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Training and Transfer of Strategic Aircraft Discrimination Skills

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We conducted two experiments to examine the effect of initial training difficulty on the acquisition and transfer of strategic aircraft discrimination skills. Participants were trained to discriminate between similar (difficult training) or dissimilar (easy training) aircraft stimuli and then transferred to discriminate between novel aircraft stimuli. In Experiment 1, participants discriminated between airplanes at the same difficulty level (easy or difficult) at training, but the different airplane set was used at transfer. In Experiment 2, participants trained with either easy or difficult discriminations between airplanes were transferred to difficult discriminations between novel airplanes. The results suggest that initial training difficulty influences strategic skill acquisition and that strategic skills are applied at transfer to a novel set of airplanes. The implications of this research are discussed in the context of training air force pilots.

key words : aircraft discrimination, pilot training, transfer of skill, strategic skill acquisition

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Visual discrimination between aircraft is an important skill for air force fighter pilots. As an example, consider the following scenario: Two enemy aircraft have engaged two Korean air force jet fighters in air to air combat. A third Korean fighter pilot sent to assist his colleagues is told that the enemy aircraft are quite similar, yet still distinguishable from each other, whereas the Korean aircraft are identical. The pilot is given direct orders to fire if two different aircraft are observed flying side by side, but to hold fire if the two observed aircraft are identical. In this illustration, the pilot has to determine whether two approaching aircraft are the same or different. Deadly consequences would result from an error of judgment in this instance. Although this is a contrived scenario, specific cases have been reported in which a pilot's inability to make a friend-foe discrimination has resulted in tragedy. In fact, an F-15 fighter pilots' inability to differentiate two American UH-60 Blackhawk helicopters from Iraqi Mi-24 Hind helicopters was a contributory cause to a fratricide incident in 1994 (Muradian & Watkins, 1994; Thompson, 1995). When the F-15's automated friend-foe identification system failed to identify the helicopters as "friendly," the pilots flew closer to visually confirm their targets. The pilots subsequently misidentified the aircraft and fired two missiles, killing all the 26 soldiers aboard (Muradian & Watkins. 1994). Clearly there is a need to develop training procedures that maximize visual discrimination speed and accuracy in such critical cases.

Although the U.S. military's top weapon systems are equipped with technology that can detect air targets beyond the human's visual range, today's warriors can still expect to fight in an environment in which unaided visual identification is required. Furthermore, when modern identification systems are not available, the soldiers' perceptual skills must be sufficiently developed to make a discernible response. The WEFT method (i.e., wings, engine[s], fuselage, and tail; Field Manual 44-80) is often used to achieve an adequate level of perceptual skill necessary for identifying one aircraft from another. This method emphasizes the aircraft's features that can be seen from a distance; aircraft features such as speed, ceiling, and armament are not considered during recognition training. In conjunction with the WEFT method, enemy aircraft silhouettes are often paired for comparison based upon the degree of similarity between aircraft, their type, and primary role, or simply to contrast new silhouettes with those previously learned. The WEFT method and paired comparisons lay the groundwork for soldier and pilots to improve their visual identification skills. Yet, mistaken identities continue to plague the military; "friendly" fire casualties during Desert Storm were 10 times higher than during any other 19th-century conflict (van Voorst, 1991), and "friendly" fire during the war on terrorism has already claimed the lives of Britons, Canadians, Afghan civilians, and Americans.

To adequately prepare pilots for combat and reduce the number of "friendly" fire incidents, training procedures must be developed that equip today's soldiers with visual skills that apply both to the specific aircraft viewed during training and to novel aircraft that may be encountered during combat. The goal of this research is to examine the extent to which initial training difficulty impacts the acquisition and transfer of strategic aircraft discrimination skills.

The remainder of this paper is organized in the following manner: We first examine different learning theories and their ability to predict pilot performance in combat, such as the scenario outlined above. Next, we discuss previous research that supports the strategic explanation of learning and suggests that initial training difficulty impacts the type of strategies that are acquired and transferred. Then, we discuss the present research, which extends previous research to the use of stimuli relevant for air force training (i.e., aircraft silhouettes) and examines the extent to which the strategies acquired as a function of initial training difficulty may be transferred to novel stimuli. Finally, we discuss the theoretical and applied implications of this research.

Learning Theories

Stimulus-Specific Explanation of Learning

Some learning theorists (e.g., Brown & Carr, 1993; Logan, 1988; Meyers & Fisk, 1987; Schneider & Shiffrin, 1977) have postulated that learning takes place through repeated exposure to specific stimuli and that what is learned is stimulus-specific skill. The learning mechanism in such frameworks entails strengthening associations between specific stimuli and their learned responses (e.g., Schneider & Detweiler, 1988). In their strictest interpretation, stimulus-specific learning theories do not address transfer of skill to novel stimuli. In the combat scenario above, strict stimulus-specific theorists would predict that performance would be a function of the amount of exposure the pilot has to the specific airplanes encountered.

Strategic Explanation of Learning

Other theorists agree that stimulus-specific skill is acquired through repeated exposure to particular stimuli. However, they also postulate that an additional form of skill is acquired that is not tied to the specific stimuli experienced (e.g., Anderson, 1982; Brown & Kane, 1988; Doane, Alderton, Sohn, &

Pellegrino, 1996; Doane, Sohn, & Schreiber, 1999; Haider & Frensch, 1996, 1999a, 1999b; Pellegrino, Doane, Fischer, & Alderton, 1991; Schmidt & Bjork, 1992; Strayer & Kramer, 1994). These theorists suggest that processing particular stimuli leads to the acquisition of strategic skills that can be transferred to novel stimuli. That is, these theorists suggest that during training, pilots develop strategies for distinguishing between aircraft that can be applied to aircraft they have not yet seen.

