

Reinforcement Duration on Continuous Reinforcement for Lake Sturgeon

by

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Abstract

Darkness has previously been shown to be an effective reinforcer for certain species of fish. In the present study, the effects of various lengths of darkness were tested consecutively as reinforcers for two lake sturgeons (*Acipenser fulvescens*) to determine the relationship between rate of behavior and reinforcement duration during a continuous reinforcement schedule. The results showed a small positive correlation between reinforcement duration and rate of responding, with the 20 seconds of reinforcement condition showing the most consistently high results.

Keywords: reinforcement duration, continuous reinforcement, lake sturgeon, *Acipenser fulvescens*

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Reinforcement Duration on Continuous Reinforcement for Lake Sturgeon

Operant reinforcement is often conceptualized as a nearly instantaneous event. While this conceptualization works well when each reinforcement consists of, for example, a small food pellet that an experimental subject can consume in a negligible amount of time, not all reinforcement can be conceptualized this way. For example, in Dr. Pear's Fish lab, we have studied darkness as a reinforcer for various species of bottom feeder fish which are likely to prefer darkness over light. This raises the question of how long should an interval of darkness last in order to be maximally effective as a reinforcer. For example, a reinforcement length of .0001 seconds would be too short to be noticed by the subject, while a reinforcement interval that lasts the entire experimental session would be too long to be considered effective as it would severely restrict the amount of time available to study the reinforced behaviour.

A given duration of darkness corresponds to the size or magnitude of darkness as a reinforcer; that is, the longer darkness lasts following a response the greater the magnitude of darkness as a reinforcer. While one would expect a larger reinforcer to show faster and/or larger changes in behavior, the effects of manipulating reinforcement magnitude have been inconsistent (Bonem & Crossman, 1988). Some studies have shown a direct relationship between reinforcement magnitude and rate of responding. For example, Silverman, Chutuape, Bigelow, and Stitzer, (1999) found a direct relationship between rate of responding and reinforcement magnitude in humans addicted to a particular drug. That is, humans addicted to the drug were more likely to provide drug-free urine samples when rewarded with larger monetary vouchers compared to smaller monetary vouchers. There have also been studies showing no relationship between reinforcement magnitude and responding, such as Paden and Kodak (2015) who found

that children with autism showed a preference for larger amounts of food according to a magnitude preference assessment but the speed of skill acquisition did not vary with reinforcement preference or magnitude.

There have also been studies that showed an inverse relationship between reinforcement magnitude and response rate. For example, Belke (1997) found that when rats' lever pressing was reinforced with running time on a wheel, the longer the time available for running the lower the rate of lever pressing. Lowe, Davey, and Harzem (1974) also found an inverse relationship between reinforcement magnitude and response rate. In this study rats were given a variety of concentrations of milk for pushing a lever and the post-reinforcement pause increased (i.e., responding after reinforcement decreased) with the concentration. Pickens and Thompson (1968) found an inverse relationship between reinforcement magnitude and response rate with rats responding for cocaine, but only within a certain range. Different dosages of cocaine were self-administered by rats, with only some dosages maintaining behavior. Dosage levels (.5 to 1.5 mg/kg/infusion) that maintained behavior showed an inverse relationship of dosage level with response rate, with the infusion levels below this range (e.g., .25 mg/kg/infusion) producing long pauses that sometimes led to cessation while infusion levels above this range (e.g., 2.0 and 3.0 mg/kg/infusion) caused responses to cease.

The apparent inconsistencies in the above results might be caused by uncontrolled variables. An example is deprivation. For example, Pinkston, Ginsburg, and Lamb (2009) showed with pigeons pecking on a fixed-ratio (FR) schedule for access to grain that responding for shorter access times was more easily disrupted by deprivation. Stabler (1962) also found that deprivation has an effect; in his study rats ran down a runway to receive a sucrose solution while either satiated or deprived. In this study there was a significant interaction effect, where response

rate and concentration of sucrose had an inverse relationship while in a low drive condition and a direct relationship while in a high drive condition.

The schedule of reinforcement might also account for the inconsistency of the previous research. Most of the studies previously mentioned only used one type of schedule of reinforcement. If two different studies used different schedules of reinforcement then the difference in results could be due to the differing schedules. An exception to studies that only tested one schedule of reinforcement is Hulse, Snyder, and Bacon (1960) who tested two different FR schedules, reinforcing every lick or reinforcing every 5 or 6 licks, for a rat to receive one of two volumes of saccharine with one of three concentrations. Another exception is Pickens and Thompson (1968) who tested three different types of schedules of reinforcement for rats receiving different cocaine dosages. The rate of reinforcement was varied for each of these schedules.

Presenting the different reinforcement magnitudes sequentially or concurrently can also have an effect. Neuringer (1967) found with pigeons that while choice varied with reinforcement duration, response rate was constant regardless of reinforcement duration. Catania (1963) tested pigeons on variable-interval schedules with a single response key and with two response keys. When the pigeons had only one key to choose from the rate of pecking stayed the same regardless of duration of access, while in the two-key situation the rate of pecking was directly related to the duration of access to grain.

When reinforcement length is near-instantaneous controlling for consumption time or not controlling for consumption time is irrelevant: the most effective reinforcer would remain the same - the reinforcer that produces the highest rate of responding. However, when reinforcement is not near-instantaneous, effectiveness must be determined by controlling for consumption time.

Effectiveness while controlling for consumption time is calculated by removing the time it takes for the subject to consume the reinforcer and determining if there was an increase in the rate of responding based on session time minus total consumption time. Determining which among several reinforcers is the most effective would be done by comparing the increases in the rate of responding because the time spent consuming each reinforcer would be controlled for.

The duration of access to a reinforcer is usually studied in terms of access to food (e.g., Carlson & Wielkiewicz, 1976; Catania, 1963; Hulse, Snyder, & Bacon, 1960; Lowe, Davey, & Harzem, 1974; Neuringer, 1967; Paden, & Kodak, 2015) and usually is studied using pigeons (e.g., Catania, 1963; Neuringer, 1967; Pinkston, Ginsburg, & Lamb, 2009) or rats (Belke, 1997; Carlson & Wielkiewicz, 1976; Hulse, Snyder, & Bacon, 1960; Lowe, Davey & Harzem, 1974; Pickens & Thompson, 1968; Stabler, 1962). The present study will add to the ongoing body of research on reinforcement magnitude by examining a species – lake sturgeons (*Acipenser fulvescens*) – and reinforcer – darkness – not often, if ever, studied in basic behavioral research.

Method

Subjects

Two lake sturgeons from the University of Manitoba's Department of Biological Sciences were used courtesy of Dr. Gary Anderson, the owner of the fish. The subjects were selected on the basis of health by animal care technicians in the Biological Sciences Animal Holding Facility. Selecting them on the basis of health was done to reduce potential attrition due to illness.

Materials and Apparatus

The subjects were tested in a tank with a 10 cm-by-10 cm square base and translucent walls 40 cm in length and width and 19 cm in height. The tank was filled to roughly 10 cm with

dechlorinated water each session at a temperature within 1° Celsius of the temperature of their home tank. The experimental tank was on a white platform and below four work lights and two cameras which were connected to a computer in an adjacent room for monitoring and administering reinforcement. This setup reduced the chances of distractions or other factors outside of the tank affecting behavior by eliminating or obscuring as many variables that could become distractors and keeping as many variables uniform. The video cameras and computer constituted a video tracking system (VTS) that tracked the fish's position in 3 dimensions. The VTS scanned from front-to-back and top-to-bottom and records the middle pixel of any three dark pixels detected by the system. The platform the tank was on was painted white, as was everything else in view of the VTS's cameras, to contrast with a dark fish. Each VTS camera visually displayed the subject's behavior to the adjacent room and also visually recorded the subject's position and movement in the tank so that raters could work whenever they were available. The tank had four target areas marked underneath by white tape in the form of quarter-circles with a radius of 10 cm, one in each corner. These marked areas coincided with the four target areas that a computer program called FishCamp, specifically developed for a VTS, monitored while tracking the fish. Visual observations were supplemented by the VTS which recorded the fish's position against a white background 10 times per second, as described above.

