ABSTRACT

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Research has shown that penalties can effect target acquisition movements (Sorge, 2004). Unpublished research by Gillan and Wardlaw showed that 30 second time penalties during a training session result in longer movement times and poor conformity to Fitts' Law during a testing session, an effect which persists for at least 30 minutes. The current study examined whether this effect would transfer to different response tasks. Experiment 1 tested whether experiencing penalties during a training session would impact target acquisition movements during a testing session if the testing session had different target sizes and movement distances, but similar indexes of difficulty (IDs). Results showed longer movement times and some disruption of the relationship between ID and movement time, although not as strong of an effect during the transfer testing session, indicating imperfect transfer. Experiment 2 tested whether experiencing penalties in a training session would impact target acquisition movements in two following test sessions with different response tasks. These tasks included vertical movement and a horizontal tapping task using a touch screen. Participants who received penalty training had longer movement times than participants who had no penalties during training. The relationship between ID and movement time during testing was weaker for participants who experienced time penalties, but this disruption was weaker than shown in previous experiments, even for participants whose response task was horizontal mouse movement, the same task used in prior studies. Mouse movement analysis showed that participants who experienced time penalties spent more time on both ballistic and homing movements.

Fitts' Law, Time Penalties, and Transfer

by
Wesley Wardlaw

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APPROVED BY:

____
Dr. Douglas Gillan
Committee Chair

____
Dr. Christopher Mayhorn

____
Dr. Anne McLaughlin

____
Dr. Chang Nam

BIOGRAPHY

Wesley Wardlaw completed his undergraduate studies at the University of Texas at Dallas. After obtaining a Master's degree at the University of Texas of the Permian Basin he began his studies at North Carolina State University in the Fall of 2012.

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INTRODUCTION

Humans acquire targets in order to achieve goals. Sometimes the target is a desired object and reaching it is the end goal, but sometimes reaching a target is a part of a larger task. Accordingly, environments should be designed so that targets can be acquired as quickly and accurately as possible. Researchers have long been trying to describe the approach individuals take when acquiring a target. Woodworth (1899) was an early observer of the relationship between speed and accuracy during goal-directed movements, noting that as the speed of movements increased, accuracy decreased and that decreasing speed increased accuracy, up to a point. Because target acquisition movements are goal-directed this relationship becomes important.

One approach to balancing speed and accuracy in target acquisition movements is to divide the movement into a ballistic phase that is rapid but inaccurate and a homing phase that is slower but more accurate. Initially, Fitts' own explanation of Fitts' Law focused on information theory constructs rather than speed and accuracy (Fitts, 1954). However, later research found that target acquisition movements and Fitts' Law provided a model for the tradeoff between speed and accuracy, echoing the ideas of Woodworth (1899) (Crossman & Goodeve, 1983; Meyer et al., 1988). Fitts' Law is an effective method of modeling user performance in pointing movements that begin at rest at a specific starting point and move to rest within a target area (MacKenzie, 1991). This has been helpful for the evaluation of effective designs for graphical user interfaces, providing a method to compare the effectiveness of one design over another (Felton, Radwin, Wilson, & Williams, 2009; Gillan, Holden, Adam, Rudisill, & Magee, 1992; McGuffin & Balakrishan, 2005).

Fitts' Law formally models the tradeoff between speed and accuracy that takes place as individuals move to acquire a target. Fitts (1954) proposed the law in order to explain the apparent consistency in the human motor system when controlling the amplitude of movement. Early experiments (including studies of a reciprocal tapping task, a disc transfer task, and a pin transfer task) supported the argument that there was a general relationship between speed, accuracy, and amplitude. Movement time (MT) can then be described by the following formula, which is Fitts' Law:

$MT = a + b \log_2$ *(Index of Difficulty), where Index of Difficulty (ID) = (2 x Amplitude/Target width)*

Thus, movement time is a linear function of the log base 2 of the ratio of amplitude (*A*) and the target size (*W*). In the formula, *a* represents the start/stop time of the device (the intercept) and *b* represents the relation between the index of difficulty and MT. *A* is measured as the distance from the starting point to the center of the target; *W* is measured as the width of the target along the axis of motion.

Motivation

The speed/accuracy tradeoff is based on motivation, where two opposing goals are pitted against each other - reaching the target quickly and reaching the target without error. If the possibility of an error is eliminated, then speed becomes the only motive, and width can be removed from the formula (Gan & Hoffmann, 1988).

The formula for Fitts' Law takes into account only control of movement by stimuli, the distance and target size. This does not directly consider motivation, although there is evidence that motivation impacts target acquisition movement. Fitts and Radford (1966) observed small effects of payoffs for speed and accuracy, but discounted their influence. Al-Imam and Lank (2006) found a small decrease in overall time when rewards were given for hitting a target, but no effect when penalties were given for hitting a target. In contrast, Sorge (2004) observed a strong effect of a 30 second time-out as a penalty for missing the target in a target acquisition movement, which affected both overall movement time and the Fitts' Law slope parameter. Detailed examination of the target acquisition movement showed that the penalty caused participants to increase the homing movement and decrease the ballistic movement.

Recent Experiments

Prior studies on motivational influences have focused on rewards or penalties for accuracy at the end of the movement. Unpublished researched by Gillan and Wardlaw examined the effect on movement of a penalty invoked for a feature of the movement that occurred during the path between the start and end. Two experiments were conducted in order to further explore the impact of time penalties on target acquisition movements. The first experiment used a 3 X 7 within-subjects factorial design, with independent variables of penalty condition and index of difficulty (ID). The design had three levels of penalty condition (0 seconds, 5 seconds, and 30 seconds), and 7 levels of ID (3.0, 3.5, 4.0, 4.5, 5.0, 5.5, 6.0). The order of the presentation of the penalty conditions was counterbalanced across participants. The major dependent variable was time to move from a start button to a target. Participants were instructed to make this movement in a direct linear path between the start button and the target, and it was explained that if their cursor was moved too high or too low on the vertical axis they would experience a time-out penalty where the screen went white and they would be unable to progress until the experiment automatically moved to the next trial. Results showed that there was a three-way interaction between the order of the conditions, penalty condition, and ID. Participants who were in a penalty condition for the first set of trials had motion times that were slower overall and were fit less well by Fitts' Law than participants who started with the no penalty condition. The time penalty had persistent consequences on movement time for the rest of a participant's trials, with movement behavior still altered during the later blocks of trials in which participants received no penalty. This indicates that target acquisition movements can be influenced by prior experience, as well as the controlling stimuli

One might argue that if the effect of penalties on target acquisition movement is relatively short lived, then the above finding is less important. A second experiment was conducted to examine the persistence of the effect of time penalties on Fitts' Law. The same IDs were used as the first experiment, but the design included a between-subjects variable with participants receiving one of four conditions. Each participant completed two sets of trials, but two groups had a thirty minute break between trials during which they participated in an unrelated mental rotation task. Participants either completed two sets of trials where there were no penalties or they completed a set of trials with 30 second time penalties as in the previous experiment, followed by a set of trials with no penalties. Thus, the conditions can be noted as penalty-break-no penalty, penalty-no break-no penalty, no penalty-break-no penalty, and no penalty-no break-no penalty. The conditions with no penalty produced similar results in the first and second set of trials, whether or not there was a 30 minute break in between sets and movement times during these trials conformed well to Fitts' Law ($R^2s >$ .90). In the conditions where the 30 second penalty was in effect during the first session, movement times were not fit well by Fitts' Law during both the set of trials with penalties and during the following set of trials when the penalty had been removed. Movement times were also increased. This is consistent with the initial experiment. Fitts' Law fit the data from the second set of trials somewhat better in the penalty-break-no penalty (R^2 =.58) condition than in the penalty-no break-no penalty condition (R^2 = .42), but this is still a much worse fit than for participants who have never experienced a time penalty. These results show some support for the persistence of the effect of time penalties on Fitts' Law. The effect of the penalties is still present after a 30-minute delay.