Previous research supporting strategic skill acquisition suggests that the difficulty of initial training influences the acquisition and transfer of strategies for processing artificial visual stimuli such as polygons (e.g., Doane et al., 1996, 1999). In the combat example mentioned above, theorists supporting the strategic view would predict that pilot performance is a function of the visual discrimination strategy acquired during training and that the development of this strategy is dependent upon initial training difficulty. The focus of the present research is on strategic skill acquisition and transfer in the context of aircraft discrimination.

Previous Research

Evidence for strategic skill acquisition has been obtained in studies of problem-solving skills (Anderson, Fincham, & Douglass, 1997; Carlson & Yaure, 1990) and alphabet string verification (Haider & Frensch, 1996, 1999a, 1999b). For example, Carlson and Yaure found that random presentation of Boolean logic functions resulted in superior transfer performance compared with blocked presentation, even though the stimulus-specific experience of the random and blocked groups was identical. They suggested that participants in the random presentation condition had to reinstate problem conditions more often than blocked condition participants and that this resulted in superior condition reinstatement skills that facilitated transfer performance. Haider and Frensch examined strategic skills by asking participants to verify the truth of alphabetic strings (e.g., "Is A {3} D E F true?") in which errors were located only in the initial letter-digit-letter triad. With practice, participants optimized string processing by attending only to the non-redundant string information. These strategic skills transferred to novel stimuli, evidence that such skills are not entirely stimulus-specific.

Evidence for strategic skills has also come from studies of performance in visual search (Czerwinski, Lightfoot, & Shiffrin, 1992; Lightfoot & Shiffrin, 1993) and discrimination (Doane et al., 1996, 1999). Czerwinski et al. and Lightfoot and Shiffrin examined the features participants used to develop a percept of a whole visual figure. They found that the visual search strategy differed depending on the features deemed optimal for differentiating between figures. In studies conducted by Doane and her colleagues, participants trained to make visual discriminations between either similar (difficult training) or dissimilar (easy training) polygon pairs were then transferred to discriminations between novel similar polygon pairs. Transfer performance was superior for participants exposed to difficult training. Since transfer polygons were novel and identical for both training groups, between-group performance differences are not readily explained by stimulus-specific skills acquired during training trials.

Doane et al. (1996, 1999) concluded that the strategy acquired for processing polygons differed with initial training difficulty. Specifically, participants trained on similar discriminations acquired strategic skills that were positively transferred to making similar discriminations between completely novel polygons. The acquired strategies are clearly developed from processing specific polygons during training. However, the ability to transfer these processing strategies to novel polygons indicates that they are not stimulus-specific. Taken together, previous research suggests that skill acquisition involves the development of strategic processing skills that may be transferred to novel stimuli and that these skills differ as a function of initial training difficulty.

Present Research

Research Goals

The goal of the present research was to extend Doane et al.'s (1996, 1999) research to stimuli relevant to air force training (i.e., airplane silhouettes) and to examine whether participants' strategic skills are acquired as a function of initial training difficulty. In addition, the current research examined the extent to which initially acquired skills transfer to novel stimuli.

For this research, participants were asked to discriminate between airplane silhouette pairs that varied in similarity for numerous training trials using a same-different judgment task (cf. Posner & Keele, 1968). On each trial, a silhouette was either paired with itself or with one of six distractors that systematically varied in their average rated similarity to the target. Training difficulty was manipulated by asking half the participants to discriminate between very similar stimulus pairs and the other half to discriminate between very dissimilar pairs. Participants were trained at their respective difficulty levels for numerous trials and then transferred to discriminating between novel silhouette pairs not seen during training. By transferring participants to a completely novel stimulus set, we ruled out the possibility of any explanation of differential transfer performance based solely on stimulus-specific skills.

Experimental Design

The study consisted of two experiments, each containing three sessions of visual discrimination trials. Table 1 shows the design of each experiment, and Figures 1 and 2 show the stimulus sets used.

In Experiment 1, participants discriminated between airplane silhouettes at the same difficulty level (easy or difficult) for the first two sessions, but the stimulus set used for the second session differed from that for the first session (see Figures 1 and 2). In Experiment 2, participants trained with either easy or difficult discriminations between silhouettes in the first session were transferred to difficult discriminations between novel silhouettes in the second session.

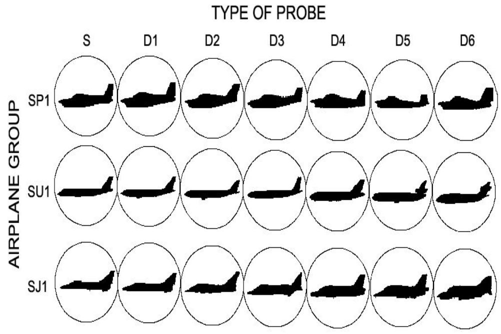

Figure 1. Airplane silhouette stimulus set 1.

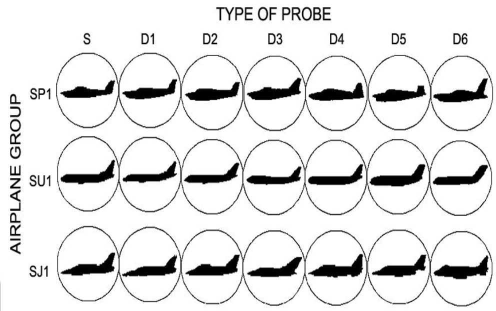

Figure 2. Airplane silhouette stimulus set 2.

