-human subjects.

The second process of motor skill learning according to this theory is perceptual motor integration. This process requires the subject to determine movement targets or reference points that will lead to goal achievement. This information must then be integrated with goal information and learning becomes necessary when the relationship between these is changed. It is assumed that non-humans presented with the CTS system make this integration through practice with joystick manipulation after making the determination of joystick control over cursor movement and goal identity.

The third process, known as sequencing, involves the ordering of these spatial reference points of movement in such a way that the goal will be achieved. In the case of joystick manipulation, this would occur when subjects learn directional control of the joystick to direct cursor movement to the goal.

The final process of motor skill acquisition is the dynamic process. This process involves the learning of a pattern of muscle firing to direct appropriate movements. Here, this would involve refining control of joystick movements in order to direct the cursor to any location on the monitor. These processes in place, the subject will attain mastery of the joystick.

There are two proposed modes in which these four processes of motor skill learning can develop (Willingham et al., 1999). The first of these modes is the unconscious mode. It is in the unconscious mode that the subject is aware only of the environmental goal. In the case of the motor skill of joystick manipulation, this environmental goal would be the desire of the subject to place the cursor within the highlighted region to obtain a food reward. The second mode, or the conscious mode, consists of the development of strategic processes by which to attain this goal. Thus, the subject selects the necessary spatial targets for movement, sequences these behaviors appropriately, and learns a pattern of muscular action sufficient to attain the goal. It is in the conscious mode that joystick users learn joystick movements, patterns of directional control, and refine this control to attain the goal under a wide variety of circumstances.

While the theory of Willingham (1999) can nicely describe the process that we assume to be developing during skill acquisition, the theory derives no specific predictions as to what we might observe in our subjects. Therefore, while it describes the mental associations that must occur in skill development and performance refinement, it does not provide us with testable hypotheses as to how behavior markers will change during acquisition.

Thus, the acquisition of the joystick is an interesting skill to examine and warrants my investigation. Not only is the nature of this skill quite unlike that of those traditionally addressed by researchers in this field but it also forces us to revise and remold both classic and contemporary theories of skill acquisition. In my study I will focus on three main variables (rate of acquisition, visual tracking of the cursor, and body-tilting) and monitor how they change during acquisition in two different testing conditions (isomorphic and inverted joystick/cursor directional relationships). I plan to use the predictions of Schmidt's (1975) Schema Theory as well as the observations of previous researchers to develop my hypotheses as to how these animals will acquire this skill. Coming to better understand how this skill develops will lead to increased understanding of this skill in humans as well as shed light on how and with what modifications theories of skill acquisition can address the numerous computerized tasks that have become important in our daily lives.