Procedure

Each of six experimental conditions consisted of a continuous reinforcement schedule (each response reinforced) for one of the target areas with the length or duration of reinforcement varied as follows: 1-second, 5-seconds, 10-seconds, 20-seconds, 40-seconds, and 60-seconds reinforcement durations. Reinforcement durations were programmed into FishCamp which

automatically provided the reinforcement when the fish was detected by the VTS to be within a designated target region.

Figure 1 shows the original design visually. Both subjects began with a baseline condition in which there was no reinforcement for swimming into any target area, as shown as the left-most rectangles in Figure 1. According to the original design, once the stability criterion (see below) was met in a condition the subject moved to the next condition, alternating between a baseline condition and an experimental condition. The first subject moved to the 1-second reinforcement condition after its first baseline, and then each time the subject started a new experimental condition it moved to the experimental condition with the next shortest length of reinforcement, as shown by the pattern of phases next to Fish A in Figure 1. The second subject moved to the 60-second reinforcement condition after its first baseline, and then each time the subject started a new experimental condition it moved to the experimental condition with the next longest length of reinforcement, as shown by the pattern of phases next to Fish B in Figure 1. The target area with the second least number of hits for each subject during a preliminary baseline was selected as the reinforced target – i.e., the target whose entry into will be reinforced – during all conditions in which reinforcement is scheduled throughout the experiment and was given a discriminative stimulus. The second least visited target area was used to avoid a ceiling effect, as well as a floor effect, as any reinforcement duration that ended up being punishing could also be detected. Once all experimental conditions were completed by a subject, the subject went on to go through another return to baseline, followed by a repeat of the condition that was deemed the most effective (as defined by the largest response rate for the condition) for the subject. These last two phases are shown in Figure 1 as the second row of rectangles for each

fish. This procedure was selected to provide control or the ability to detect maturation effects, testing effects, and sequence effects.

Due to subject attrition and a global pandemic the research could not be conducted as ideally as its conception. Figure 2 shows which sessions were conducted as well as when each subject started compared to the other. While not ideal, there was enough data to draw some tentative conclusions. Because of this 33 sessions were conducted with Fish A while 21 sessions were conducted for Fish B.

The stability criteria for changing conditions was developed from previous research in Dr. Pear's Fish Lab and recommendations in textbooks. Kazdin (2011) recommends that the trend of the data should be neutral or in the opposite direction expected (i.e., the stability criterion could be met if there is a negative trend during a baseline phase or a positive trend during an intervention phase). For a stable and neutral trend, a stability criterion mentioned by Sidman (1960) for monkeys and rats is a difference of .1 hits per minute between two out of the three most recent sessions. This is somewhat similar to the stability criteria used in Dr. Pear's Fish Lab, requiring a minimum of 3 sessions and a range derived from those sessions' percentage of total hits of 10% or less for all corners. This experiment used the stability criteria used previously in the lab to define a neutral trend. While it is not as strict as the stability criteria recommended by Sidman (1960), using such a strict stability criterion could lead to problems with extending the experiment's length.

An inter-rater agreement score was to be calculated between the experimenter, a rater, and the computer through a series of correlations. The Pearson-product-moment correlation coefficient was used because the VTS does not track the subject in the same way as an observer, which would negatively affect the inter-rater reliability score if it were calculated by percent

agreement. The VTS tracks by detecting the parts of the subject that are dark enough as opposed to tracking the subject's entire body. Sometimes the lighter parts of the subject can enter a target area without the VTS detecting it. At other times the dark parts of the subject can become obscured due to refraction or glare. In these cases the VTS stops tracking those parts of the fish. If this occurs, the VTS will consider the subject as having left the target area and then re-entering it even if the subject has not moved. In infrequent incidents in which the VTS loses tracking of a fish, the VTS records a tracking error. Tracking errors are usually below 900 in a 30-minute session, or .5 per second. Due to equipment problems there were no video records of the sessions which lead to no inter-rater scores being conducted, so only initial scores and VTS scores can be compared.

Hit Measurements

A target hit was recorded whenever a part of the subject entered a target area. A second hit could not occur until the subject fully exited the target area and then re-entered it. Hits were only calculated when the work lights were on. Number of hits on each target area, when the work lights were on, constituted the raw score each target area received during a session. These scores were the basis from which all other scores were derived. Percentage of total hits on each target area is calculated by dividing the number of hits for a target area by the sum of hits on all target areas within a session. Percentage of total hits was used as a metric for determining if there was a neutral trend, as defined by the stability criteria. Percentage of total hits also served as another method of determining effectiveness by comparing its average across a phase with the average percentage of total hits in the preceding baseline phase. Hits per minute is calculated with the time the subject spends in darkness removed from the denominator, as the time spent in darkness is the consumption time. This value serves to determine the effectiveness of each intervention.

Conduct of Session

Once the experimental tank was filled and its temperature matched the subject's home tank temperature, the subject was transferred to the experimental tank. It was then placed in the same position and direction in each session, and given 2 minutes to become accustomed to the experimental tank while in darkness. The VTS was started during this time. Once the session started the experimenter records by hand each time the subject swims into a target area. The VTS will also track how often the subject swims into each target area. When a session ended the subject was returned to its home tank. A video recording using a camcorder was supposed to be made of each session, however this did not occur due to various hardware and software errors.

Results

Reliability

Correlations were conducted between the number of hits for a corner as counted by the observer and the VTS. For Fish A $r = .77$; for Fish B $r = .71$; and when both datasets were combined $r = .75$, which is shown in Figure 3. At the beginning of the experiment the VTS had trouble tracking subjects when they were in the top half of the tank (near target area B and C). The correlation using only data prior to the recalibration was $r = .47$ for Fish A, $r = -.15$ for Fish B, and when both datasets are combined $r = .32$, which is shown in Figure 4. This problem was fixed by recalibrating the VTS. When data prior to recalibration were excluded, the correlation values increased to $r = .90$ for Fish A, $r = .95$ for Fish B, and when their data is combined $r = .92$, which is shown in Figure 5. All data was used in the calculations presented within this paper, as removing the data prior to recalibration would have removed four baseline sessions for Fish B as well as removing fifteen sessions from Fish A, including all sessions involving the 1-second and 10-second intervention phases. Calibration didn't have an effect on the reliability of

the reinforcer since Fish A had target area A as its reinforced corner. While Fish B had target area C as its reinforced corner, no intervention phases were conducted prior to recalibration.

Regression

Several regression models were applied to the data to determine the effects of potential covariables. The covariables included were the number of days since the start of the experiment, the time of day that the session started at, the temperature of the tank, the number of days since the prior session, and the duration of the reinforcer, with baseline being 0 seconds. These variables were compared to the total number of hits in a session as well the percentage of total hits for the reinforced corner for each subject, and the combined data of both subjects. Table 1 shows that days since the start of the experiment and reinforcement duration were significant predictors for the total hits for Fish A ($r = .42, p = .026$ and $r = -.82, p < .001$, respectively), while Table 2 shows that only reinforcement duration was the only significant predictor for total hits for Fish B ($r = -.78, p < .001$), although these results must be interpreted cautiously due to violations of some underlying statistical assumptions, as is the case for other tests of statistical significance reported in this thesis. When both subjects' data were combined, as shown in Table 3, reinforcement duration was the only significant predictor for total hits ($r = -.77, p < .001$). For predicting the percentage of total hits for the reinforced corner, no variable was a significant predictor for Fish A, as shown in Table 4. For Fish B, reinforcement duration is the only significant predictor, as shown in Table 5 ($r = .76, p < .001$). When both subject's data was combined, as shown in Table 6, reinforcement duration was still the only significant predictor ($r = .49, p < .001$).