Table 1. Experimental Design Used in Experiments 1 and 2

Experiment/Condition	Session 1: Training Set	Session 1: Training Difficulty	Session 2: Training or Transfer Set	Session 2: Training or Transfer Difficulty	Session 3: Transfer Set	Session 3: Transfer Difficulty
1 Stimulus set change						
Difficult A/difficult B/all B	A	D1-D3	B	D1-D3	B	D1-D6
Easy A/easy B/all B	A	D4-D6	B	D4-D6	B	D1-D6
2 Stimulus set and difficulty change						
Difficult A/difficult B/all B	A	D1-D3	B	D1-D3	B	D1-D6
Easy A/difficult B/all B	A	D4-D6	B	D1-D3	B	D1-D6

Note. The order of exposure to stimulus sets A and B was counterbalanced (see Figures 1-4). A change from A to B from Session 1 to 2 indicates a change in stimulus set.

Experiment 1: Stimulus Set Change

The purpose of the first experiment was to extend Doane et al.'s (1996, 1999) previous research to stimuli relevant for air force pilots (i.e., airplane silhouettes) and to determine whether the difficulty of initial discrimination training impacts performance at transfer to novel airplane silhouettes. This experiment also allowed us to verify that the two sets of airplane silhouettes (one set for training and one set for transfer) were equally difficult to discriminate. Participants were given either easy or difficult discriminations between airplane silhouettes in Session 1 and then transferred to a new within-category stimulus set in Session 2, with no change in discrimination difficulty. In Session 3, both groups made easy and difficult discriminations on the stimulus set viewed in Session 2 (see Table 1).

Method

Participants

Thirty-two undergraduates participated in this experiment to fulfill a course requirement. The participants were assigned to one of two training groups: difficult-discrimination training (17 participants) and easy-discrimination training (15 participants). Exposure to stimulus sets was counterbalanced: 9 participants in the difficult-discrimination training group and 8 in the easy-discrimination training group received airplane silhouette set 1 (see Figure 1) followed by airplane silhouette set 2 (see Figure 2). The remaining participants in each group received the stimulus sets in the opposite order.

Apparatus and Materials

We created two stimulus sets of airplane silhouettes by adopting the procedure used by Doane et al. (1996) and Cooper and Podgorny (1976). Side-perspective silhouettes were chosen from the 1997-1998 editions of Jane's All the World's Aircraft (Jackson, 1997) and were modified for computer presentation using Adobe Photoshop. The silhouettes were divided into three airplane groups based on major structural features (e.g., number of propellers, engine location) and are referred to as Jet, Propeller, and Turbofan.

In pilot studies, participants were asked to select the most representative silhouette, or standard, for each of the airplane groups. Participant ratings of silhouette similarity to the chosen standards were used to develop two stimulus sets. Each stimulus set consisted of three standard silhouettes from the Jet, Propeller, and Turbofan airplane groups, as well as six different silhouettes or deviations from each standard (D1-D6), for a total of 21 silhouettes. D1-D6 varied in their average rated similarity to their respective standards, with D1 being most similar and D6 being most dissimilar. Figures 1 and 2 show the stimulus sets used in this experiment.

In the present experiment, participants made discrimination judgments between airplane silhouettes. Within each stimulus pair, the silhouette on the left was always a standard (S) and the silhouette on the right was either the identical standard or one of the D1-D6 silhouettes for that standard. The stimuli were viewed from a distance of approximately 51 cm, averaged 6.15 cm in width, 2.14 cm in height, with an average separation of 1.73 cm, subtending 6.90°, 2.40°, and 1.94°, respectively.

In each session, stimuli were arranged into 8 blocks presented in four random orders to which, participants were randomly assigned. Each block of silhouette discriminations consisted of 72 trials, with an equal number of same and different judgments.. Thirty-six same judgments consisted of 12 presentations of each of the Jet, Propeller and Turbofan standard silhouettes. Thirty-six different judgments consisted of four presentations of either D1-D3 (for difficult discriminations) or D4-D6 (for easy discriminations) silhouettes in Sessions 1 and 2, and two presentations of all different silhouettes (D1-D6) in Session 3, for each of the three airplane groups. In total, participants received three sessions, consisting of 576 trials per session.

Procedure

Participants read instructions indicating that both speed and accuracy were important before completing a set of practice trials and commencing the experiment. In Session 1, participants were randomly assigned to one of two training groups: difficult-discrimination training (the standard silhouette compared with itself for a "same" judgment or one of the D1-D3 silhouettes for a "different" judgment) or easy-discrimination training (the standard silhouette compared with itself for a "same" judgment or one of the D4-D6 silhouettes for a "different" judgment). Participants remained in their assigned training difficulty groups but transferred to discriminations between silhouettes from a novel stimulus set in Session 2 (see Table 1 and Figures 1-2). In Session 3, participants were presented with silhouettes from each level of difficulty (the standard compared with itself or D1-D6) from the stimulus set viewed in Session 2. The first two sessions took place in one 2-hour period. Approximately 24-48 hours after the initial two sessions, the third session took place in one 1-hour period.

During each trial, participants viewed a pair

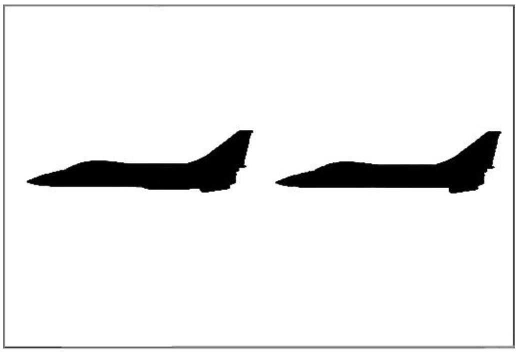

Figure 3. Example visual discrimination trial

of airplane silhouettes on a computer screen (see Figure 3) and were asked to determine whether the two silhouettes were the same ("S" key) or different ("L" key). Each same-difference judgment was self-paced such that pressing either key ended the current trial, and the next trial began. Response time and accuracy were recorded for each participant.