This experiment with a delay of 30 minutes was seeking to determine whether the effect of penalties transferred over time. Considering the duration, it would probably be considered a test of near transfer (Barnett and Ceci, 2002). Although time is an important test of transfer, for more practical applications, it is important to know whether the effect transfers in other ways. How much does the context have to change before the effect is no longer present? The current research provides a start to answering this question.

One possible explanation for the results in the Gillan and Wardlaw research is that receiving a penalty causes participants to adopt a new strategy that, in addition to trading off speed and accuracy, also avoids penalty. Once this strategy is adopted, how broadly will a participant transfer this strategy as the task changes? The current research is designed to answer this question, with a focus on changes in the responses of participants.

Two experiments were conducted to test whether changes in the response in a second set of trials (the transfer test) after experiencing a penalty in the first set of trials (the training) changed the impact that time penalties had on target acquisition movements. Broadly, Experiment 1 tested the effect of using distances and target sizes that are different in the second set of trials (although still maintain relatively similar IDs). Experiment 2 tested the effect of changing the direction of movement from horizontal in training to vertical during testing. It also tested changing the response method from using a mouse to using a stylus and touch input.

Design

The general design of Experiment 1 is shown in Table 1.

Table 1

Design of Experiment 1

Group	Phase 1 (Training)	Phase 2 (Transfer Test)
1	No Penalty, Motion A	No Penalty, Motion B
2	Penalty, Motion A	No Penalty, Motion A
3	Penalty, Motion A	No Penalty, Motion B

Comparing Group 1 with Groups 2 and 3 during training will demonstrate the training effect of the penalty. Comparing the performance of Groups 1 and 3 during the transfer test will demonstrate the persistence of the effect of the penalty even when the penalty is no longer being delivered. Comparing the performance of Groups 2 and 3 during the transfer test will show the degree of transfer of training as well as any reduction in the effect due to differences between Motion A and Motion B.

Table 2 shows how the design of Experiment 2 expanded on Experiment 1.

Table 2

Design of Experiment 2

Group	Phase 1 (Training)	Phase 2 (Transfer Test 1)	Phase 3 (Transfer Test 2)
Pen/No Trans	Penalty, Motion A	No Penalty, Motion A	No Penalty, Motion A
Pen/Trans	Penalty, Motion A	No Penalty, Motion B/C	No Penalty, Motion B/C
No Pen/No Trans	No Penalty, Motion A	No Penalty, Motion A	No Penalty, Motion A
No Pen/Trans	No Penalty, Motion A	No Penalty, Motion B/C	No Penalty, Motion B/C

Comparing penalty groups (1 and 2) with no penalty groups (3 and 4) during training will demonstrate the training effect of the penalty. Comparing Groups 1 and 3 during transfer test 1 and transfer test 2 will demonstrate the persistence of the penalty even when the penalty is no longer being delivered. Comparing Groups 1 and 2 during transfer phases will determine how persistent the effect of penalty is when response type is changed. Comparing Groups 3 and 4 during transfer phases demonstrates that simply changing the response type alone without having experienced penalties does not affect movement times.

Experiment 1

Method

Design. Table 1 provides an overview of the design, which involved a mixed-model design. One between-subjects independent variable was the Penalty Condition. All participants received two sets of trials, with the first set of trials serving as a training phase and the second set of trials serving as a transfer phase. Groups 2 and 3 received a 30 second time out on certain trials during the training phase. Group 1 did not receive any penalties during the training phase. During the transfer phase no penalties were given to any of the groups. Training Index of Difficulty (ID) was a within-subjects variable. During the training phase all participants received IDs of 3.0, 3.5, 4.0, 4.5, 5.0, 5.5, and 6.0. A third independent variable was transfer – for Groups 1 and 3, the distances and target sizes used for the IDs during the transfer phase differed from those during the training phase (although the range of ID values -- 3.0 to 6.0 -- was the same between training and transfer. For Group 2, the distances and target sizes used for the IDs during the transfer phase were identical to those for the training phase. Comparing training performance of Group 1 with that of Groups 2 and 3 demonstrates the effect of penalties during training. Comparing transfer phase performance between Groups 2 and 3 shows the degree of transfer of the effect of penalty – differences between these two groups during that phase must be due to the change in the specific characteristics of the trials during the transfer phase. Finally comparing transfer phase performance between Groups 1 and 3 demonstrates the persistence of the effect of penalties received during training in a later phase with no penalties. Both Groups 1 and 3 receive identical treatment in the transfer phase, so any differences in performance would have to be due to the difference in penalties during training.

Participants. 48 undergraduate students from North Carolina State University were recruited from a participant pool to participate in this study. Their participation allowed them to receive credit as part of a requirement for their Introduction to Psychology course. A power analysis indicated that in order to detect a medium to large effect size 19 to 47 total participants were necessary.

Materials. An iMac G4 desktop computer with a 38 cm (15 in) monitor running MAC OS as an operating system was used in this experiment. A program developed for this experiment using HyperCard 2.2 was used to present the visual stimuli. On a mouse tracking scale that is part of the OS, which ranges from Very Slow (0) to Fast (10), mouse tracking was set at 7.

Stimuli. On each trial, in both phases, the screen displayed a rectangular start button with a height of 1.2 cm on the left side of the screen in a position that was constant over every trial. The target was a rectangle located on the right side of the screen with a height of 5cm and a width that varied from trial to trial. Figure 1 shows what a trial looked like.

Figure 1. Example of trial with arrow showing direction of movement.

The training phase for all groups and the transfer phase for Group 2 had the following IDs: 3.0 (distance (d) = 24, target size (ts) = 3), 3.5 (d = 23, ts = 2), 4 (d = 16, ts =1), 4.5 (d = 23, ts = 1), 5 (d = 19.2, ts = 0.6), 5.5 (d = 23, ts = 0.5), and 6.0 (d = 19.2, ts = .3). During the transfer phase, for Groups 1 and 3, the following IDs were used: 3.0 (d=2, ts = .25; d = 4, ts = .5; d= 8, ts = 1; d = 16, ts = 2), 3.5 (d = 6, ts = .5), 4.0 (d = 4, ts = .25; d = 8, ts = .5; d = 16, ts = 1), 4.5 (d = 6, ts = .25), 5.0 (d = 8, ts = .25; d = 16, ts = .5), 6.0 (d = 16, ts = .25).

Procedure. Participants were tested in 30-minute sessions. The session began with the participant being provided with informed consent and reading instructions for the experiment. The instructions were displayed on the computer screen and described what a participant needed to do on each trial. The components of the task (clicking the start button, moving to the target, clicking the target) were described as well as whether any penalties were involved and what kind of movement would result in those penalties (movements in the vertical dimension that take the cursor outside of boundaries that dictate a linear path, see Figure 2 for a visual explanation of these boundaries). Instructions stated to move both as quickly and accurately as possible. Questions were encouraged after reading instructions and during practice trials. Participants performed three practice trials before beginning the experiment. At the beginning of each set of trials, the instructions indicated whether the trials would have no penalties or 30 second penalties.

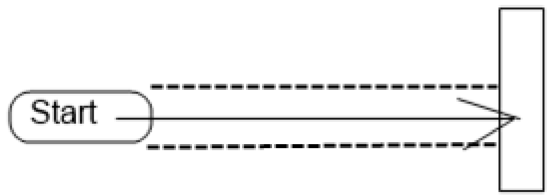

Figure 2. Dotted lines show boundaries that result in a penalty when crossed. These are not visible to the participant.

On each trial, a participant clicked on the start button, then moved on a direct horizontal path to the target and clicked on the target. If the participant deviated too far from a straight horizontal line, moving the mouse too far vertically either up or down, they received the penalty for that trial. They were not able to see the size of the safe path that they could take, but it was equivalent to the height of the start button (1.2cm). The no penalty condition was designed to have no penalties. In the 30 second penalty conditions, if the movement path went outside of the boundaries, a white screen was shown immediately and remained for 30 seconds, at which point the next trial began. Each trial ended whenever the participants experienced a penalty, clicked the target, or clicked outside the target (misses). Movement times were recorded from the click of the start button to either the beginning of the penalty or a click on or outside the target. In all Groups, participants completed 42 trials (7 IDs x 6 replications) during training. During testing, participants in Group 1 completed 42 trials (7 IDs x 6 replications) and participants in Groups 2 and 3 completed 48 trials (12 distance / target size combinations x 4 replications).

