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The Effect of Training Context on Fixations Made During Visual Discriminations

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Abstract

The present research probed the relationship between the difficulty of initial training and the nature of the resulting strategic visual skills. Participants were trained to discriminate between polygons that varied in similarity and were then transferred to a novel stimulus set of similar polygons. Eye movements were recorded during both training and transfer, providing information about the acquisition and transfer of a strategic visual discrimination skill. The results suggest that training difficulty affects the processing strategies developed by participants: Participants trained on difficult stimuli initially allocated more fixations to higher complexity stimuli. These participants exhibited superior transfer performance, potentially because they learned to optimize their allocation of fixations. Participants trained on easy stimuli developed less optimal strategic skills and did not sufficiently modify these skills at transfer.

Keywords: Strategic Skill; Eye Movements; Visual Discrimination.

Introduction

In many real-life situations, people are asked to determine whether two objects are the "same as" or "different from" each other (just think about selecting a pair of dark socks that should be the same from a drawer full of "singles"). Clearly there is a strong influence of experience on discrimination skill: people improve with practice (e.g., Logan, 1988). At question here is the nature of the discrimination skill: how general or specific is it, and how does initial training difficulty impact its development?

Several theories of stimulus processing relevant to the theoretical question of interest have been advanced (e.g., Fisher & Tanner, 1992; Haider & Frensch, 1996; Logan, 1988). In Logan's view, stimuli must be processed algorithmically when initially encountered, but as the number of exposures to specific stimuli increase, the processing gives way to direct retrieval of a response. Thus, Logan would predict a stimulus-specific improvement in performance over time, but would not predict initial training to impact the processing of novel stimuli. Haider and Frensch, on the other hand, postulate an improvement in performance that is not tied to the specific stimuli, but rather to the strategy used for processing stimuli in general. Their *information reduction hypothesis* states that people learn through practice to eliminate redundant comparisons during task performance. If this were true, then initial training leading to the development of optimal strategies would lead to superior transfer performance.

The current research builds on the work of Doane and colleagues (Doane, Alderton, Sohn, & Pelligrino, 1996; Doane, Sohn, & Schreiber, 1999), which showed that visual discrimination skills consisted of both stimulus-specific and strategic processing elements. Doane et al. (1999) trained participants to discriminate between polygons that varied in similarity and complexity. Some of the participants were initially trained to discriminate between very similar polygons (difficult training), while others were initially trained to discriminate between dissimilar polygons (easy training). After completing 960 training trials, both training groups were transferred to another stimulus set, and had to make discriminations between very similar novel polygons. Participants trained to make difficult discriminations were more accurate at discriminating between novel polygons, and their advantage lasted for at least 1900 more trials.

In effect, Doane et al.'s (1996; 1999) difficult training group learned to use a superior processing strategy that they were able to transfer to the novel stimuli. The results supported the information reduction hypothesis, but differences in processing strategies across training groups could only be inferred by transfer performance. The information reduction hypothesis would be further supported by finding evidence for differences in processing strategies used by the two training groups. For example, Doane et al. have suggested that participants trained in the difficult condition learn to use a *point-by-point comparison strategy*. Such a strategy would involve making successive comparisons between individual corresponding features on each of the to-be-compared stimuli, terminating either when a difference was found or when no features remained to be compared (Fisher & Tanner, 1992). As the stimuli are learned through repeated exposure, this point-by-point comparison strategy should become more refined, focusing only on points that change between the standards and the comparison polygons.

Alternatively, Doane et al. (1996; 1999) suggested that participants trained in the easy condition develop an *unconstrained and early terminating feature search*. This would mean the participants select a random subset of possible features for comparison. Thus, a participant using an unconstrained and early terminating feature search would be likely to examine multiple points during any given trial to determine if differences between stimuli exist at the selected locations. “Different” judgments would require fewer fixations overall because the search would terminate when a difference was discovered. This pattern is similar to the point-by-point comparison strategy, but no specific points would receive more attention over time, nor would all points be examined in the case of “same” judgments. If the participants carried this strategy over to the transfer session, they would continue to sample points for comparison but would be less likely to effectively identify and rely on diagnostic points.