Results and Discussion

The comparability of the two within-category stimulus sets, the effects of extended practice, and the impact of initial discrimination difficulty on performance during all stages of practice were of particular interest in this experiment. These issues were addressed by examining the differences in performance accounted for by stimulus set and practice and by parsing performance measures for same- and different-judgment trials.

Stimulus Set Effects

Separate analyses of variance (ANOVAs) were computed on the same and different judgment accuracies for all three sessions (24 blocks) for both groups, with stimulus set exposure (set 1 vs. set 2 first) and training difficulty (difficult vs. easy) as between-participant factors, and session (1-3) and block (1-8) as within-participant factors. Additional ANOVAs were conducted for the three sessions of same and different judgment latencies. Because stimulus set was not significant, all Fs < 2, 3-way analyses were run that did not differentiate between stimulus sets.

Latency

Same-judgment latency

Figure 4 shows the mean correct same-judgment latencies for difficult- and easy-discrimination training groups in Sessions 1-3. An ANOVA was performed on the mean reaction times for same judgments, with training difficulty (difficult vs. easy) as the between-participant factor and session (1- 3) and block (1-8) as within-participant factors. All participants included in this and the following experiments obtained at least 85%

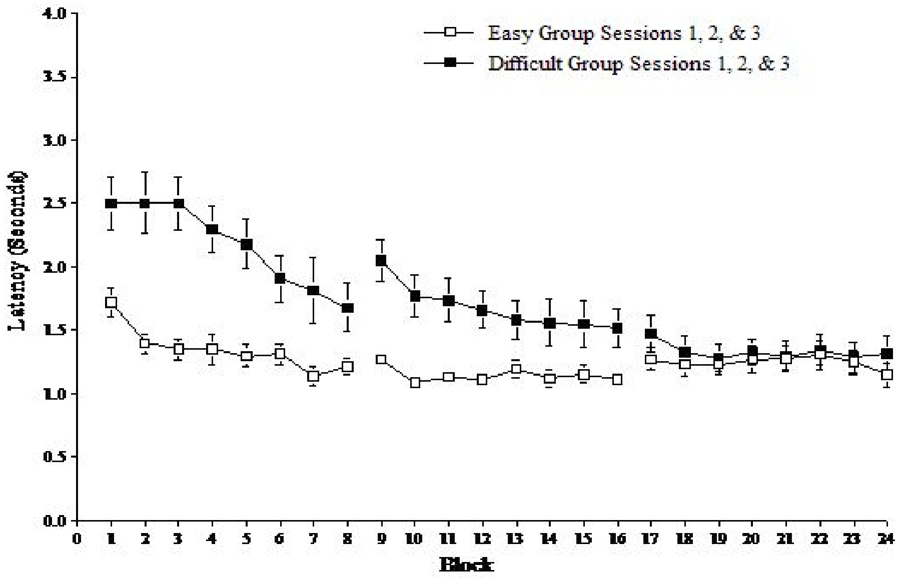

Figure 4. Mean latency for correct same discrimination judgments between airplane silhouettes as a function of block in Experiment 1.

combined accuracy on same and different judgments in the first session of trials. Even though “same” judgments were identical for the two training groups, the difficult-discrimination group took significantly longer to indicate same judgments in the first two sessions than the easy-discrimination group, $F (1, 30) = 9.17$, $MSE = 4.80$, $p < .01$. Overall, latency decreased with practice, $F (7, 210) = 15.02$, $MSE = 0.09$, $p < .01$, although practice effects were greater for the difficult-discrimination training group, $F (7, 210) = 3.57$, $MSE = 0.09$, $p < .02$.

Different-judgment latency

Figure 5 shows the correct different-judgment latencies for difficult- and easy-discrimination groups in Sessions 1-3. An ANOVA was performed on the mean latency for correct different-discrimination judgments in Sessions 1 and 2, with training difficulty (difficult vs. easy), session (1 and 2), and block (1-8) as variables. As expected, the difficult-discrimination training group generally took longer to discriminate between stimuli than the easy-discrimination group, $F(1, 30) = 44.75$, $MSE = 0.88$, $p < .01$.This finding supports the fact that D1-D3 judgments were more difficult relative to D4-D6.

Further analyses were performed on the latency data from Session 3 to tease apart the comparative difficulty of making different

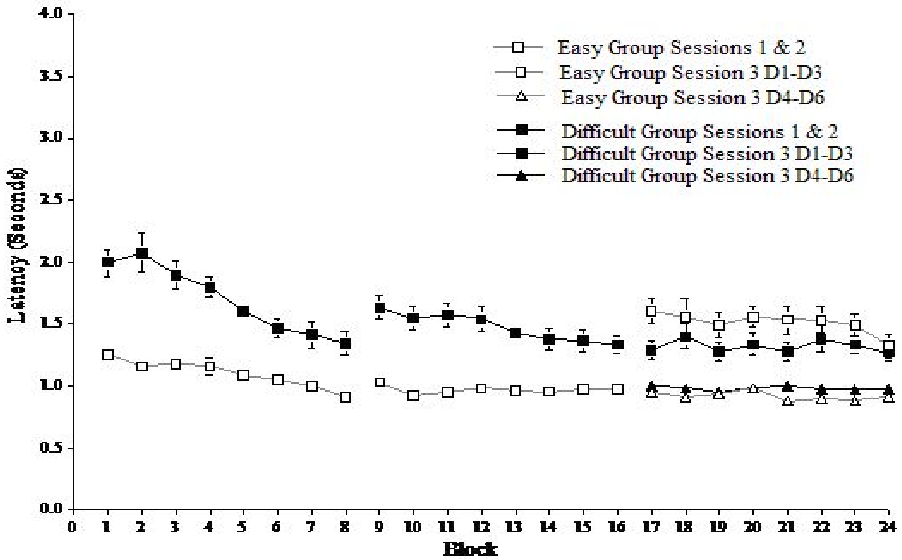

Figure 5. Mean latency for correct different discrimination judgments between airplane silhouettes as a function of block in Experiment 1.