Results and Discussion

Data were analyzed using the log transform of response time data, as a Wilk-Shapiro test showed that it made the distribution more normal for both training(*W*=.65 to *W*=.94) and transfer (*W*=.45 to *W*=.88) sessions. Only trials where the target was hit were analyzed.

Table 3

Means (and SDs) for Movement Times During Training and Testing

	Training	
Group 1	Group 2	Group 3
993.61(296.83)	2358.23(1142.26)	2058.36(2087.41)
	Testing	
Group 1	Group 2	Group 3
855.36 (253.231)	1294.29(555.79)	1436.35(1798.95)

Mean movement times are presented in Table 3. Figure 3 shows the mean movement time as a function of ID and group for both training and transfer sessions. Each graph also shows the best fitting linear regression model. During the training sessions, Groups 2 and 3 received penalties when they exceeded the boundaries around a straight path. In contrast, Group 1 received no penalties during training. Note that both of the penalty groups had much slower movements than the no penalty group, resulting in a significant effect of group, $F(2,1556) = 5.44$, $p < .01$. The slopes relating ID to movement time were similar across the three groups, resulting in no significant interaction between ID and group, $F(2,1556) = 1.36$, $p > .05$. However, note that in addition to being much slower, the regression model provided a much poorer fit in the penalty groups than in the no penalty group with R^2s of .32 and .36 with penalties and .90 without penalties.

Figure 3 also shows the movement times as a function of ID for each of the three groups during the transfer phase. During transfer, no penalties were presented and the two transfer groups (Groups 1 and 3) had IDs that consisted of different combinations of distances and target sizes from those used during training. The groups that received penalties during training were slower to move to the target than was the no penalty group, F (2,1897) = 5.89, $p < .01$. The relation between ID and movement time varied across the three conditions noticeably, resulting in a significant interaction between group and ID, F (2,1897) = 8.78, $p < .001$.

A test of the difference between independent correlation coefficients was used to compare r values of different sessions. During training, the correlation between ID and movement time was higher for participants who received no penalties, Group 1, than for those who received penalties, Group 2, $z = -4.05$, $p < .001$, and Group 3, $z = -5.57$, $p < .001$. During the transfer phase, the correlation between ID and movement time was higher for the participants who had not received penalties during training, Group 1, than for those who received penalties, Group 3, $z = -6.05$, $p < .001$, and Group 2, $z = -4.80$, $p < .001$. Note that Groups1 and 3 received identical treatments during the transfer phase (that is same IDs and no penalties), so the difference in correlations provides further evidence for a persistent effect of penalties for movements outside of the vertical boundaries during training.

Overall, the slower movement times during training and testing for the two penalty groups in comparison to the no penalty group replicates the previous findings that a penalty for departing from a straight line path causes people to slow their movements. In addition, the much lower R^2s for the regression models suggest that the penalty induced the participants to adopt a different strategy of moving to the target. Based on the overall longer movement times, one might infer that participants either slowed down their ballistic movements, increased the duration of their homing movements, or both.

The continued difference in overall movement times during the test session as a function of receiving penalties during the training phase shows the persistence of the effect of the penalty. However, movement times tended to be faster for the penalty groups during transfer than during training, indicating that the lack of penalties in the test produced a diminution of the penalty's effect. Likewise, the increased R^2s during the test relative to the training suggest that the carryover of the effects of the penalty on acquisition behavior was decreasing.

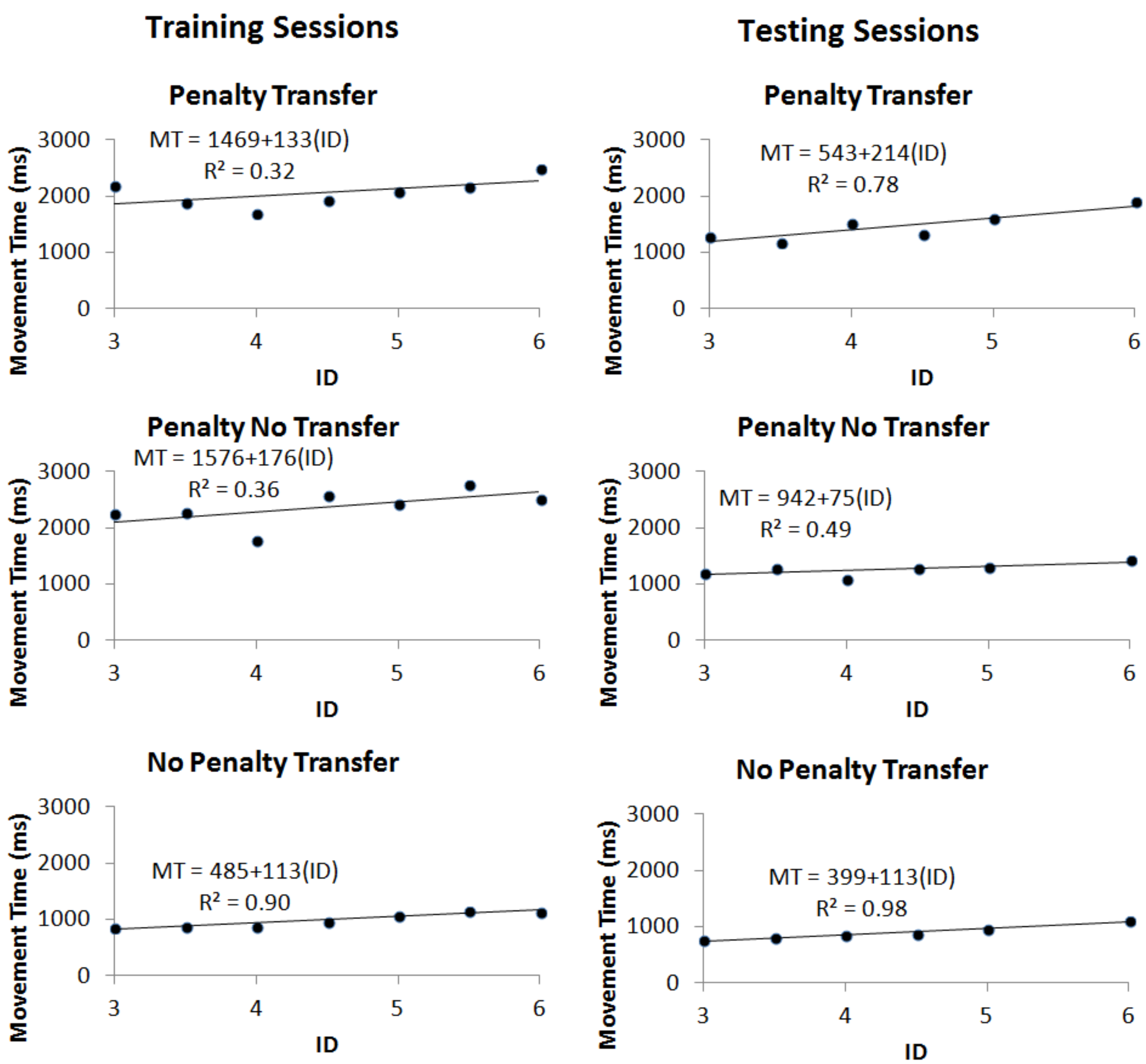

Figure 3. Training and testing graphs of conformity to Fitts' Law for all three groups.

Participants' responses (correct, miss, and penalty) during training for the three groups are shown in Table 4. Since the no penalty group did not have any penalty trials, any statistical analysis across response type would be meaningless, so these data are presented primarily (1) to show the similarity of the percentage of misses across the three groups, ranging from four to seven percent, (2) to demonstrate that penalties did occur in the two penalty conditions, and (3) that the miss rates were relatively low across conditions.