Another set of regressions were conducted, this time using only baseline sessions to better determine the effects of other variables while controlling for reinforcement duration. The

predicted and predictor variables were the same as the previous set of regressions, minus reinforcement durations since all included cases had the same reinforcement duration (i.e. 0). No variable was a significant predictor for total hits for Fish A, as seen in Table 7. No variable was a significant predictor for total hits for Fish B, as seen in Table 8. When both datasets were combined no variables were significant predictors, as seen in Table 9. No variable was a significant predictor for percentage of total hits for Fish A, Fish B, or when both datasets were combined, as seen in Table 10, Table 11, and Table 12, respectively.

Correlation

Correlations were conducted between hits per minutes and the reinforcement duration, only using sessions from the intervention phases, as well as percentage of total hits and reinforcement duration, under the same constraints. When hits per minute was correlated with reinforcement duration, $r = .37$ for Fish A, $r = .24$ for Fish B, and $r = .07$ when both sets were combined. When percentage of total hits was correlated with reinforcement duration, $r = -.15$ for Fish A, $r = -.01$ for Fish B, and $r = .25$ when both sets were combined.

Visual Inspection

Looking at Figure 6 and Figure 7 we can see, in regards to Fish A, that the experimental phase with the largest average for hits per minute and percentage of total hits is the 20-seconds condition. Looking at Figure 8 we can see, in regards to Fish B, that the experimental phases with the largest average for hits per minute is the 60-seconds condition. Looking at Figure 9 we can see, in regards to Fish B, that all three experimental phases had a nearly identical effect on percentage of total hits. Figure 10 shows the average hits per minute of each intervention phase while controlling for the average hits per minute of its previous baseline phase's average for Fish A. The 20-second condition has the biggest increase in hits per minute, followed by the 40-

second condition, with the rest of the conditions having negative and/or negligible effects. Figure 11 shows a similar pattern, though it replaces the average hits per minute with the average percentage of total hits. The 20-second condition shows the largest increase in average percentage of total hits, with the 5-second and 40-second conditions showing a negligible increase in average percentage of total hits, and the 1-second and 10-second condition showing a decrease in average percentage of total hits. Figure 12 shows the average hits per minute of each intervention phase while controlling for the average of its previous baseline phase for Fish B. The 60-second condition has the biggest increase in hits per minute, followed by the 40-second and then 20-second condition. Figure 13 shows a similar pattern, though it replaces the average hits per minute with the average percentage of total hits. The 60-second condition still shows the largest increase, but the 20-second condition is the next highest, followed by the 40-second condition. Figure 14 shows the average hits per minute of each intervention phase for both subjects. The data seems to have a bell-curve shape, with the 20-second condition having the highest average hits per minute, even when using the average of both subject's averages in that condition. One potential problem with this comparison is that the average total hits during baseline sessions for Fish A was 368.78 while for Fish B it was 310.42. This difference also showed in how many hits per minute the reinforced corner was receiving on average during baseline sessions, with 3.05 for Fish A and 2.46 for Fish B. This means that Fish A hit 1.19 times more target areas. Figure 15 shows the average hits per minute of each intervention phase for both subjects once the difference in total hits being corrected for. The same bell-shape still occurs, with the 20-second condition having the highest results. Figure 16 shows the average percentage of total hits of each intervention phase for both subjects. The data seems to show a

slight increase in the average percentage of total hits as reinforcement durations get longer, though there is quite the difference between the averages for the 40-second conditions.

Percentage of Non-overlapping Data

Percentage of Non-overlapping Data (PND) is a metric used in single-subject research to determine effectiveness. PND was calculated by determining what percentage of treatment phase scores were higher than the highest baseline score. A series of PNDs were conducted on the hits per minute and percentage of total hits for both fish. PNDs were conducted comparing each intervention to its most recent baseline as well as all baselines. Table 13 shows the results as they relate to Fish A, Table 14 shows the results as they relate to Fish B. The 20-second and 60-second conditions show the highest PND scores in all categories, with the 40-second condition showing a noticeable decrease in PND in comparison.

Discussion

The data seems to point that 20 seconds of reinforcement seems to be the most effective. It out-performed all other conditions with the exception of the 60 seconds of reinforcement condition which was comparably effective in some measures. Due to the weaker and inconsistent results of the 40-second condition it's hard to say what type of relationship reinforcement duration has. The regression and correlation data indicate a small, positive, linear relationship; but with the inconsistencies of the 40-second intervention phase's results a quadratic or curvilinear relationship might fit better. Because of the likelihood of a non-linear relationship, 20 seconds of reinforcement may not be the highest point of the bell-curve in the relationship between reinforcement duration and response rate, as untested reinforcement durations might be more effective. However, this data should provide an effective starting point for those that would wish to look into other durations.

The number of days since the last session, the age of the fish, tank temperature, and the time of day that the session started were not shown to be significant factors on the rate of behavior. While one of the regressions showed that the number of days since the start of the experiment had a significant relationship when all data was used, this was likely due to the number of days since the start of the experiment co-varying with reinforcement duration. This result not appearing on the other subject (who did not have days since the start of the experiment co-varying with reinforcement duration), as well as the significant effect disappearing when only baseline data was used, points to this being the likely explanation. This is extremely helpful for future research as some of these variables are difficult or impossible to keep constant. From these results, future research is unlikely to require controlling for these variables.

It should be noted that there are some weaknesses within these regressions results, as the single subject design does not meet all the assumptions of the regression model, such as the independence of all scores, and the scores used within the regression model do not cover the entire range of possibilities for those variables. Days since the last session were primarily 1 or 2 days, with one exception of 13. It is unknown if this result would stay the same if the data points were more evenly distributed, or were to include even higher values. However, it is recommended that experimenters in Dr. Pear's Fish Lab run sessions five or more times a week, so these longer gaps between sessions should not be happening. Subjects were tested up until they were a couple months old (Fish A was tested from early February to the end of March while Fish B was tested from late February to the end of March), but lake sturgeons live for several decades and some behavior changes have been noted once they are over a year old. However, this age range falls within what is typical within the Fish Lab so labs similar to it will not have to worry about older subjects. The home tank temperature varied little (12.7 °C to 13.3 °C) so it is

unknown if other temperature values (that would still be safe for the subjects) would have an effect on behavior. However, these variations in temperature are normally controlled for as much as possible so the values tested should fall within a typical range for experimental tanks. Session start time only varied by a couple hours (10:13 to 14:39). Additionally, other experiments in lab have shown a dramatic decrease in behavior if subjects are tested near meal-times. Because of this the relationship between time and rate of behavior may be more curvilinear. However, the recommendations in the Fish Lab is to wait at least an hour after feeding before starting an experiment and to keep experiments within 2 hour window each day. Another way that time relates to satiation is that the home tank is kept in the dark from 19:00 to 7:00 each night, and when the lights are on there is a lid that blocks most of the light from entering the home tank. Testing during or closer to lights out may show different results. Any future experiments that follow these guidelines and stay within the typical ranges for these variables should not have to worry about mediating effects.

Two notable flaws with the data is that it was not completed and the problems with the inter-rater reliability. While every condition was covered between the two subjects, not every condition was covered by each subject. Additionally, subjects were not able to return to the best intervention phase in ABAB format, which would've further strengthened the results. While the data that was collected acted as an adequate stop-gap, it would have been preferable to collect everything first-hand. Inter-rater data was also lacking. No human-to-human data was collected due to certain mechanical problems, and it's recommended that at least 30% of trails have inter-rater data. All sessions had human-to-computer data, though it did not have the highest inter-rater scores early on. Once sessions before the camera system was recalibrated were removed the inter-rater reliability reached much more appropriate levels. Additionally, the nearly complete

darkness that was used as a reinforcer may not be the most effective reinforcer, as lake sturgeons are typically found at depths of 5 to 10 meters where roughly 50% of natural light is yet to be absorbed.

In summary, the results showed a small positive correlation between reinforcement duration and rate of responding, with the 20 seconds of reinforcement condition showing the most consistently high results. This study adds to the literature of the effect of reinforcement magnitude on responding, suggesting a direct relationship between reinforcement magnitude and response rate. It is not clear why a number of other studies on this problem have not also obtained this relationship. However, the present study offers a new methodology for addressing the problem, as well as providing new data on a little-studied species and reinforcer. It is also worth noting that the finding of 20 seconds of reinforcement appearing to potentially be an optimal duration of reinforcement may also merit looking into in future research.