discrimination judgments at both levels of complexity (i.e., D1-3 and D4-6) after initial training. ANOVA was performed on the correct different-discrimination reaction times, with initial training difficulty (difficult vs. easy) as the between-participant factor and discrimination difficulty (D1-D3 vs. D4-D6), and block (17-24) as within-participant factors. As can be seen in Figure 5, difficult-discrimination judgments took significantly longer than easy-discrimination judgments, $F(1, 30) = 126.02$, $MSE = 0.22$, $p < .01$, although this effect was greater for the easy-discrimination training group, $F(1, 30) = 8.77$, $MSE = 0.22$, $p < .01$.

Accuracy

Same-judgment accuracy

Figure 6 shows the group mean accuracies for same judgments in Sessions 1-3. Although the mean accuracies were high for both training groups (range = 89-97%), the difficult-discrimination group generally showed higher accuracy for the same judgments than did the easy group, $F(1, 30) = 5.30$, $MSE = 0.03$, $p < .03$.

Different-judgment accuracy

Figure 7 shows the group mean accuracies for different judgments in Sessions 1-3. In the analysis of the first two sessions, the

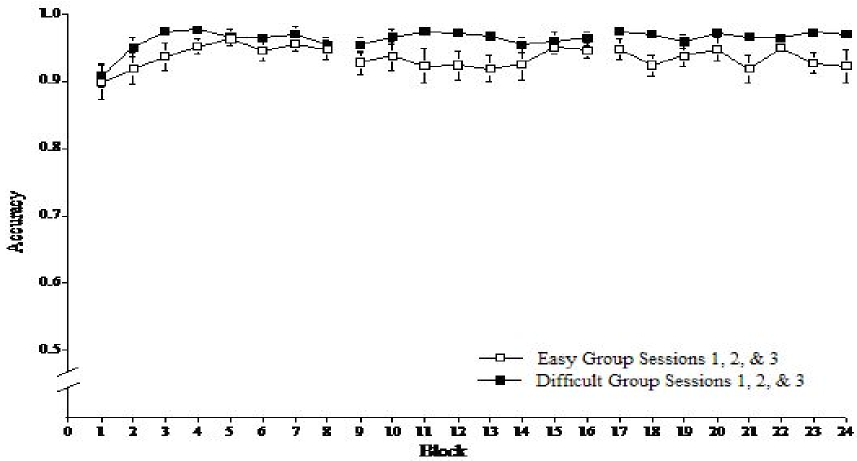

Figure 6. Mean accuracy for same discrimination judgments between airplane silhouettes as a function of block in Experiment 1.

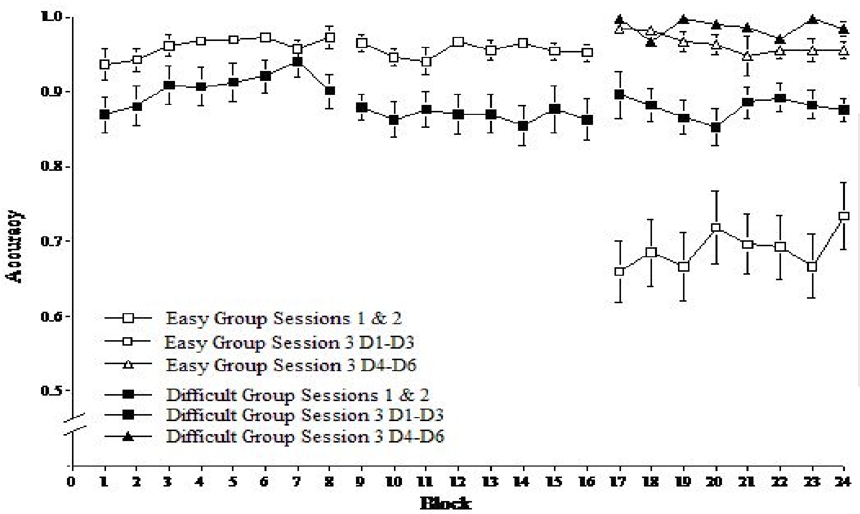

Figure 7. Mean accuracy for different discrimination judgments between airplane silhouettes as a function of block in Experiment 1.

difficult-discrimination group was less accurate than the easy group, $F(1, 30) = 12.60$, $MSE = 0.05$, $p < .01$, highlighting the increased difficulty in discriminating D1-D3 stimuli compared to D4-D6. Together with the latency data, these findings provide a measure of face validity for the new stimulus sets.

An ANOVA performed on the different-judgment accuracies for Session 3, with training difficulty as the between-participant factor and discrimination difficulty and block as within-participant factors, indicated that the difficult-discrimination group was significantly more accurate at making different judgments than the easy group, $F(1, 30) = 19.52$, $MSE = 0.07$, $p < .01$. Moreover, this group difference was more pronounced for D1-D3 judgments, $F(1, 30) = 22.48$, $MSE = 0.04$, $p < .01$. Both training groups were less accurate at making D1-D3 discrimination judgments than they were at making D4-D6 judgments, $F(1, 30) = 117.00$, $MSE = 0.04$, $p < .01$.