Table 5 shows the frequencies and percentages of hits and misses during the transfer test session. No penalties were given during the test. Both Group 1 and Group 2 had relatively low rates of misses, whereas Group 3 had a higher rate of misses. This pattern resulted in a significant chi square, χ^2 (2, N = 2157) = 25.56, $p < .001$. The higher rate of misses in Group 2 and Group 3 indicates that receiving penalties during the training phase resulted in a higher miss rate during the subsequent transfer phase. This result is somewhat surprising given that receiving penalties made participants slower to move and the reduced speed might be expected to produce greater accuracy. The higher rate of misses in Group 3 compared to Group 2 shows that changing the specific distances and target sizes but not the IDs had an effect on responding, even though movement times were similar.

Table 4

Frequencies(and Percentages) of Misses, Hits, and Penalties Across Groups for Training

Training							
Group 1				Group 2			
Miss	Hit	Penalty	N	Miss	Hit	Penalty	N
29 (4)	621 (96)	0 (0)	650	39 (6)	525 (80)	90 (14)	654
Group 3							
Miss	Hit	Penalty	N				
44 (7)	506 (79)	90 (14)	640				

Table 5

Frequencies (and Percentages) of Misses, and Hits Across Groups for Testing

Testing								
Group 1			Group 2			Group 3		
Miss	Hit	N	Miss	Hit	N	Miss	Hit	N
36 (5)	725 (95)	761	44 (7)	621 (93)	665	84 (11.5)	647 (88.5)	731

Consistent with previous experiments, Experiment 1 results showed that when participants had time penalties in their first set of trials their movement in the second set of trials were slower and were less well fit by Fitts' Law. This effect was also shown to partially transfer to a different response situation where different distances and target sizes were used to make similar IDs.

Experiment 2

The transfer examined by Experiment 1 was very near transfer. In order to determine the degree to which the effect of penalties transfers, tests of broader transfer were needed. Experiment 2 examined other, broader types of response-based transfer.

Method

Design. The design of Experiment 2 is outlined in Table 2 above. The basis for this experiment involved a 2 x 2 design with Penalty during training as a between-subject variable with two levels and Transfer following training as another between-subject variable, also with two levels. Thus, the experiment consisted of four groups, with participants completing three sessions of trials – training followed by two transfer sessions. The training session involved trials just like training in Experiment 1 – participants moved the mouse horizontally across distances that varied from trial to trial to acquire a target that varied in size from trial to trial. Training involved time penalties for two groups on trials in which the target acquisition movement violated the vertical boundaries as in Experiment 1; the other two groups received no penalties during training. In the two transfer sessions, participants did not receive penalties on any trials in any groups. One of the groups that received penalty trials during training and one of the groups that received no penalties during training continued with the horizontal mouse movement during both transfer sessions. These are the No Transfer groups (Penalty-No Transfer and No Penalty-No Transfer, respectively). One of the groups that received penalty trials during training and one of the groups that received no penalties during training performed target acquisition tasks that differed from the horizontal mouse movement during the two transfer session. These are the Transfer groups (Penalty-Transfer and No Penalty-Transfer, respectively). Both of the Transfer groups did different tasks during the two transfer sessions – (1) a vertical mouse movement from the starting point to the target and (2) a horizontal tapping task with a stylus that was lifted off the surface of the computer

Participants. A new set of 88 participants was selected from the same participant pool as in Experiment 1. A power analysis indicated that in order to detect a medium to large effect size at an alpha level of .05 22 to 55 participants were needed, indicating sufficient data was collected for this purpose.

Materials. This experiment was conducted using a Lenovo G780 laptop running Windows 8 connected to a Wacom Cintiq 21UX monitor. Mouse input was completed using a Dell optical mouse. The pointer speed was set at 10. Touch screen input was done using the "eraser" end of a digital stylus packaged with the monitor. PsychoPy 1.81.02 was used to create and present the stimuli as well as to record data

Stimuli. The display during training was very similar to that used during Experiment 1, except that this experiment used a different type of computer. In No Transfer groups, transfer sessions were identical to training sessions. In Transfer groups, during vertical transfer the target was at the top of the screen and the start button was at the bottom of the screen. During touch input transfer the stimuli were the same as during training accept that a mouse cursor would not appear. The IDs and target sizes are the same as training sessions in Experiment 1. Figure 4 shows examples of horizontal and vertical movements used during training and transfer.

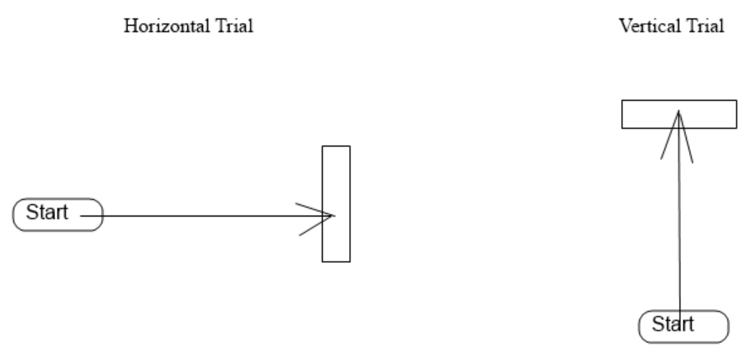

Figure 4. Examples of a horizontal trial and a vertical trial and the paths of movement. The target was a rectangle with a height of 5cm and a width that varied from trial to trial. IDs range from 3.0 to 6.0, just as in Experiment 1.

Procedure. Participants followed essentially the same procedure as in Experiment 1. The task of the participant was similar and when penalties occurred they were only during training trials with horizontal movements. Vertical movement trials required a different movement direction, but to successfully complete a trial the participant still had to click the start button and then the target. The task for touch input trials was to tap the start button and then tap the target.

Results and Discussion

Similar to Experiment 1, only trials where targets were hit were analyzed.

Figure 5 shows the mean movement time as a function of ID for the training sessions for the Penalty and No Penalty groups (Note that the Penalty data come from Penalty-Transfer and Penalty-No Transfer groups; likewise, the No Penalty data come from No Penalty-Transfer and No Penalty-No Transfer groups. Each graph also shows the best fitting linear regression model. The slopes relating ID to movement time differed as a function of penalty condition, resulting in a significant training type (penalty vs. no penalty) by ID interaction, $F(6,3284) = 4.81$, $p < .001$. Overall movement times during the training session were longer for penalty conditions, resulting in a main effect of condition, $F(6,3284) = 1574.41$, $p < .001$. There is a general trend of increased movement time as ID increases, as would be predicted by Fitts' Law, although as can be seen in the figure, Fitts' Law describes the no penalty condition data better than it does the penalty condition data. These results are similar to those in previous experiments for sessions that contain penalties.

In the no penalty training sessions, target hit rate was 90%, with the other 10% being misses. In the penalty training sessions the target hit rate was 81%, with the other 19% being broken down into 10% misses and 9% penalties. So, the penalty training appears to result in different movement behavior than the no penalty training, $\chi^2(2, N=3654)=180.47$, $p<.001$, but only because of the penalties being given in the penalty condition. The data, especially movement time data provide evidence that the penalty training results in different movement behavior than the no penalty training.