The present results should also serve as the start to a handbook for future basic research in the fish operant behaviour lab used in the present study as well as other similar labs. By following the recommendations and data of this article, or expanding on it with similar research, researchers should be able to better optimize their basic research involving lake sturgeons and better determine the relationship between reinforcement duration and response rate.

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Tables

Table 1

Regression Results Using All Data for Fish A Total Hits

Variables	Unstandardized Coefficients		Standardized Coefficients		Sig.	Correlations		
	B	Std. Error	Beta	t		Zero- order	Partial	Part
(Constant)	1376.579	1394.312		.987	.332			
DSS	2.217	.923	.377	2.403	.023	-.206	.420	.246
Start Time	-6.445	11.019	-.062	-.585	.563	.091	-.112	-.060
Temp.	-77.430	108.470	-.096	-.714	.481	-.060	-.136	-.073
DSLS	8.193	4.676	.181	1.752	.091	.279	.320	.179
R-Duration	-7.383	.977	-.955	-7.556	.000	-.779	-.824	-.773

Note. DSS = days since the start of the experiment. Temp = Temperature, measured in Celsius.

DSLS = days since last session. R-Duration = reinforcement duration in seconds.

Table 2

Regression Results Using All Data for Fish B Total Hits

Variables	Unstandardized		Standardized			Correlations		
	Coefficients		Coefficients					
	B	Std. Error	Beta	t	Sig.	Zero-order	Partial	Part
(Constant)	913.518	3020.996		.302	.767			
DSS	-1.895	2.732	-.112	-.694	.498	-.201	-.176	-.107
Start Time	6.363	20.266	.050	.314	.758	.060	.081	.049
Temp.	-43.566	227.725	-.031	-.191	.851	.121	-.049	-.030
DSLS	-36.085	51.676	-.119	-.698	.496	.208	-.177	-.108
R-Duration	-4.359	.913	-.822	-4.775	.000	-.784	-.777	-.738

Note. DSS = days since the start of the experiment. Temp = Temperature, measured in Celsius.

DSLS = days since last session. R-Duration = reinforcement duration in seconds.

Table 3

Regression Results Using All Data for All Subjects Total Hits

Variables	Unstandardized		Standardized		Sig.	Correlations		
	Coefficients		Coefficients			Zero-	Partial	Part
	B	Std. Error	Beta	t		order		
(Constant)	840.257	1427.440		.589	.559			
DSS	.422	.925	.053	.456	.650	-.289	.066	.039
Start Time	1.365	10.801	.011	.126	.900	.076	.018	.011
Temp.	-41.988	110.455	-.040	-.380	.706	-.081	-.055	-.033
DSLS	8.856	5.971	.130	1.483	.145	.235	.209	.128
R-Duration	-5.003	.607	-.788	-8.242	.000	-.790	-.765	-.712

Note. DSS = days since the start of the experiment. Temp = Temperature, measured in Celsius.

DSLS = days since last session. R-Duration = reinforcement duration in seconds.

Table 4

Regression Results Using All Data for Fish A Percentage of Total Hits

Variables	Unstandardized		Standardized		Sig.	Correlations		
	Coefficients		Coefficients			Zero-	Partial	Part
	B	Std. Error	Beta	t		order		
(Constant)	-.285	.828		-.344	.735			
DSS	.001	.001	.453	1.376	.189	.452	.335	.309
Start Time	.002	.006	.072	.316	.757	.033	.081	.071
Temp.	.040	.064	.173	.613	.549	.378	.156	.138
DSLS	-.001	.002	-.066	-.282	.782	.022	-.073	-.063
R-Duration	-.001	.002	-.148	-.509	.618	.192	-.130	-.114

Note. DSS = days since the start of the experiment. Temp = Temperature, measured in Celsius.

DSLS = days since last session. R-Duration = reinforcement duration in seconds.

Table 5

Regression Results Using All Data for Fish B Percentage of Total Hits

Variables	Unstandardized		Standardized		Sig.	Correlations		
	Coefficients		Coefficients			Zero-	Partial	Part
	B	Std. Error	Beta	t		order		
(Constant)	.113	.940		.121	.906			
DSS	.002	.001	.271	1.790	.094	.377	.420	.260
Start Time	-.003	.006	-.076	-.512	.616	-.118	-.131	-.074
Temp.	.009	.071	.018	.122	.905	-.089	.031	.018
DSLS	-.001	.016	-.011	-.071	.944	-.335	-.018	-.010
R-Duration	.001	.000	.739	4.575	.000	.771	.763	.665

Note. DSS = days since the start of the experiment. Temp = Temperature, measured in Celsius.

DSLS = days since last session. R-Duration = reinforcement duration in seconds.

Table 6

Regression Results Using All Data for All Subjects Percentage of Total Hits

Variables	Unstandardized		Standardized		Sig.	Correlations		
	Coefficients		Coefficients			Zero-	Partial	Part
	B	Std. Error	Beta	t		order		
(Constant)	.881	.664		1.326	.191			
DSS	-2.585E-5	.000	-.010	-.060	.952	.115	-.009	-.007
Start Time	-.001	.005	-.033	-.268	.790	-.075	-.039	-.033
Temp.	-.047	.051	-.138	-.913	.366	-.096	-.131	-.112
DSLS	.001	.003	.066	.532	.597	-.007	.077	.065
R-Duration	.001	.000	.525	3.862	.000	.502	.487	.474

Note. DSS = days since the start of the experiment. Temp = Temperature, measured in Celsius.

DSLS = days since last session. R-Duration = reinforcement duration in seconds.

Table 7

Regression Results Using Baseline Data for Fish A Total Hits

Variables	Unstandardized Coefficients		Standardized Coefficients			Correlations		
	B	Std. Error	Beta	t	Sig.	Zero- order	Partial	Part
(Constant)	481.144	1837.461		.262	.798			
DSS	1.850	1.328	.494	1.394	.187	.470	.361	.338
Start Time	-5.320	17.060	-.080	-.312	.760	-.144	-.086	-.076
Temp.	-5.816	146.031	-.014	-.040	.969	.293	-.011	-.010
DSLS	-15.897	50.005	-.081	-.318	.756	.067	-.088	-.077

Note. DSS = days since the start of the experiment. Temp = Temperature, measured in Celsius.

DSLS = days since last session.

Table 8

Regression Results Using Baseline Data for Fish B Total Hits

Variables	Unstandardized		Standardized		Sig.	Correlations		
	Coefficients		Coefficients			Zero-	Partial	Part
	B	Std. Error	Beta	t		order		
(Constant)	980.361	3997.345		.245	.813			
DSS	3.084	4.731	.238	.652	.535	.147	.239	.225
Start Time	24.834	33.406	.268	.743	.481	.199	.271	.257
Temp.	-76.589	301.814	-.090	-.254	.807	-.023	-.095	-.088
DSLS	-53.362	65.729	-.285	-.812	.444	-.262	-.293	-.280

Note. DSS = days since the start of the experiment. Temp = Temperature, measured in Celsius.

DSLS = days since last session.

Table 9

Regression Results Using Baseline Data for All Subjects Total Hits

Variables	Unstandardized Coefficients		Standardized Coefficients			Correlations		
	B	Std. Error	Beta	t	Sig.	Zero-order	Partial	Part
(Constant)	1328.253	1815.973		.731	.471			
DSS	1.770	1.398	.326	1.266	.217	.143	.245	.239
Start Time	9.414	16.372	.112	.575	.570	.055	.114	.109
Temp.	-82.591	142.244	-.143	-.581	.567	.030	-.115	-.110
DSLS	-55.248	38.736	-.280	-1.426	.166	-.212	-.274	-.269

Note. DSS = days since the start of the experiment. Temp = Temperature, measured in Celsius.

DSLS = days since last session.