An additional ANOVA was performed on D4-D6 judgments, with training difficulty (difficult vs. easy), and block (17-24) as variables. As shown in Figure 7, the difficult-discrimination training group made more accurate discrimination judgments on novel D4-D6 stimuli than did the easy-discrimination training group, $F(1, 30) = 5.48$, $MSE = 0.01$, $p < .03$.

Summary

The results suggest that manipulating the discrimination difficulty of airplane silhouettes viewed during training effectively induced different processing strategies in the two discrimination groups. The finding that participants trained on similar stimuli (D1-D3) were more accurate at visual discriminations on dissimilar stimuli (D4-D6) than the easy-discrimination training group, which had prior exposure to the specific stimuli, is particularly important. The results cannot readily be explained by stimulus-specific theories. Overall, the results replicate and extend Doane et al.'s (1996, 1999) findings, using real airplane silhouettes.

Experiment 2: Stimulus Set and Difficulty Change

In order to evaluate the strength of the impact of initial training condition, we examined whether the difference in performance at transfer would be observed with a smaller amount of prior training. That is, if the easy-discrimination training group were switched to difficult discriminations in Session 2, would this alleviate the performance decrement observed in Session 3? To answer this question, participants who received difficult discriminations in Session 1 (called the difficult-first group) also received difficult discriminations from a novel stimulus set in Session 2, and in Session 3 received the full set of discrimination difficulties from the stimulus set viewed in Session 2 (see Table 1).

Participants who received easy discriminations in Session 1 (called the easy-first discrimination training group) were switched to difficult discriminations from a novel stimulus set in Session 2, followed by the full set of discrimination difficulties on that same stimulus set in Session 3 (see Table 1). Thus, the only difference between these two groups was whether they initially learned to make difficult or easy discriminations during their first session. From Block 9 onwards, both groups were matched in terms of the difficulty, order and frequency of the stimuli shown.

If initial difficult training conditions facilitate the development of a more discerning visual discrimination strategy then the difficult-first group should exhibit superior performance on transfer stimuli. These performance differences should be observed in Session 3, despite the frequency of stimulus-specific exposure to transfer silhouettes being identical across groups. Earlier exposure to difficult discriminations (compared to the easy group from Experiment 1), and an equivalent degree of stimulus-specific exposure to transfer stimuli (compared to the difficult-first group in this experiment) by the easy-first group was predicted to be ineffective in countering against the negative effect of initially training under easy-discrimination conditions.

Method

Participants

Fifty undergraduates participated in this experiment to fulfill a course requirement. The participants were equally assigned to one of two training groups: difficult-first discrimination and easy-first discrimination. Exposure to stimulus sets was counterbalanced.

Apparatus, Materials, and Procedure

The apparatus, materials, and procedures for this experiment were identical to those in Experiment 1, except for the difficulty exposure differences. All participants received only difficult discriminations in Session 2.

Results and Discussion

Latency

Same-judgment latency

Figure 8 shows the group mean latencies for correct same judgments in Sessions 1-3. An ANOVA was performed on the mean latencies, with training difficulty (difficult-first vs. easy-first) as the between-participant factor and session (1-3) and block (1-8) as within-participant factors. The difficult-first group

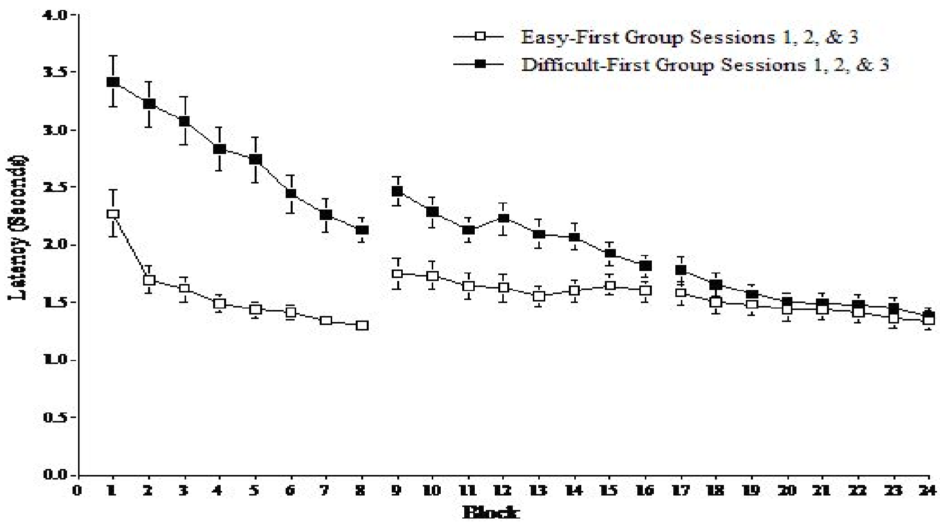

Figure 8. Mean latency for correct same discrimination judgments between airplane silhouettes as a function of block in Experiment 2.

took longer to indicate same judgments than the easy-first group, F (1, 48) = 23.66, MSE = 4.43, p < .01. In addition, reaction time decreased with practice, F (7, 336) = 55.24, MSE = 0.11, p < .01, with a greater reduction over time for the difficult-first group, F (7, 336) = 6.59, MSE = 0.11, p < .01.