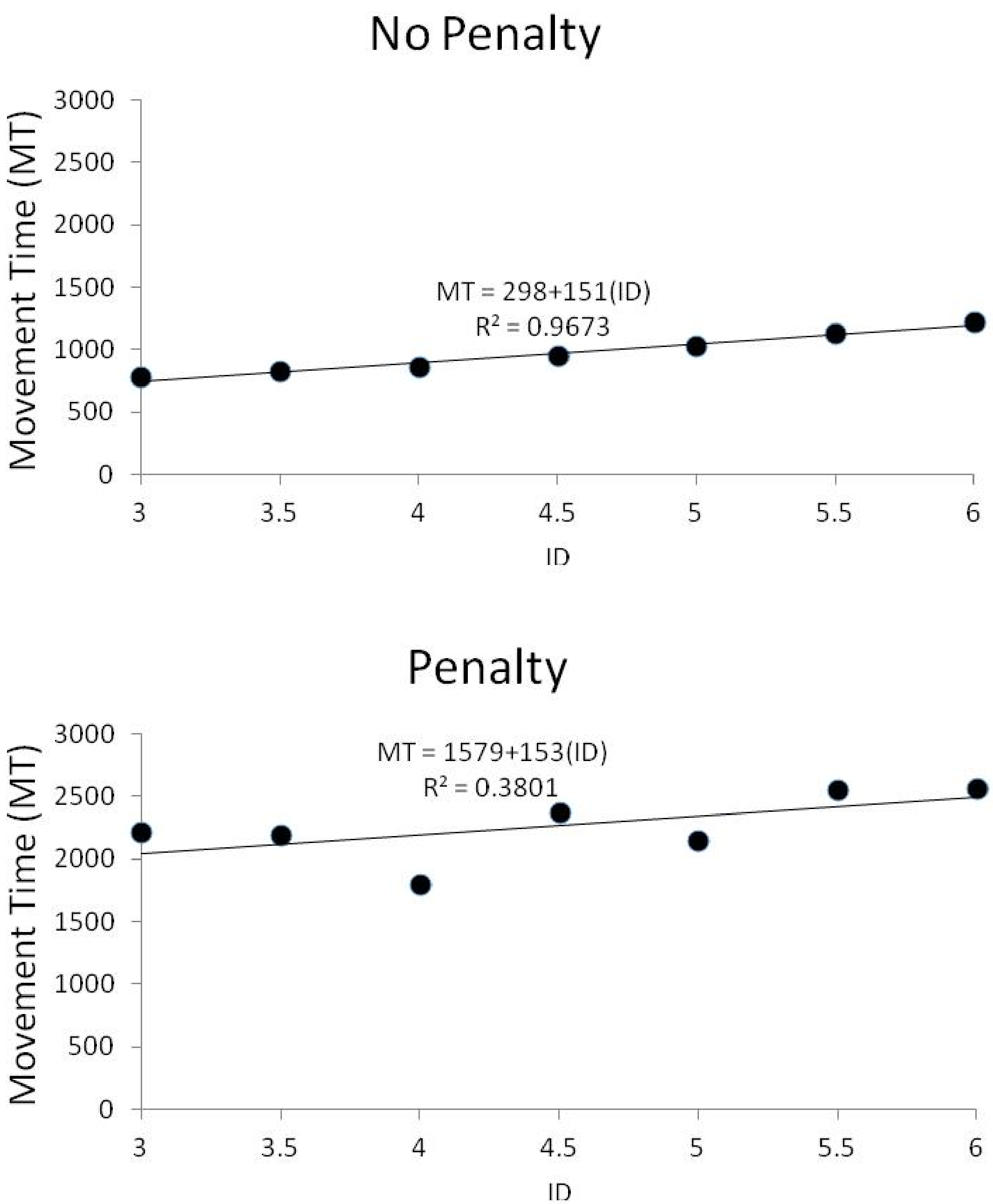

Figure 5. Session one IDs by movement times (MT) for penalty and no penalty conditions.

Figure 6 shows differences in mean movement times for session two (Transfer Session 1) as a function of type of training received (penalty vs. no penalty) and the type of response in session two (horizontal mouse movement, horizontal touch tapping, or vertical mouse movement). This is supported by an interaction between training type and response type, $F(2,3172) = 35.66$, $p < .001$. Participants that received penalties during training produced slower movement times during the first transfer session. Participants completing the horizontal mouse movement task, horizontal touch tapping task, and the vertical mouse movement task during the first transfer session had longer movement times if they were in the penalty horizontal mouse movement condition during training. Movement times for session two were different for all training conditions. Horizontal mouse movement had longer movement times than vertical mouse movement, which had longer movement times than horizontal touch tapping, indicating imperfect transfer. Differences between means were determined as significant at $p < .05$ using a Newman-Keuls test.

As might be expected from the interaction, Transfer Session 1 had a main effect of response type, $F(2,3172) = 141.20$, $p < .001$. For Transfer Session 1, Figure 7 shows a general trend of increasing mean movement times as ID increases, as indicated by a main effect of ID, $F(6,3172) = 49.39$, $p < .001$. During Transfer Session 2, participants also experienced longer movement times if they experienced a penalty during training. There was again an interaction between training type and type of response, $F(2, 3178) = 5.88$. Figure 6 displays that the mean movement times for participants who completed the touch tapping task and participants who completed the horizontal movement task were nearly identical when participants had previously had a penalty training session. There was no significant difference in mean movement times for these groups. These two groups had longer movement times than Transfer Session 2 participants who completed the vertical task and had a penalty session for training. Mean differences are significant at $p < .05$ using a Newman-Keuls test. As might be expected from the interaction, Transfer Session 2 had a main effect of response type, $F(2,3178) = 134.58$, $p < .001$. For Transfer Session 2, Figure 7 shows a general trend of increasing movement time as ID increases, which is supported by a main effect of ID, $F(6,3178) = 83.39$, $p < .001$. Table 6 summarizes means for all three sessions.

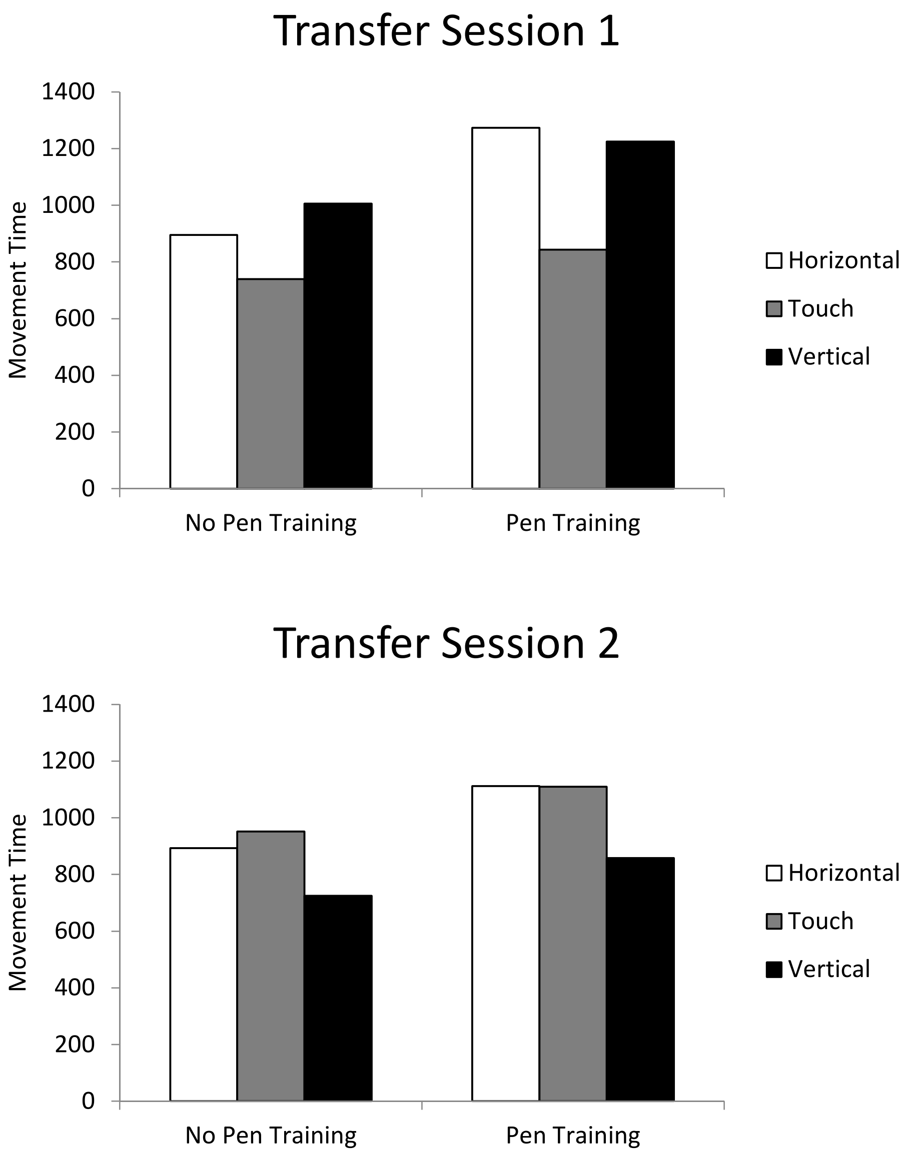

Figure 6. Movement times for session two and session three.