Because of the nature of the visual discrimination task (comparing individual features or global shapes of multiple stimuli), fixations should follow shifts in attention, and thus visual processing should be observable through eye movement recording. Thus, this research used the same basic methodology as Doane et al. (1999, Exp. 2) for the visual discrimination task, but with additional eye-movement measures including number of fixations and dwell time in order to better understand the processes involved in learning a visual discrimination strategy. If differences in eye movements consistent with Doane et al’s predictions are discovered, the information reduction hypothesis would be more strongly supported.

Method

Participants

Seventy-one students from the undergraduate population of Mississippi State University were paid for their participation. Participants were randomly assigned to one of two training groups: *difficult training*, involving difficult same/different judgments between similar stimuli, or *easy training*, involving same/different judgments between dissimilar stimuli. After the training session, all participants were transferred to a discrimination task involving a novel set of similar (i.e., difficult) stimuli. Data from 7 participants were excluded from analyses because of relatively poor accuracy (below 80%) during the training session. Additionally, 7 participants were excluded from the eye movement analyses due to problems with equipment calibration.

Apparatus and Materials

The experiment was conducted using a Dell personal computer with a 43.2 cm (17 in.) monitor at a viewing distance of 65 cm. Figure 1 gives an example of a trial. Each set of polygons includes a standard polygon on the left, paired either with itself or with one of three other polygons of varying similarity to the standard on the right. Polygons averaged 4.7 cm x 5.0 cm (4.1^o x 4.4^o), with a 2.4 cm (2.1^o) separation between them.

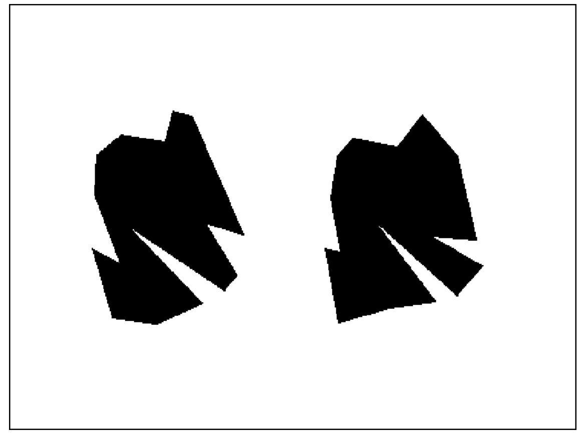

Figure 1. Sample “easy” visual discrimination trial.

The stimulus sets used for this experiment each contained 35 polygons divided into five complexity levels, with 7 polygons per complexity level. The complexity level of the polygons was based on the number of unique points used to create the polygon, ranging from 6 to 20 (see Figure 2). The seven polygons within a complexity level differed by varying degrees, so that a D1 polygon was similar to the standard polygon (S) on the left, whereas a D6 polygon was quite different. These polygons were then grouped into sets of 20: a “difficult” similarity set, consisting of D1-D3 polygons and the standard (S) polygons; and an “easy” similarity set, consisting of D4-D6 polygons and the standard (S) polygons. Because the transfer session included only “difficult,” similar stimuli, only the standards and D1-D3 polygons from the second stimulus set were used (see Figure 3).

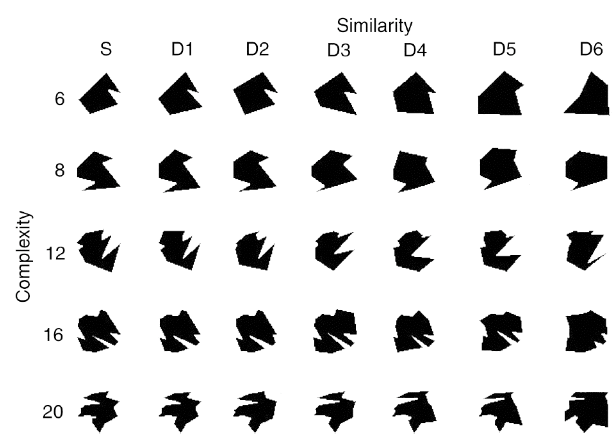

Figure 2. Doane and Liu polygon stimulus set, ordered by similarity (left-to-right) and complexity (top-to-bottom). Adapted from Doane et al. (1996).