Different-judgment latency

Figure 9 shows the group mean latencies for correct different judgments in Sessions 1-3. An ANOVA was performed on the mean latencies in Sessions 1 and 2, with training difficulty (difficult-first vs. easy-first) as the between-participants factors and session (1 and 2) and block (1-8) as within-participants factors. The difficult-first discrimination training group required more time to make different judgment decisions (D1-D3) in Session 1 than the easy-first discrimination training group (D4-D6), but this difference disappeared in Session 2 when both made difficult judgments (D1-D3), F(1, 48) = 72.45, MSE = .25, p < .01. With practice, both groups required less time to make a discrimination judgment, F (7, 336) = 41.69, MSE = .11, p < .01. An additional ANOVA was performed on D1-D3 and D4-D6 judgment latencies in Session 3.No significant differences between training groups were observed, F < 1. Both groups were significantly quicker at making different (i.e., D4-6) compared to similar judgments.

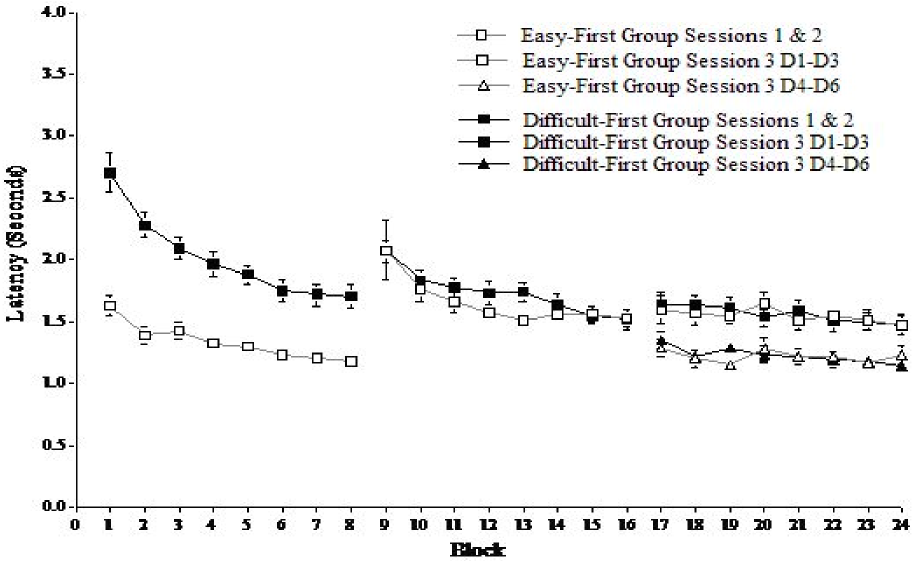

Figure 9. Mean latency for correct different discrimination judgments between airplane silhouettes as a function of block in Experiment 2.

Accuracy

Same-judgment accuracy

Figure 10 shows the group mean accuracies (range = 94-98%) for same judgments in Sessions 1-3. No significant training difficulty or practice effects were observed (all Fs < 1).

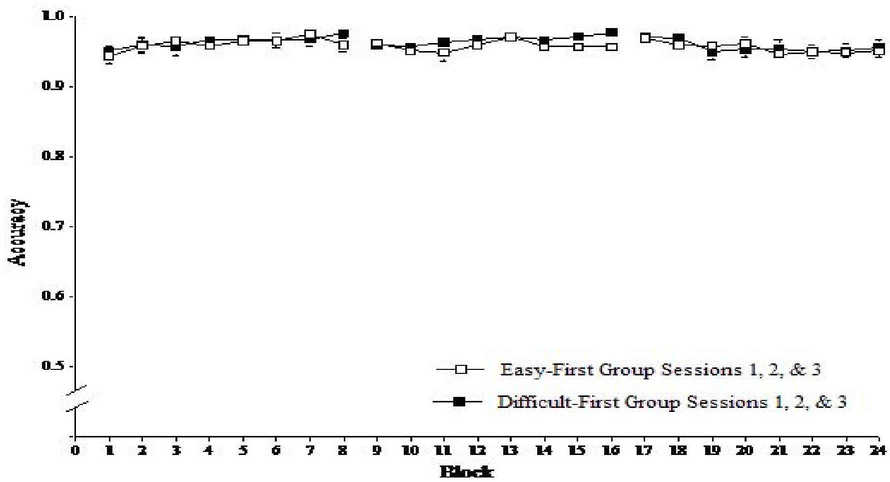

Figure 10. Mean accuracy for same discrimination judgments between airplane silhouettes as a function of block in Experiment 2.

Different-judgment accuracy

Figure 11 shows the group mean accuracies for different judgments in Sessions 1-3. An ANOVA was performed on the mean accuracies, omitting Session 3 as per the previous analyses of accuracy. The difficult-first group was less accurate than the easy-first group in Session 1, but this was reversed in Session 2, $F(1, 48) = 30.56$, $MSE = 0.04$, $p < .01$. The group differences observed in Session 2 indicate that initial difficult training produced superior performance on novel difficult stimuli than did initial easy training.

An ANOVA performed on the mean accuracies for Session 3, with training difficulty (difficult-first vs. easy-first) as the between-participant factor and discrimination difficulty (D1-D3 vs. D4-D6) and block as within-participant factors demonstrated that the impact of initial training difficulty on accuracy performance when participants were transferred to all levels of discrimination difficulty, $F(1, 48) = 4.68$, $MSE = 0.06$, $p < .04$. The easy group performed significantly worse overall, however, group differences were more pronounced for D1-D3 judgments, $F(1, 48) = 5.31$, $MSE = 0.04$, $p < .03$. Because both groups had identical stimulus-specific exposure to these silhouettes, these results were not caused by differential experience with the stimuli or stimulus-specific knowledge.