Table 6

Average MT(ms) for Each Session

Training					
PH		NPH			
2268		971			
Transfer Session 1					
Touch		Vertical		Horizontal	
P	NP	P	NP	P	NP
1110	950	850	720	1270	900
Transfer Session 2					
Touch		Vertical		Horizontal	
P	NP	P	NP	P	NP
840	740	1220	1010	1110	890

Figure 7 and Figure 8 show relationships between IDs and mean movement times for Transfer Sessions 1 and 2 as well as the best fitting linear regression lines and R^2 values for all training and response type conditions. This results in graphs for no penalty horizontal, no penalty vertical, no penalty touch, penalty horizontal, penalty vertical, and penalty touch. This naming scheme describes the type of training received in Training (penalty vs. no penalty) and the response task for Transfer sessions (horizontal mouse movement, horizontal touch tapping task, or vertical mouse movement). The intercept of the graphs makes clear the longer overall response times for participants who were in a penalty training condition, indicating that they took more time to reach the targets. This is true both overall and for every response task. However, while the R^2 values for these participants are worse than participants who were in no penalty training conditions, Fitts' Law does not appear to be disrupted as much as in previous experiments. It's unclear why this is, particularly for the no penalty horizontal group in Transfer Session 1, within which participants would have had a nearly identical experience to participants in prior experiments. It is possible that movements are effected more by participant strategies than IDs, and strategies may vary, making it difficult to predict outcomes.

Participants performing touch and vertical tasks had lower R^2 values than participants performing the horizontal task, both when they received penalty training and when they received no penalty training. In addition, the test of independent correlation coefficients showed that during training there was a stronger relationship between ID and movement time for participants in the no penalty groups (r = .57, N = 1664) than the penalty groups (r = .14, N = 1466), z = 14.13. This was also true for Transfer Session 1 no penalty (r = .53, N = 1594) and Transfer Session 1 penalty (r = .29, N = 1620), z = 8.23, $p < .001$. Transfer Session 1 no penalty horizontal (r = .58, N = 844) had a stronger relationship between ID and movement time than Transfer Session 1 penalty horizontal (r = .25, N = 853), z = 8.34. The same was true for Transfer Session 1 no penalty vertical (r = .53, N = 423) and Transfer Session 1 penalty vertical (r = .33, N = 422), z = 3.56. There was no difference between Transfer Session 1 no penalty touch (r = .31, N = 327) and Transfer Session 1 penalty touch (r = .34, N = 345), z = -.43, $p > .05$, *ns*. Participants who were in no penalty training also had a stronger relationship between ID and movement time in Transfer Session 2 (r = .53, N = 1623) than participants who had penalty training (r = .36, N = 1597), z = 6.04, $p < .001$. Transfer Session 2 no penalty horizontal (r = .61, N = 865) and Transfer Session 2 penalty horizontal ($r = .33$, N = 842) showed the same pattern ($z = 7.55$, $p < .001$), as did Transfer Session 2 no penalty vertical ($r = .53$, N = 407) and Transfer Session 2 penalty vertical ($r = .41$, N = 405), $z = 2.19$, $p < .05$. Transfer Session 2 no penalty touch ($r = .30$, N = 351) and Transfer Session 2 penalty touch ($r = .34$, N = 350) were not significantly different from each other, $z = -.59$, p > .05, *ns*.

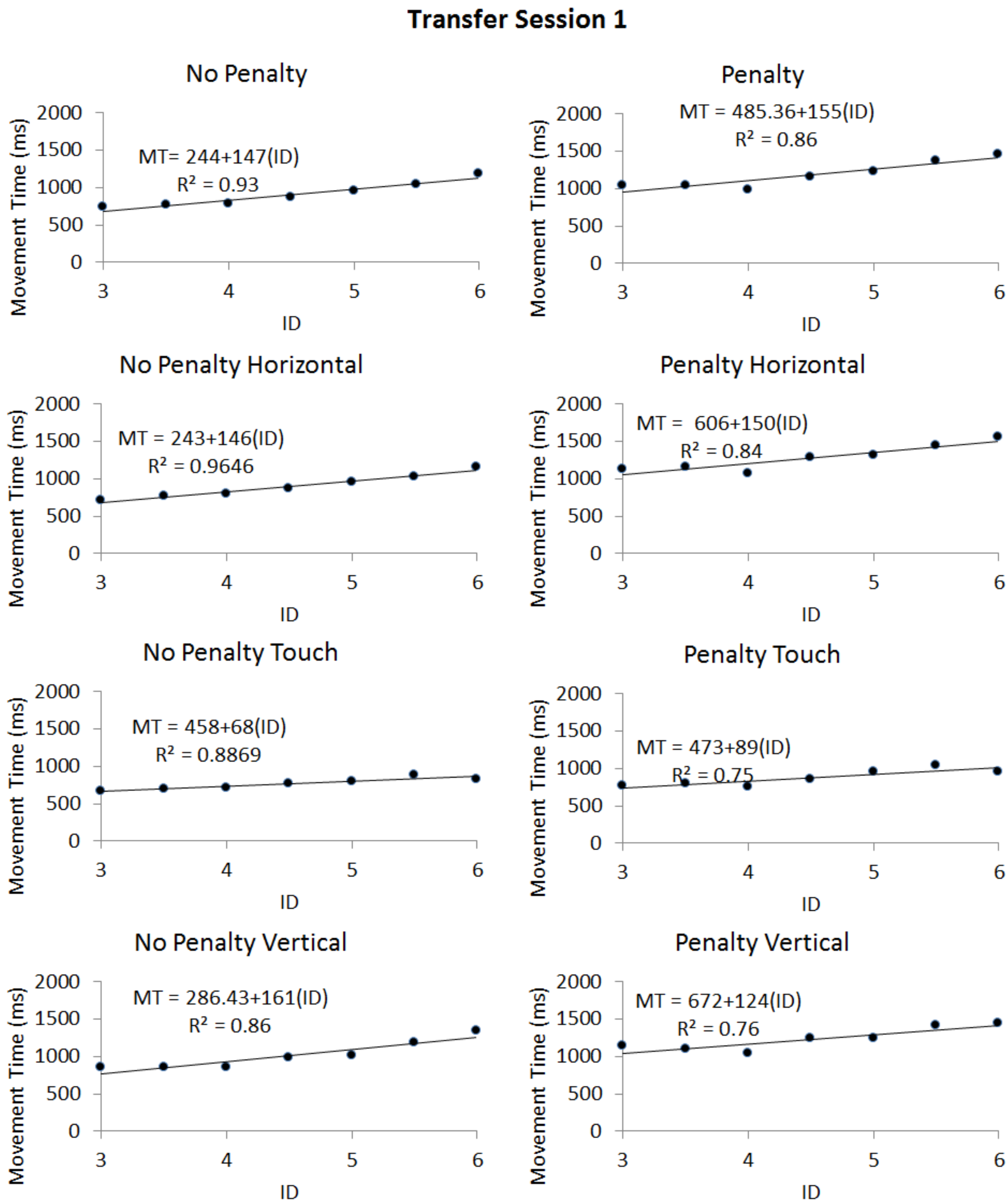

Figure 7. Session 2 graphs of conformity to Fitts' Law for participants who received penalty training or no penalty training as well as more specific subgroup graphs.