Eye movements were recorded with an ASL Series 5000 oculometer, including a Series 501 (Ascension Flock of Birds) magnetic head tracker to compensate for head movements. Eye movements were recorded at a rate of 60

Hz. Eye movements, latency, and accuracy information were synchronized to a time stamp from the system clock to permit data analysis.

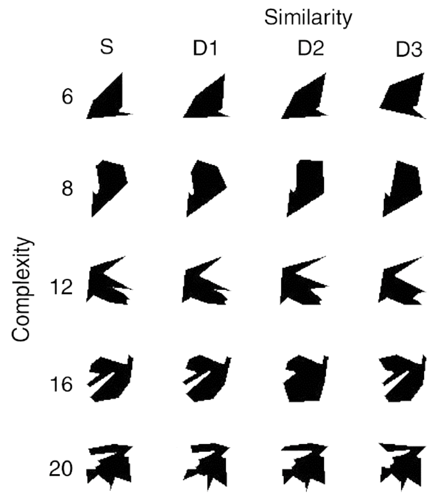

Figure 3. Cooper polygon stimulus set, ordered by similarity (left-to-right) and complexity (top-to-bottom). Adapted from Cooper and Podgorny (1976).

Procedure

The experiment was divided into two sessions of visual discrimination trials. Each session was divided into 8 blocks, for a total of 16 blocks. On each trial, two images were presented on the screen and participants were asked to indicate (via a key press) if the images were the same or different. Accuracy and latency were recorded for each trial, as were the eye fixations made by the participants.

In this experiment, a *same judgment* consisted of a standard compared to itself, and a *different judgment* consisted of a standard compared to one of the D1-D6 comparison images. During the first session, participants were assigned to one of two training groups: difficult or easy training. During their second session, participants switched to a novel stimulus set and made difficult discriminations.

Results

The purpose of this experiment was to examine the nature of the strategies developed by participants trained to make either difficult or easy visual discriminations. Because the difficult group was asked to initially discriminate among highly similar stimuli, it was hypothesized that this group would develop a point-by-point comparison strategy. If this were the case, the number of fixations made by the difficult group should be high early in training and transfer (particularly for more complex stimuli), and decrease over each session once diagnostic points had been identified. The easy group, by contrast, was expected to develop an early terminating feature search strategy. This strategy would lead to fewer overall fixations with little decline across experimental blocks as no diagnostic points would be specifically identified. Although the primary focus of this research was on examining the nature of the strategies developed, it is important to demonstrate that the basic effects found by Doane et al. (1999) were replicated. Thus, the first analyses presented will demonstrate the effect of initial training on transfer performance. The eye movement data will then be discussed in detail.

Latency and Accuracy

Latency for Same Judgments Our primary dependent variable in assessing transfer is accuracy, but it is important to consider latency differences as well. Figure 4 shows the group mean latencies for correct same judgments during the 16 blocks of trials. Recall that the "same" judgment stimuli were identical for the two training groups throughout the experiment. During the training session, the difficult training group took significantly longer to make same judgments than did the easy training group. The latency differences were reduced during the transfer session, and significant group differences were no longer present. Same-discrimination latencies increased in both groups when they transferred to making novel difficult discriminations. To examine group differences in same-judgment latencies, an analysis of variance (ANOVA) was performed on the mean latencies, with training group (difficult vs. easy) as a between-participant variable, and block (1-8), session (training and transfer), and stimulus complexity (6, 8, 12, 16, 20 points) as within-participant variables. Consistent with Figure 4, significant effects of training group, block, and a training group × session interaction were obtained: $F(1, 60) = 11.21$, $MSE = 51.63$, $p < .01$; $F(7, 420) = 67.82$, $MSE = 1.13$, $p < .01$; and $F(1, 60) = 21.66$, $MSE = 9.27$, $p < .01$, respectively.