Table 10

Regression Results Using Baseline Data for Fish A Percentage of Total Hits

Variables	Unstandardized Coefficients		Standardized Coefficients			Correlations		
	B	Std. Error	Beta	t	Sig.	Zero- order	Partial	Part
(Constant)	1.440	1.064		1.353	.199			
DSS	4.342E-5	.001	.021	.056	.956	-.225	.016	.014
Start Time	.003	.010	.075	.278	.786	.020	.077	.071
Temp.	-.095	.085	-.408	-1.123	.282	-.358	-.297	-.287
DSLS	.014	.029	.127	.471	.645	.050	.130	.121

Note. DSS = days since the start of the experiment. Temp = Temperature, measured in Celsius.

DSLS = days since last session.

Table 11

Regression Results Using Baseline Data for Fish B Percentage of Total Hits

Variables	Unstandardized Coefficients		Standardized Coefficients		Sig.	Correlations		
	B	Std. Error	Beta	t		Zero-order	Partial	Part
(Constant)	.095	.702		.135	.897			
DSS	-4.499E-6	.001	-.002	-.005	.996	-.053	-.002	-.002
Start Time	.003	.006	.211	.552	.598	.211	.204	.202
Temp.	.008	.053	.053	.142	.891	.014	.054	.052
DSLS	.004	.012	.135	.365	.726	.133	.137	.133

Note. DSS = days since the start of the experiment. Temp = Temperature, measured in Celsius.

DSLS = days since last session.

Table 12

Regression Results Using Baseline Data for All Subjects Percentage of Total Hits

Variables	Unstandardized Coefficients		Standardized Coefficients		Sig.	Correlations		
	B	Std. Error	Beta	t		Zero-order	Partial	Part
(Constant)	.987	.648		1.523	.140			
DSS	.000	.000	-.092	-.361	.721	-.263	-.072	-.068
Start Time	.002	.006	.069	.356	.725	.075	.071	.067
Temp.	-.059	.051	-.282	-1.155	.259	-.330	-.225	-.216
DSLS	.005	.014	.066	.340	.737	.007	.068	.064

Note. DSS = days since the start of the experiment. Temp = Temperature, measured in Celsius.

DSLS = days since last session.

Table 13

Percentage of Non-overlapping Data Points for Fish A

Condition	Hits per Minute		Percentage of Total Hits	
	Previous	All	Previous	All
I-1	.33	.00	.00	.00
I-5	.00	.00	.67	.00
I-10	.67	.33	.33	.33
I-20	1.00	1.00	1.00	.67
I-40	.33	.33	.67	.00

Note. The number next to the “I-“ denotes the length of time in seconds of the reinforcer in the given intervention phase. Previous and All refer to if only the preceding baseline data was used, or if all baseline data was used.

Table 14

Percentage of Non-overlapping Data Points for Fish B

Condition	Hits per Minute		Percentage of Total Hits	
	Previous	All	Previous	All
I-20	.67	.33	1.00	1.00
I-40	.33	.33	.67	.67
I-60	.67	.67	1.00	1.00

Note. The number next to the “I-“ denotes the length of time in seconds of the reinforcer in the given intervention phase. Previous and All refer to if only the preceding baseline data was used, or if all baseline data was used.

Figures

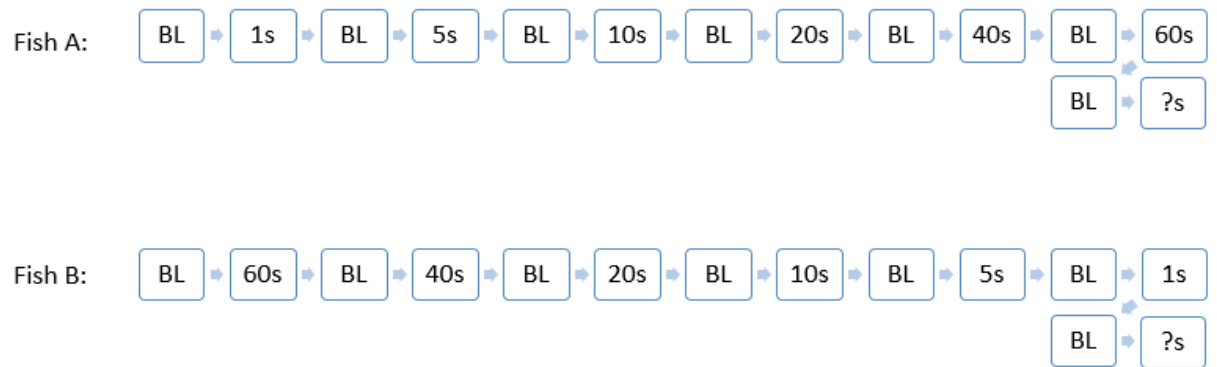


Figure 1. Planned order of phases for each subject and the length of reinforcement for each phase according to the original design. *BL* refers to baseline which was 0 seconds of darkness while ? refers to the phase which contained the duration of darkness that was found to be the most effective for that subject. All other phases denote the length of reinforcement in seconds.

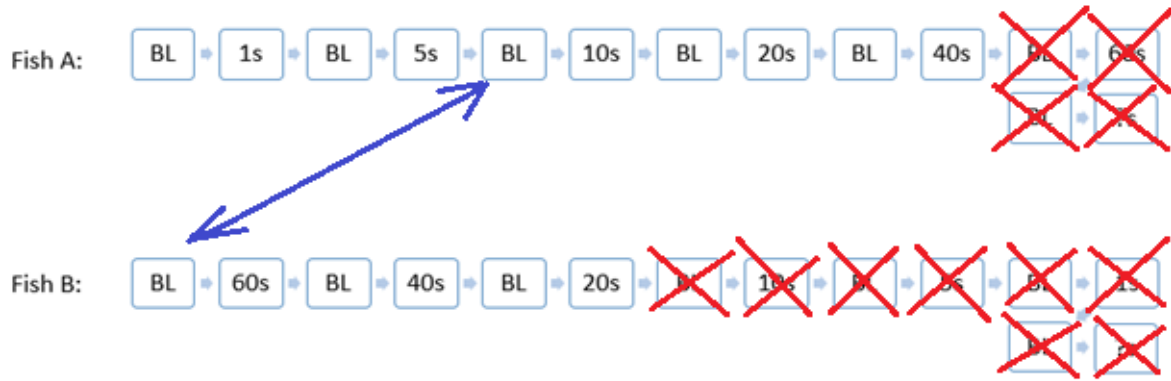


Figure 2. Order of phases for each subject that were completed. Phases that are crossed out were not completed. The double-headed arrow indicates phases that were started at the same time.



Figure 3. Comparing rater and VTS target area total number of hits scores for both subjects using all sessions.

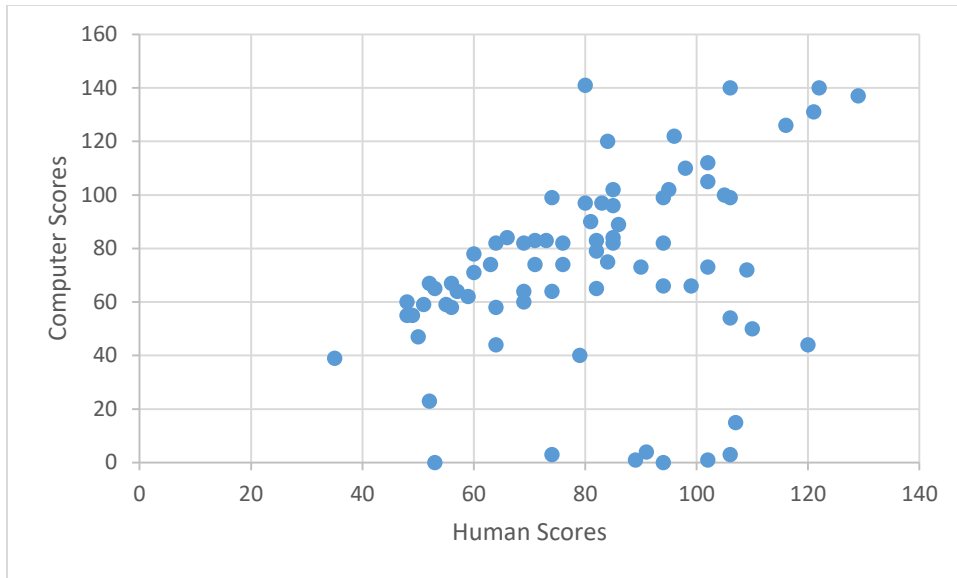


Figure 4. Comparing rater and VTS target area total number of hits scores for both subjects prior to recalibration.