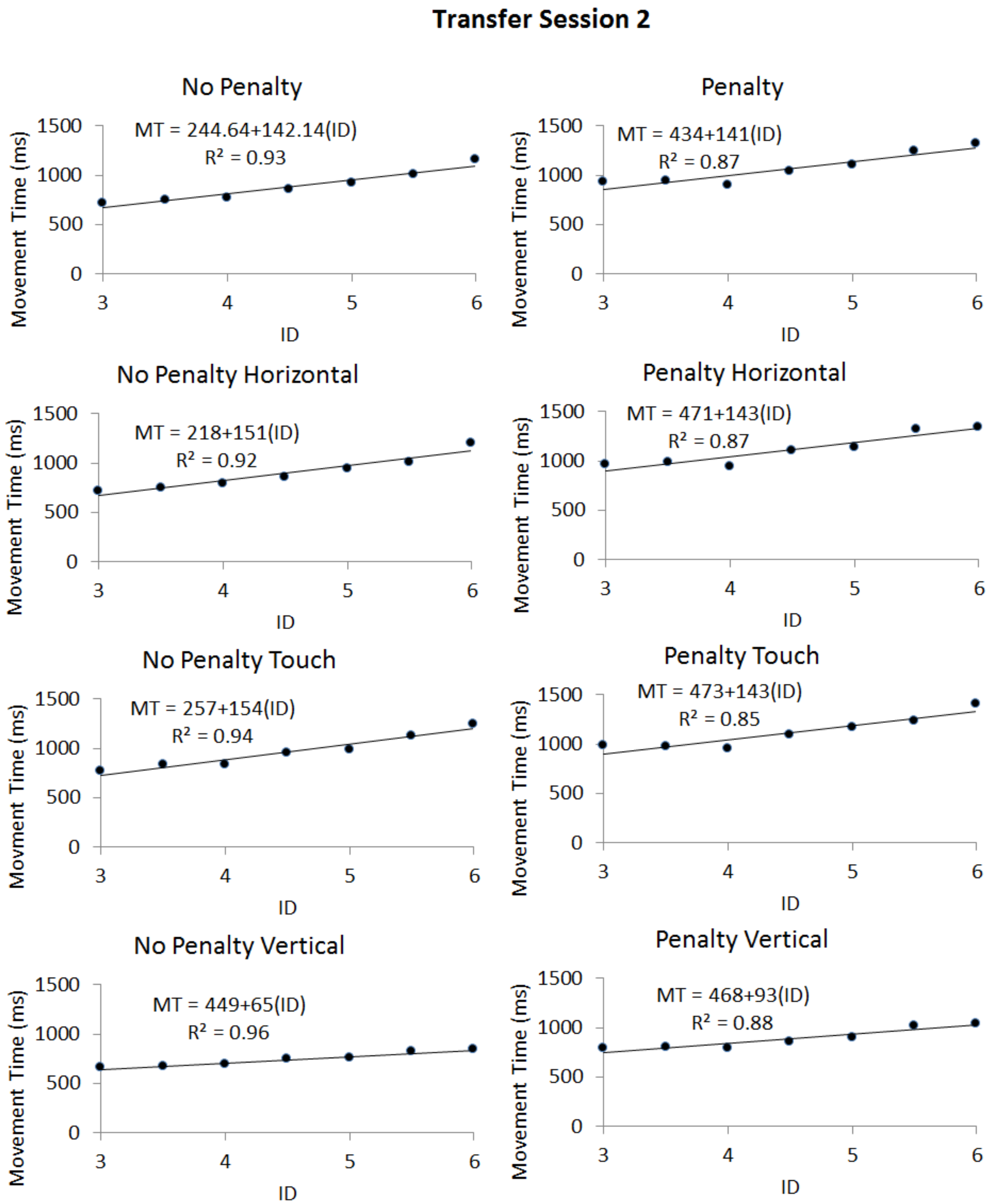

Figure 8. Session 3 graphs of conformity to Fitts' Law for participants who received penalty training or no penalty training as well as more specific subgroup graphs.

In order to get a more detailed understanding of the differences in mouse movement, (x,y) coordinates were collected for each frame of each trial at a rate of 32 frames per second, thus 32 coordinate pairs. This produced a very large amount of data. In order to reduce this down to something interpretable, averages were taken for each ID within each session in each condition. This resulted in 84 lists of coordinates, one for each of these IDs. The distance between each coordinate was calculated in order to determine how much the mouse position had changed from the previous frame. This created 84 new lists of distances. Using these it was possible to graph the change in mouse position over time for each ID and to fit an equation to each graph. Figure 9 is an example of one of these graphs for a training session with penalties. Figure 10 is an example of one of these graphs for a training session without penalties.

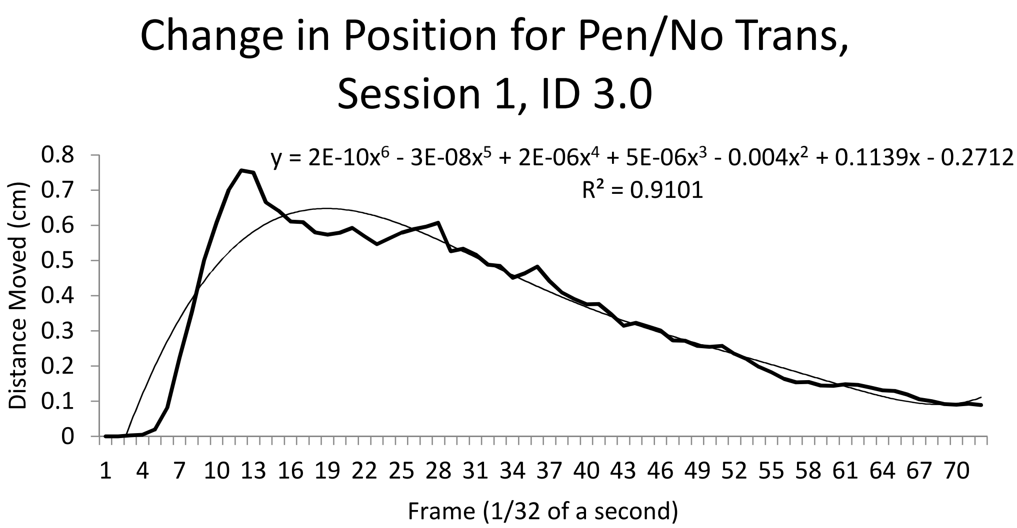

Figure 9. Graph of change in position over time for ID 3.0 in session one in Pen/No Trans.

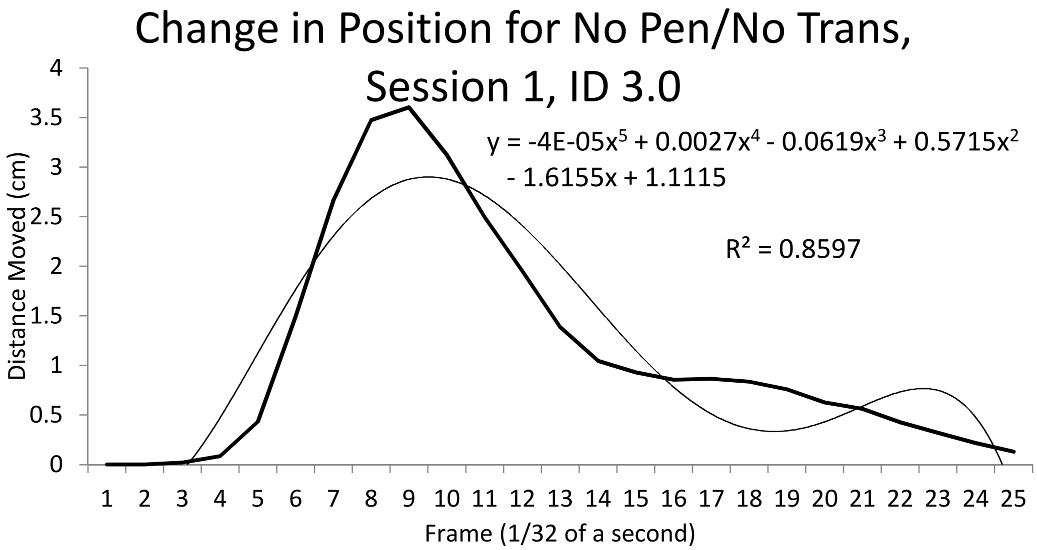

Figure *10.* Graph of change in position over time for ID 3.0 in session one in No Pen/No Trans.