Latency for Different Judgments Figure 5 shows the group mean latencies for correct "different" discrimination judgments as a function of trial block. As expected, the difficult training group took longer to make high-similarity (D1-D3) discriminations than the easy training group took to make low-similarity (D4-D6) discriminations during the training session, but this difference was absent when both groups viewed the same high-similarity polygons during the transfer session. An ANOVA was performed on the mean latencies for the transfer session, with training group (difficult vs. easy) as a between-participant variable, and stimulus complexity (6, 8, 12, 16, 20), and block (1-8) as within-participant variables. This analysis was limited to the transfer session because of the differing similarity levels of different judgments during training (similar polygons for the difficult training group compared to dissimilar polygons for the easy training group). At transfer, the latencies for the two groups were not significantly different. Both groups' latencies did decrease with practice, $F(7, 406) = 80.64$, $MSE = 0.40$, $p < .01$.

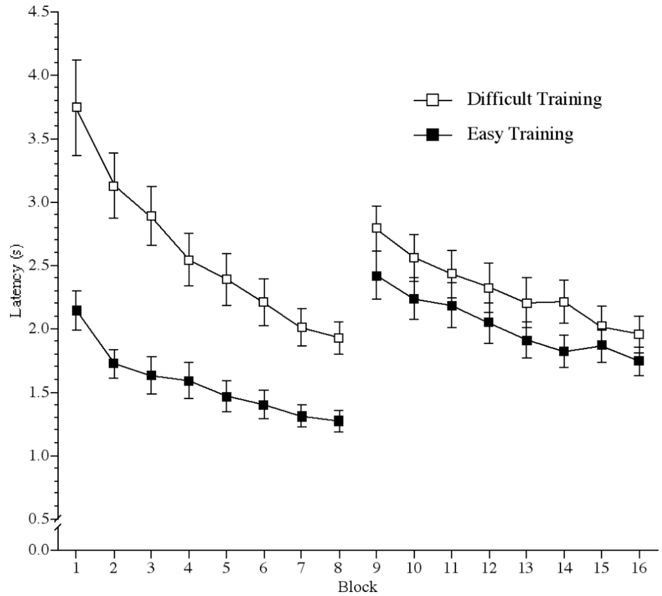

Figure 4. Latency (seconds) means and standard errors for correct "same" discrimination judgments as a function of blocks of trials.

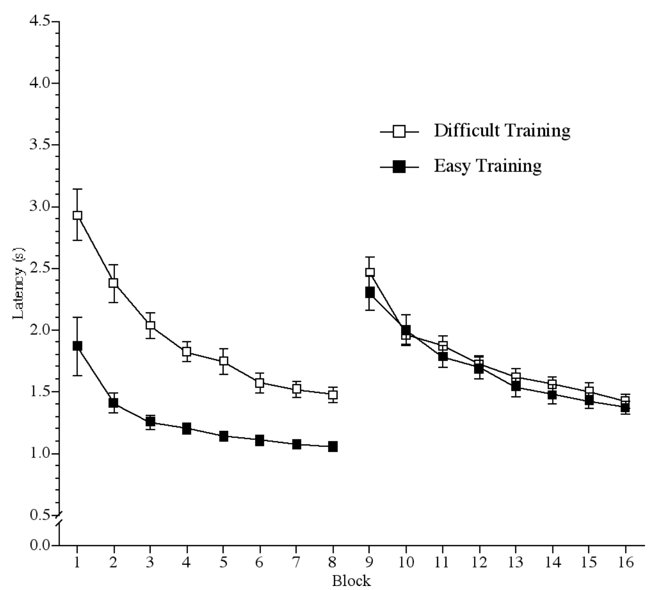

Figure 5. Latency (seconds) means and standard errors for correct "different" discrimination judgments as a function of blocks of trials.