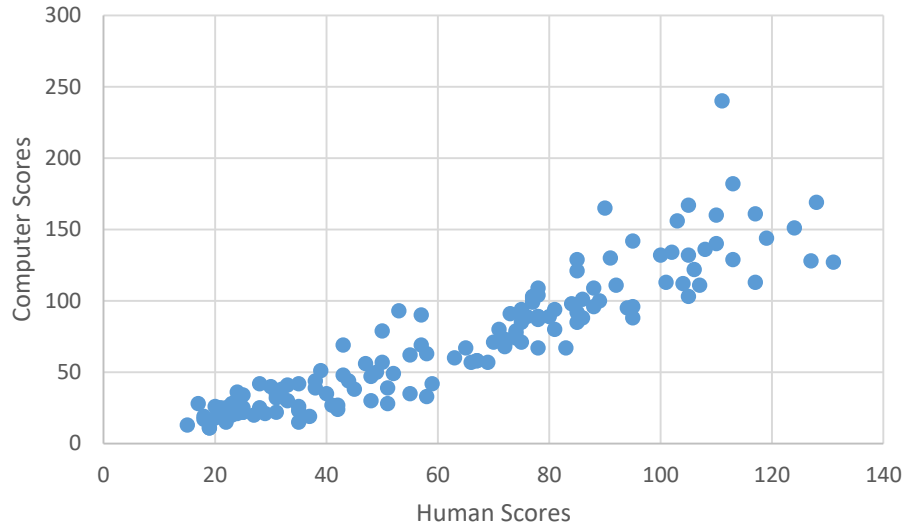


Figure 5. Comparing rater and VTS target area total number of hits scores for both subjects after recalibration.

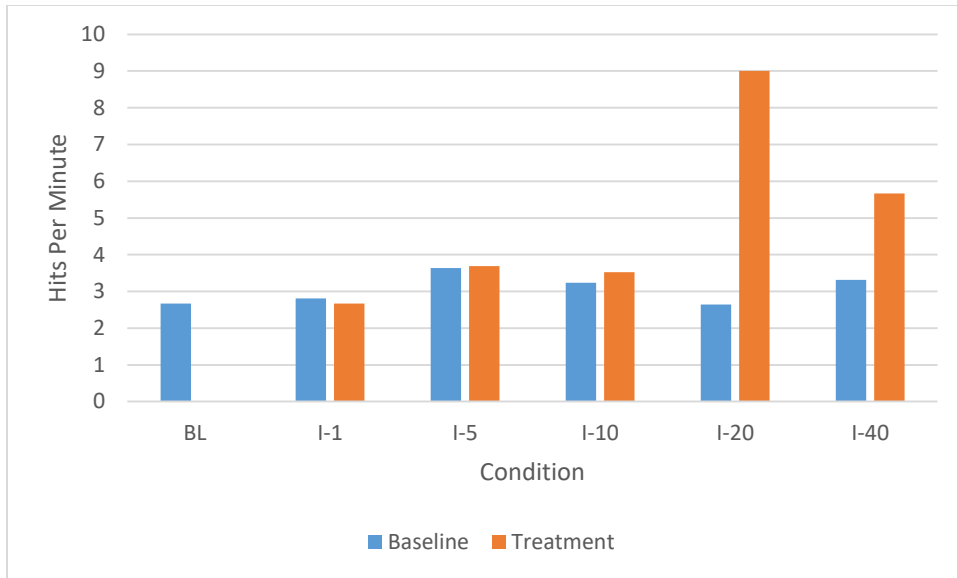


Figure 6. Hits per Minute of each phase for Fish A. “I-“ refers to the intervention phase with the following number as the length of the reinforcement duration during the treatment phase.

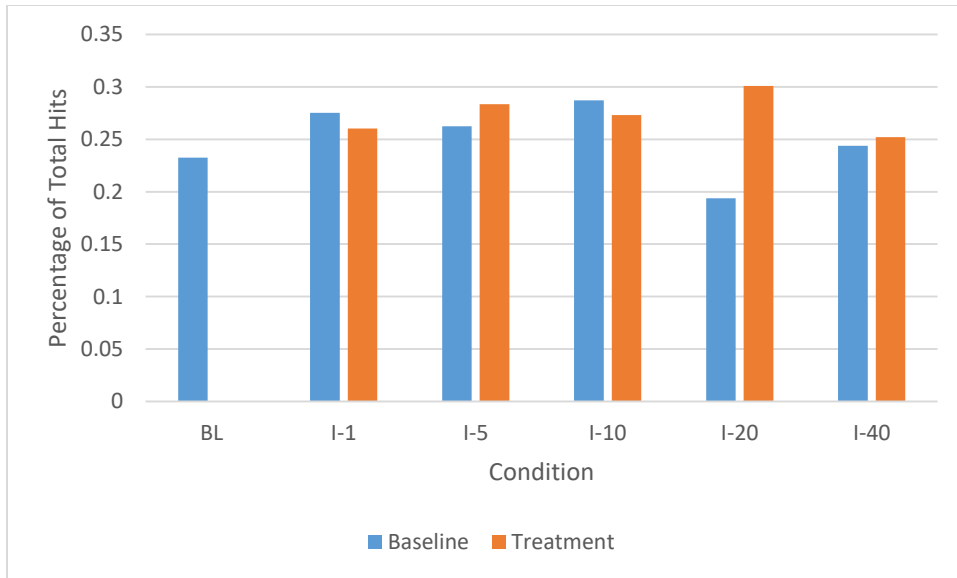


Figure 7. Percentage of Total Hits of each phase for Fish A. “I-“ refers to the intervention phase with the following number as the length of the reinforcement duration during the treatment phase.

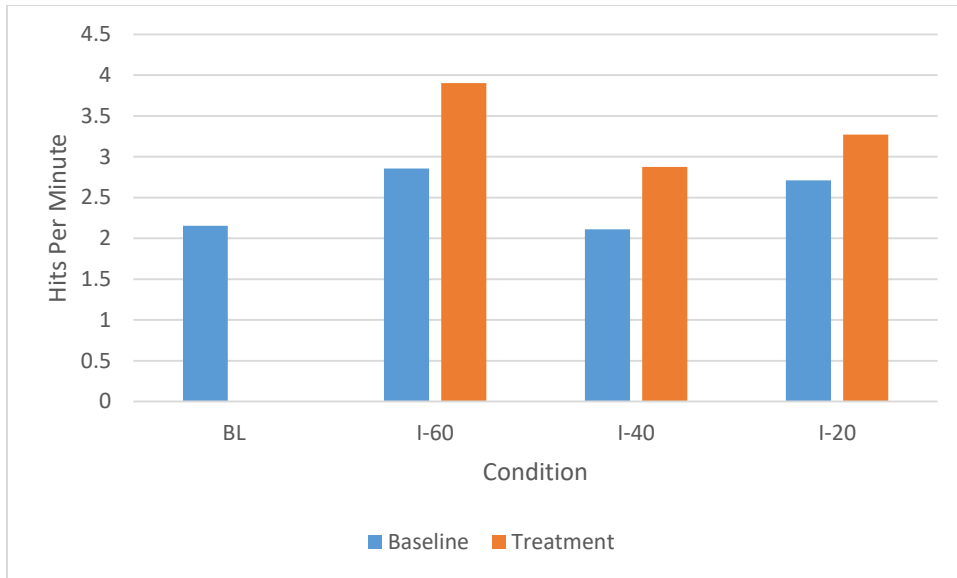


Figure 8. Hits per Minute of each phase for Fish B. “I-“ refers to the intervention phase with the following number as the length of the reinforcement duration during the treatment phase.