Critical points for these equations were calculated and for each graph a point was found that indicated when participants stopped accelerating and began decelerating. Dividing which frame this occurred by the total number of frames in the movement resulted in a percentage that describes how much of the total movement time is ballistic. This can be subtracted from 100 to determine how much of the movement is homing.

During Transfer Session 1 and Transfer Session 2, participants who were in a penalty training condition during training did not differ in ballistic movement from participants who were in a no penalty training condition, $F(1,54) = .61$, *ns*. This indicates that homing movements for penalty training and no penalty training during Transfer Session 1 and Transfer Session 2 were also similar to each other, as homing is just calculated by subtracting the ballistic movement from the total movement. This indicates that participants who had penalty training did not spend more time in only the ballistic movement or only the homing movement, but took longer to perform both parts of the overall movement. An analysis of all conditions and all sessions showed that index of difficulty affected the size of the ballistic movement, $F(6,77) = 3.79$, $p < .01$. A Tukey test indicated that this was a result of the ID 3.0 (M =51.75), the lowest ID in the trials, was significantly different from ID 5.5 (M=34.17) and ID 6.0(M=33.17), the two highest IDs in the trials, both at $p < .01$. This is consistent with Fitts' Law. Table 7 shows the percentage of movement that is ballistic for each ID.

Table 7

Percentage of Ballistic Movement for Each ID

ID	*M*	*SD*	N
3.0	51.75	15.70	12
3.5	44.75	11.76	12
4.0	45.08	12.60	12
4.5	41.67	12.47	12
5.0	39.92	9.94	12
5.5	34.17	7.42	12
6.0	33.17	9.31	12

Experiment 2 tested broader transfer of response tasks and was able to find support for partial transfer of the effect of time penalties on Fitts' Law. Movement times were increased during sessions where participants had previously experienced time penalties in an earlier session. R^2 values were reduced, but this effect was not as large as seen in prior experiments. The inclusion of mouse position data allowed for a better understanding of the differences in movement between participants who experienced time penalties and those who did not. Distance was tested as a predictor for sessions that conformed poorly to Fitts' Law, but it did not improve predictions for any of them.

Testing Models for a Better Fit

Experiment 1 penalty training and testing sessions had fairly low R^2 values, as did the participants in Experiment 2 who received penalty training. If Fitts' Law does not successfully predict movement times in these situations, it might be beneficial to search for other models. Gan & Hoffman (1988) proposed a model using the square root of the distance, arguing that it was better for cases in which IDs were very small. Meyer et al. (1988) proposed an alternative to Fitts' Law that divided distance by target size and took the square root. Kvalseth (1980) proposed a power law for predicting movement time as opposed to a linear function. The fit for the original Fitts' Law model is shown in Table 8 along with the fit of these alternative models.

Table 8

R^2 Fit for Models to Predict Movement Time

	Models			
Condition	a+b(ID)	a+b(√D)	a+b(√(D/TS)	a(D/TS)^b)
PT Train	.32	.32	**.44**	.22
PT Test	.78	**.95**	**.81**	.73
PNT Train	.36	**.48**	**.37**	.30
PNT Test	.49	.23	**.62**	**.50**
Exp. 2 Pen Train	.38	**.59**	**.42**	.27

Note: PT = Penalty Transfer, PNT = Penalty No Transfer, bold indicates that the R^2 was higher than for the Fitts' Law model

General Discussion

Previous research (e.g., Sorge, 2004; Wardlaw and Gillan, unpublished) has provided evidence that time penalties given during target acquisition movements result in slower movement times, a change in movement strategy, and consequently, a reduction in the fit of

Fitts' Law to the movement time data. This change in behavior has been shown to persist for at least 30 minutes (Gillan & Wardlaw, unpublished). The results of the present research adds to that literature by showing that the effects of penalties transfer to new response situations that differed from the conditions of training. Experiment 1 demonstrated that the effects of the penalty transferred when the change involved only distance and target size. Experiment 2 examined larger changes in the response task, altering the movement direction in one case and the specifics of the motor task in the second case.

The transfer tasks were chosen because transfer to these scenarios would indicate a more robust effect of time penalties, which could potentially relate to the applicability of the effects of penalties on movement. If users are currently in or have recently been in a context where the motivation for movement behaviors has been altered, the present results suggest that the overall movement times may be altered and, at least some of the time, so might the fit of Fitts' Law to movement time. The results finding partial transfer indicate that the effect of time penalties on movement behavior transfers over more than just time. Movement behavior on a Fitts' Law task can be affected by previous experiences during a similar, but not identical movement. The results for the horizontal touch tapping task indicate that transfer is even possible for different methods of input. Given that the effect of time penalties was still present, it is not known how far the transfer would have to be before participants' movements conformed to Fitts' Law at a level that matched what it would be if they had never been exposed to a penalty training session. One way to effect more distant transfer might be to make multiple changes in the response task, such as using a vertical touch tapping task.

Anderson and Singley (1989) provide some historical perspective concerning which transfer tasks might result in a complete lack of transfer. They discuss the doctrine of formal discipline, which was the belief that all learning transfers to new situations, essentially arguing that the brain functioned like a muscle and exercising it with any task would improve performance on all other tasks and that there was no need to study a broad range of topics. Thorndike reacted strongly against this perspective, creating what he called the theory of identical elements. He argued that training in one task would only transfer to another if the tasks shared stimulus-response elements. In practice, his requirements for how similar tasks would need to be for transfer to occur make it difficult to even consider it transfer at all and even his own research did not support the theory well(Thorndike, 1922). Since then, researchers have moved to somewhat of a middle ground between the doctrine of formal discipline and the theory of identical elements.

The tasks in Experiment 1 and Experiment 2 can be viewed as having some similar elements and some differing elements between training and testing. In order for transfer to take place, first something has to be learned that can then be transferred to a new task. For these experiments, what seems to be learned is a strategy for approaching the task, which seems to simply be to go slower. Examples of comments from debriefing discussions are "I went slower because I didn't want to get the penalty" and "I went slower because I didn't want to have to wait". This is also shown with longer movement times during penalty training and during sessions that follow having experienced penalty training. Participants persisted in using this strategy during transfer tasks, even though it was no longer an appropriate strategy if the goal is to emphasize speed and accuracy equally. However, the strategy that is carried over is not the only relevant factor influencing movement behavior. The transfer tasks share many similar elements (IDs, sometimes movement direction, sometimes movement device) but they also intentionally differ in ways that may influence participants to begin developing new strategies. At the same time that old strategies are being applied to the new task, new learning is taking place. This results in imperfect transfer.

Future research changing more elements of the tasks will be needed to clarify how much change and what type of change is needed to completely eliminate transfer. If target acquisition movements are not just controlled by the stimuli in the situation, but also by the consequences of movement, this may have important applications. Fitts' Law may predict movement times best in situations where there are no consequences as a result of movements. However, in many contexts there are consequences. If a user of a website attempting to click a button (the target) accidently moves their mouse over an advertisement, which expands and covers the target, they will have to get rid of the advertisement before proceeding and this may affect their future movement behavior when using this website and possibly other websites. If a surgeon cuts a vein or a dentist scrapes a patient's gums on the way to their intended targets, there are consequences. The game Operation generates artificial consequences for not staying within a specified path when approaching a target. These examples focus on consequences that occur during the path of the movement, but the end of the movement can have consequence, as well (e.g., Sorge, 2004). Clicking the wrong link on a website can be costly in terms of time to recover. There are many examples of inaccurate mouse clicks resulting in wasted time (playing the wrong song, opening the wrong file, accidently closing a program or tab). A child who hits the Whack-a-Mole console in the arcade instead of the character popping up won't get any points. Pressing cancel instead of enter when processing a credit card transaction results in having to start over. A complete accounting of what may affect Fitts' Law and of target acquisition movements will need to consider both consequences that occur during the movement and consequences that occur at the end of the movement. Thus, results like those in the research described above indicate the need for a conceptualization of target acquisition movements that include factors other than stimulus control over movement by distance and target size.

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