Accuracy for Different Judgments Although accuracy for same judgments was near 100% for both groups across all blocks of the experiment, different judgment accuracy differed across blocks and groups. Figure 6 shows the group mean accuracy for different judgments as a function of practice. In the training session, the easy training group had higher overall accuracy scores, while at transfer, the difficult training group had higher overall accuracy scores. An ANOVA was performed on group mean accuracy data for different judgments in the transfer session, with training group (difficult vs. easy), block (9-16), and discrimination difficulty (D1-D3) as variables. The accuracy results reflect the significant impact of initial discrimination difficulty (i.e., superiority of the difficult training group) on transfer performance, F (1, 62) = 4.80, MSE = 0.50, p < .05. Accuracy for both groups declined as discrimination difficulty increased, F (2, 124) = 86.48, MSE = 0.05, p < .01, and both groups improved with practice, F (7, 434) = 27.58, MSE = 0.01, p < .01.

Eye Movements

Previous research provides indirect evidence for the effects of training difficulty on strategic skill acquisition and transfer (Doane et al., 1996; 1999). This research has replicated those findings, showing that participants trained to discriminate between very similar stimuli were more accurate when transferred to a novel stimulus set. Of interest in the current research is the nature of the acquired strategic skill. For these analyses, only same judgments will be discussed, both for brevity and because all groups saw identical same judgments throughout all blocks of the experiment.

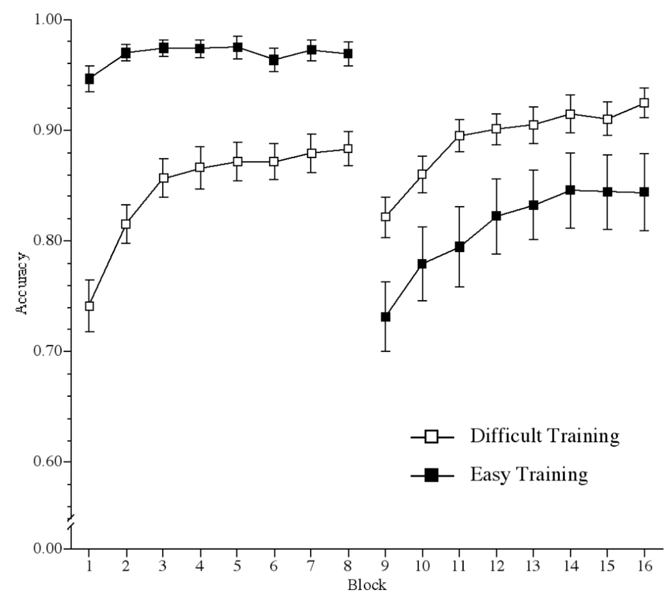

Figure 6. Accuracy means and standard errors for "different" discrimination judgments as a function of blocks of trials.

Number of Fixations for Same Judgments If the two training groups used the strategies hypothesized in the current research, then the difficult training group should have a higher number of fixations early in training in comparison to the easy training group. Figure 7 shows that the groups indeed followed the expected pattern. The difficult group had more fixations during training, F (1, 54) = 14.46, MSE = 20.12, p < .01. Interestingly, the transfer session shows no group differences for number of fixations, but considering the accuracy and latency data, the two groups must still be processing the stimuli differently.

If the two groups used the predicted strategies, the difficult training group should also have made a greater number of fixations as stimulus complexity increased. That is, with more points to examine, a point-by-point strategy would take more comparisons to lead to a decision. On the other hand, an unconstrained and early terminating feature search strategy would not be as likely to lead to a greater number of fixations as complexity increased.

In Figure 8, complexity slopes relating stimulus complexity to number of fixations are graphed as a function of trial block for the two groups. By the second block of training, the difficult group has higher complexity slopes than the easy training group, consistent with the hypothesized strategies, $F(1, 60) = 4.58$, $MSE = 0.07$, $p < .05$. Later in training, the slopes relating complexity and number of fixations did not differ significantly between the two groups because of the dramatic decrease in the difficult training group's fixation slopes, $F(7, 420) = 3.28$, $MSE = 0.03$, $p < .05$. This is consistent with the difficult group identifying diagnostic points on the polygons and narrowing their focus to those points.