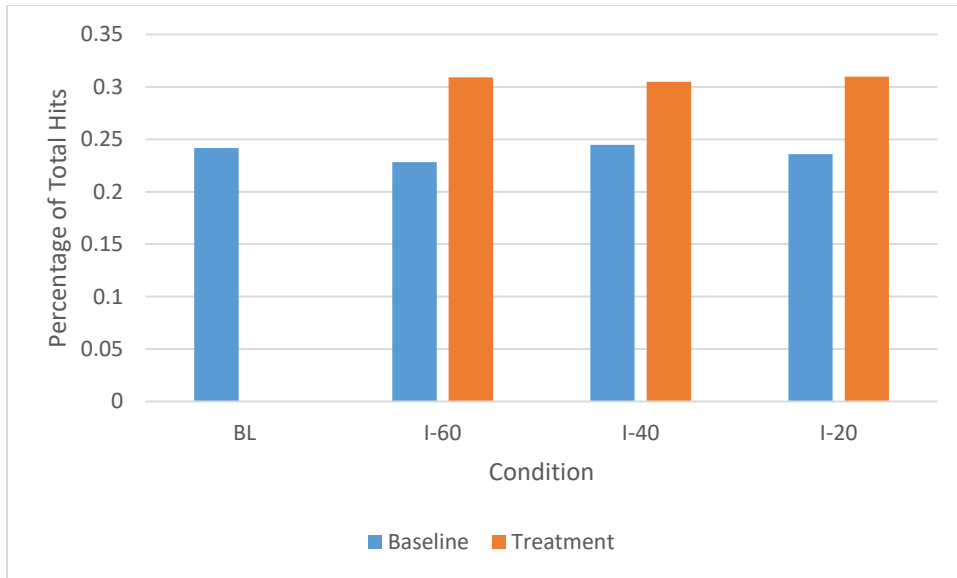


Figure 9. Percentage of Total Hits of each phase for Fish B. “I-“ refers to the intervention phase with the following number as the length of the reinforcement duration during the treatment phase.

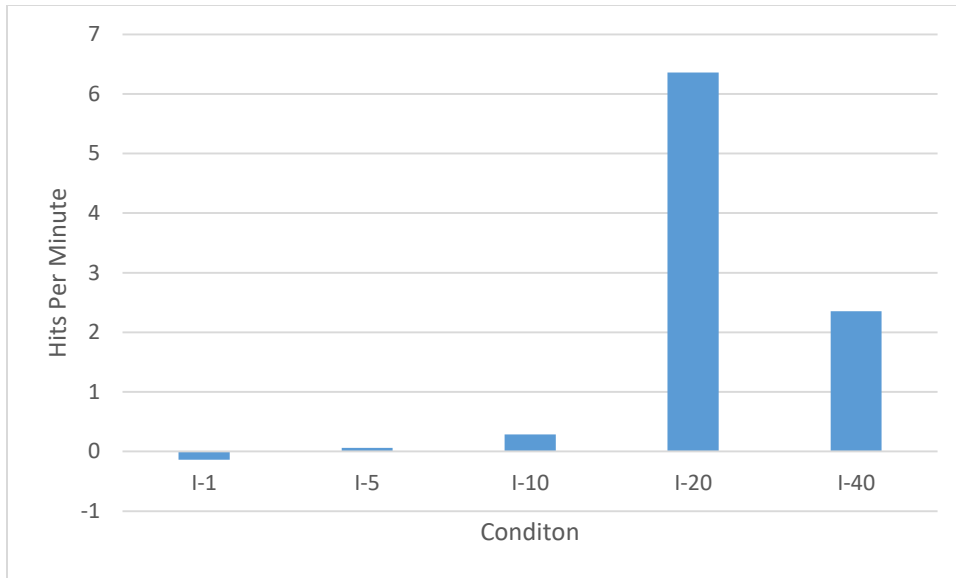


Figure 10. Hits per Minute of each intervention phase minus the Hits per Minute of its preceding baseline phase for Fish A. “I-“ refers to the intervention phase with the following number as the length of the reinforcement duration during the treatment phase.

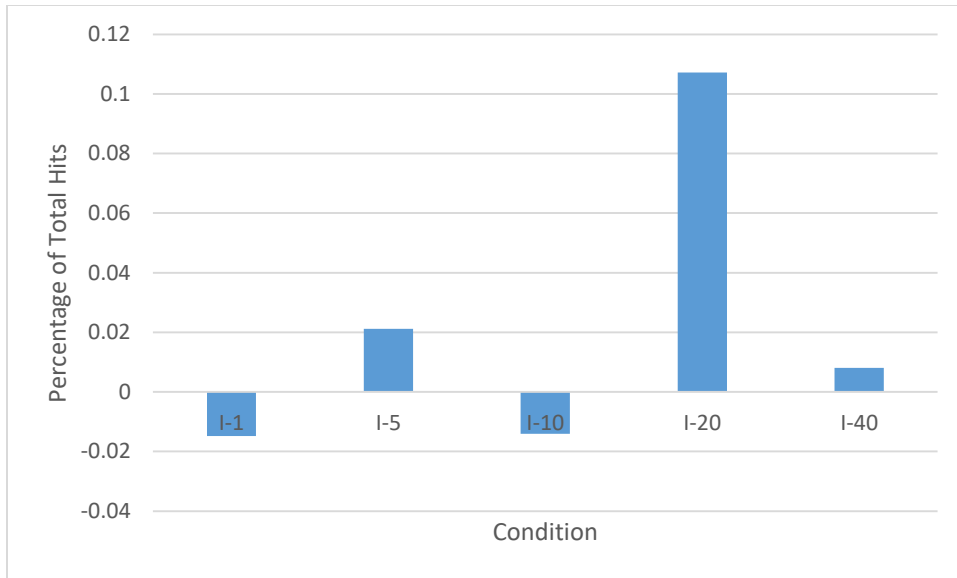


Figure 11. Percentage of Total Hits of each intervention phase minus the Percentage of Total Hits of its preceding baseline phase for Fish A. “I-“ refers to the intervention phase with the following number as the length of the reinforcement duration during the treatment phase.

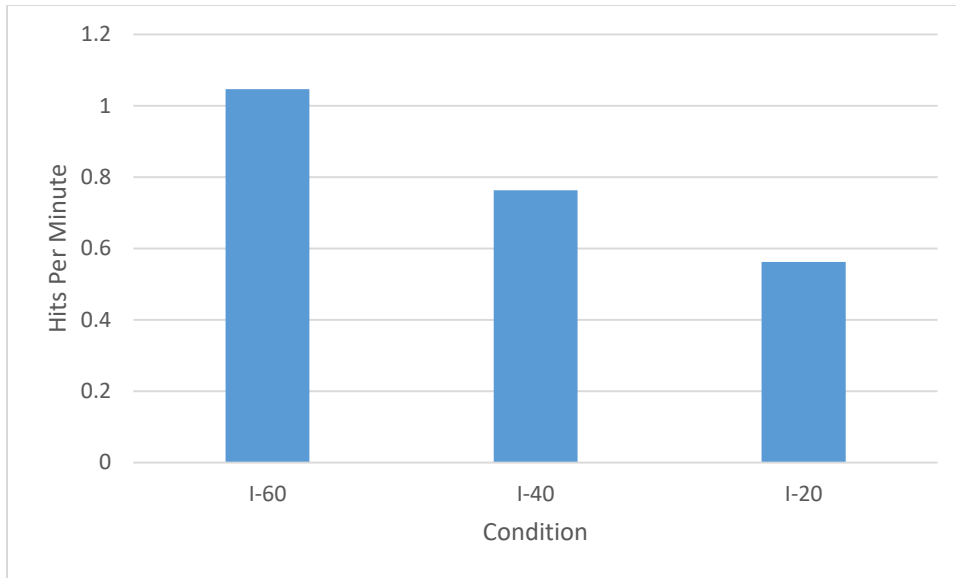


Figure 12. Hits per Minute of each intervention phase minus the Hits per Minute of its preceding baseline phase for Fish B. “I-“ refers to the intervention phase with the following number as the length of the reinforcement duration during the treatment phase.