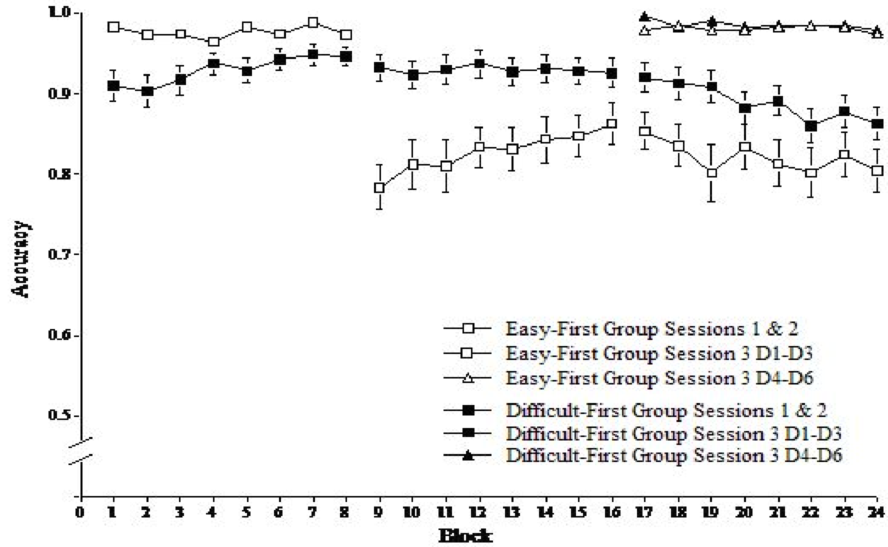

Figure 11. Mean accuracy for different discrimination judgments between airplane silhouettes as a function of block in Experiment 2.

Summary

Overall, the results provide evidence of the strength of the impact of initial training difficulty on transfer performance. Specifically, initial training difficulty on one session alone produces differential performance even when the amount of stimulus-specific exposure to transfer stimuli is equated. These results provide further support for the hypothesis that strategic skills acquired during initial training are not merely stimulus-specific but are developed as a consequence of processing specific stimuli. Moreover, the present findings further suggest that such acquired strategies can be transferred to novel stimuli as demonstrated by the transfer effects in Sessions 2 and 3. The difficult-first group exhibited superior transfer to novel stimuli, and this enhanced processing strategy and performance level persisted through extended practice trials. Although the easy-first group showed improvement during transfer trials in Session 2, they never matched the accuracy of the difficult-first discrimination training group. These results suggests that the strategic skills acquired after processing dissimilar stimuli for only 576 trials negatively impacted transfer performance even when easy and difficult groups were matched on the number of transfer stimuli processed.

General Discussion

The present experiments extend previous research to stimuli relevant for air force training (airplane silhouettes) and provide strong evidence for the impact of initial training difficulty on the acquisition and transfer of strategic aircraft discrimination skills. In two experiments, participants discriminated between airplane silhouettes that varied in similarity. During transfer sessions, participants discriminated between novel similar or dissimilar stimuli, or at all similarity levels. In both studies, initial learning context facilitated processing strategies that were stimulus-driven, but not stimulus-specific.

From an applied perspective, these results have implications for air force training. For example, if pilots are trained to make visual comparisons between aircraft that are very distinct from one another (easy-discrimination training), then the strategy they adopt during training may not result in optimal performance during combat situations that require discrimination between similar aircraft. Therefore, training procedures should expose pilots to difficult discriminations early in training in order to facilitate strategic skills that will produce superior performance on future difficult discriminations.

The cadets at the Korean Air Force Academy in particular could benefit from such a strategic approach. Currently, recognizing and distinguishing aircraft is an integral part of officer candidate training at the Academy. In less than a semester, the cadets memorize over 50 new silhouettes, along with learning about other aircraft and acquiring general military knowledge. Unfortunately, no learning method is provided to cadets to facilitate their recognition.

The present findings suggest that, with practice, participants form a processing strategy that reduces the number of redundant comparisons required to discriminate between airplane silhouettes. We assume that participants initially made unnecessary comparisons between the silhouettes, but, with practice, they acquired an optimal strategy for discriminating between their training stimuli. When participants were transferred to novel silhouettes, they continued to apply their initially acquired strategies even when they were suboptimal. This resulted in superior transfer performance by participants who initially discriminated between very similar stimuli that required more detailed comparisons.

Even though these strategy assumptions seem plausible, the present experiment did not directly examine the nature of the strategies acquired through initial training difficulty. Future research could examine these strategies using eye-tracking technology. This would provide additional information relevant to strategic skills as well as training.

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전략적 항공기 변별 기술의 훈련과 전이

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초기 훈련의 난이도가 전략적 비행기 변별 기술의 습득과 전이에 미치는 영향을 검증하기 위해서 두 가지 실험연구를 수행하였다. 참석자들은 유사한(어려운 훈련) 혹은 유사하지 않은(쉬운 훈련) 비행기 자극들을 변별하도록 훈련받았고, 이러한 훈련을 통해 습득한 기술은 새로운 모양의 비행기 자극들을 구별하는데 전이됨을 보았다. 실험 1에서는 참가자들이 계속 동일한 난이도(쉽거나 어려운)의 비행기 자극들을 변별하는 훈련을 하고, 전이를 보기 위해서 다른 세트의 비행기 자극들을 변별하도록 하였다. 실험 2에서는 참가자들이 쉽거나 어려운 비행기 자극들의 변별을 훈련받은 것이 새로운 비행기 자극들에 대한 어려운 변별 과제를 수행하는데 전이되도록 하였다. 실험결과, 초기 훈련의 난이도는 전략적 기술 습득에 영향을 주고 전략적 기술들이 새로운 비행기 자극의 전이에 적용되었다는 것을 발견하였다. 이 연구는 공군 조종사들의 효과적인 훈련을 위한 응용점을 시사한다.

주요어 : 항공기 변별, 조종사 훈련, 기술의 전이, 전략적 기술 습득