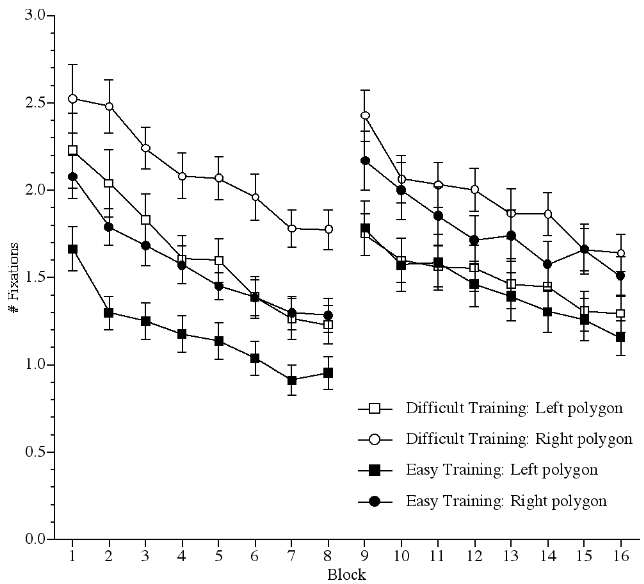

Figure 7. Means and standard errors for number of fixations per trial for correct "same" discrimination judgments as a function of blocks of trials.

During transfer, the two groups had similar fixation slopes except with regard to which polygon (left vs. right) received the greater number of fixations related to complexity. Recall that the left side polygon was always the standard, but the right side could be either a standard or a D1-D3 polygon. An ANOVA was performed on same-judgment mean complexity slopes for the transfer session, with training group (difficult vs. easy) as the between-participants variable, and block (9-16) and polygon (left vs. right) as within-participant variables. An interaction of training group × polygon was found, $F(1, 57) = 5.51$, $MSE = 0.02$, $p < .05$, indicating that the easy group attempted to modify its strategy at transfer, but failed to concentrate on the more diagnostic right-side polygon.

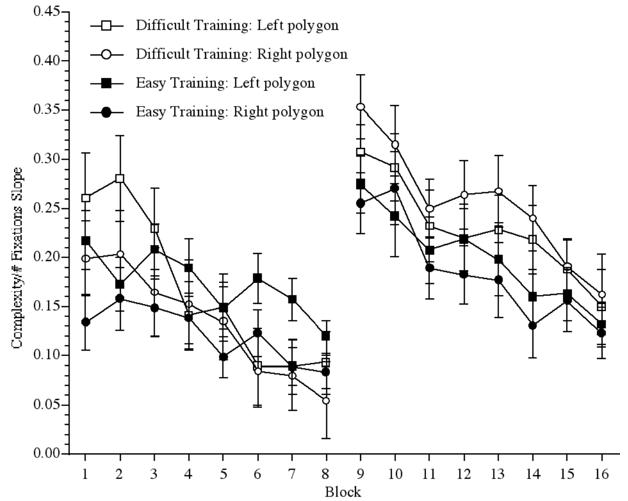

Figure 8. Regression slopes relating complexity and number of fixations for correct "same" discrimination judgments.

Dwell Times for Same Judgments Information about the strategic skills used by the two training groups is also available by comparing the dwell time results. If all fixations are equally important in providing information about the polygons to the participants, then there should be little difference in the overall dwell times across fixations. On the other hand, if longer fixations occur in areas that are considered more informative or relevant for discrimination, then a greater range of dwell times is expected. More processing would be expected to occur when fixating on relevant areas versus other areas. Less relevant areas may be fixated for confirmatory purposes or for cuing memory retrieval of previously acquired formation.