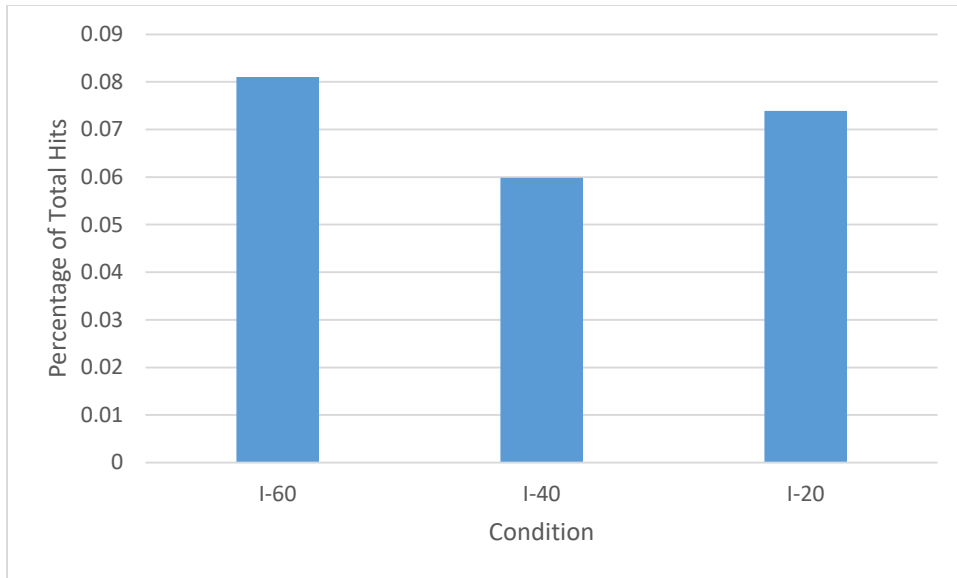


Figure 13. Percentage of Total Hits of each intervention phase minus the Percentage of Total Hits of its preceding baseline phase for Fish B. “I-“ refers to the intervention phase with the following number as the length of the reinforcement duration during the treatment phase.

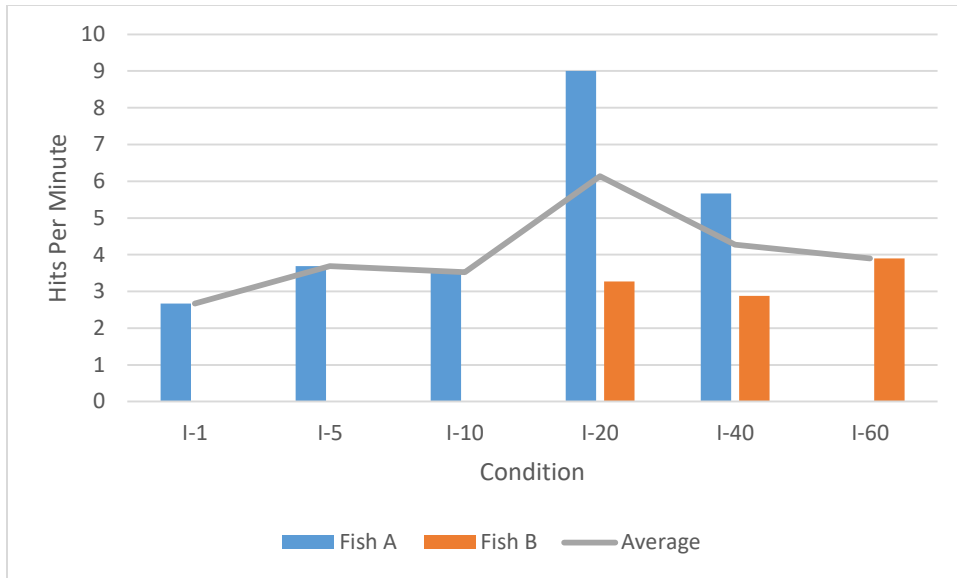


Figure 14. Hits per Minute of each phase comparing subjects. “I-“ refers to the intervention phase with the following number as the length of the reinforcement duration during the treatment phase.

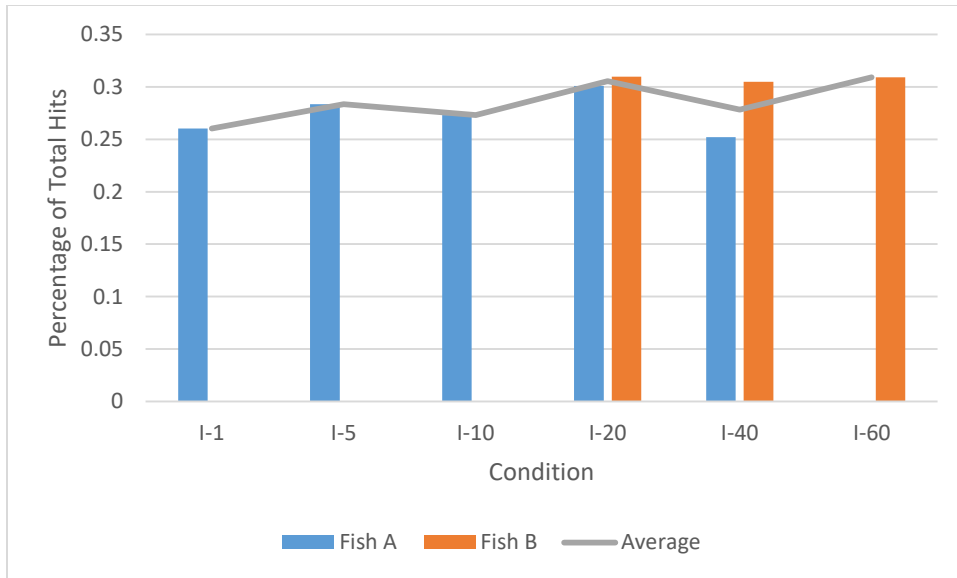


Figure 15. Percentage of Total Hits of each phase comparing subjects. “I-“ refers to the intervention phase with the following number as the length of the reinforcement duration during the treatment phase.

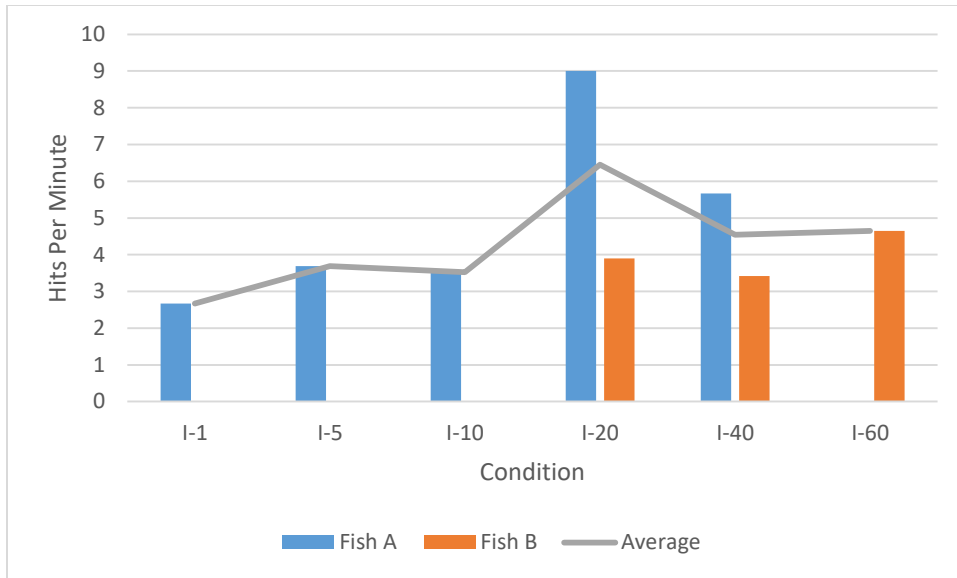


Figure 16. Hits per Minute of each phase comparing subjects while correcting for differences in total hits. “I-“ refers to the intervention phase with the following number as the length of the reinforcement duration during the treatment phase.