Figure 9 shows the group means and standard errors for the difference between dwell time maxima and dwell time means. ANOVAs were performed to compare the variability of dwell times during same judgments for training and transfer sessions. Variability of dwell times was defined as the difference between the maximum dwell time and the mean dwell time for each trial averaged over a block. For each of these analyses, training group was the between-participants variable, with complexity (6, 8, 12, 16, 20) and block (1-8 or 9-16) as the within-participant variables. The ANOVAs revealed a main effect for training group, $F(1, 55) = 11.14$, $MSE = 1074804.27$, $p < .01$, for the training session, and $F(1, 57) = 6.60$, $MSE = 861779.85$, $p < .05$ for the transfer session. The difficult training group had a greater difference between the maximum dwell time and the mean dwell time for same judgments during both sessions, potentially indicating a greater distinction in processing between areas that were considered relevant and those that were less informative. The easy training group participants had less variability in their dwell times, supporting the conclusion that these participants were more likely to treat all fixations as similarly informative.

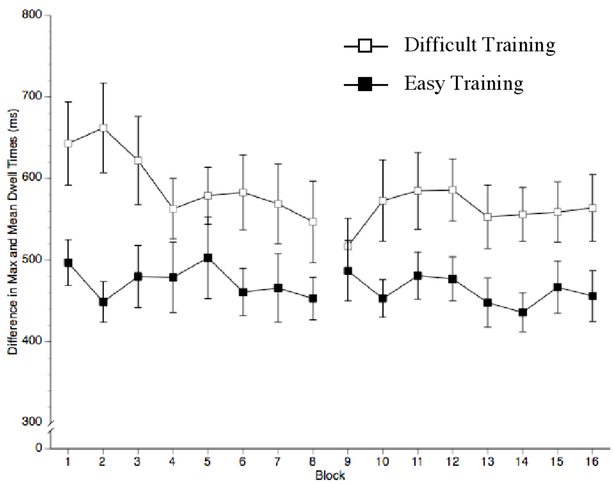

Figure 9. Mean differences between dwell time maxima and means, in milliseconds, for correct "same" judgments by block.

Discussion

Overall, the results indicate that the two groups, difficult training and easy training, developed different strategic skills due to initial training difficulty. Evidence for processing differences was found in the indirect measures of accuracy and latency, as well as in the direct measures of eye movements. The strategic skill acquired by the difficult training group involved more attention to specific features and required more individual comparisons per trial, than the skill acquired by the easy training group, which supports Doane et al.'s (1999) findings.

From the analysis of the eye movement data, several differences were found in how the two training groups processed information about the stimuli. Although the differences in the different training contexts were expected, the differences in the transfer context, when both groups discriminated among the same polygons, were more intriguing: the differences between the two training groups during transfer are not based in general eye movement patterns, reflected in the overall mean number of fixations, but in more sophisticated levels of processing, such as the attention paid to the differing complexity levels.

The present findings support previous information-reduction research findings (e.g., Doane et al., 1999; Haider & Frensch, 1999). One interpretation of the pattern of eye movement data is that the difficult training group developed a more fine-tuned strategic skill, providing more information about the polygons (particularly those of higher complexity) than did the more general skill of the easy training group. Because participants in the difficult training group processed more information to reach accurate discrimination judgments, they may have gained more sensitivity to specific diagnostic areas. The skill acquired due to initially difficult training could be applied to processing the novel stimuli during transfer. This led to increased accuracy, decreased latency, and positive transfer into the transfer session, as the relevant information found in the similarity and complexity of the polygons was recognized more quickly.

The current results support and expand the previous claims of Doane and colleagues (Cross & Doane, 2002; Doane et al., 1996; Doane et al., 1999) that initial training difficulty is an important aspect in optimizing transfer to similar tasks. When a training task is too easy in comparison to the transfer task, the acquired processing skill leads to less efficient parsing of available cues. Regardless of the precise origin of the processing differences, the persistence of the previously learned strategic skill, even after the more difficult task is recognized, should serve as a warning against overly easy training to those in fields where efficient visual processing is integral to performance (e.g., airport baggage screening, air traffic control).

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