DIFFERENTIAL BASE RATE TRAINING INFLUENCES DETECTION OF NOVEL TARGETS IN A COMPLEX VISUAL INSPECTION TASK

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We studied the effects that multiple levels of signal probability (known as *base rate*) have on the transfer of learning in an airline luggage screening task. Participants (n = 33) were presented with three base rates during the acquisition (training) phase: 100%, 50%, or 20%; at transfer, all participants detected novel targets at a base rate of 20%. Performance was measured by hit rates, false alarm rates, sensitivities, and detection times. Results revealed that participants receiving higher base rates during training obtained higher hit rates at transfer compared to participants encountering lower base rates. However, increasing the training base rate also increased the incidence of false alarms, leading to a low overall level of sensitivity during transfer. Relatively higher base rates had mixed effects on response times. These results have implications for improving training modules for individuals in complex visual inspection tasks.

INTRODUCTION

The primary goal of visual search tasks is to effectively differentiate critical signal stimuli (i.e. *targets*) from irrelevant non-signals (i.e., *distractors*). Although some studies have shown that the number of signals among distractors have little effect on detection time (Hoffman, 1978; Shiffrin & Schneider, 1977), other studies have revealed that the combination and distribution of signals and distractors presented to the observer often influences detection time (Duncan & Humphreys, 1989). Increasing the number of distractors tends to significantly increase detection time because attention must be directed to several nonsignals before the true signal is found; this implies that the observer's efficiency of nonsignal rejection is reduced (Duncan & Humphreys, 1989). Conversely, research has revealed that increasing the number of signals among distractors should have the opposite effect; that is, increasing the signal probability (or base rate) during training increases the "attention attracting tendency" of these signals (Shiffrin & Schneider, 1984), thus leading to improved detection performance.

In realistic visual inspection tasks (such as airline luggage screening, quality control inspection, etc), the base rate of critical stimuli is likely to be significantly lower than that used in most simple laboratory tasks (Parasuraman, Warm, & Dember, 1987). In the case of luggage screening in particular, the signals encountered in the actual screening task are often different from those seen during training. The primary purpose of this research was to examine whether using high base rates during training led to more effective detection when transferring to lower base rates in the context of a simulated airline luggage screening task.

Manipulating base rates during training could have two possible effects. On the one hand, the results of training and transfer could be very 'specific'; that is, transfer would be best facilitated if the conditions during training are the same as those during transfer (e.g., Healy, Wohldmann, Parker & Bourne, 2005; Healy, Wohldmann, Sutton & Bourne; 2006). If the specificity of training hypothesis holds, then one would expect that training under low base rates would lead to better transfer to similarly low base rates compared to training on higher base rates.

However, the luggage screening task that we used in this study differs from the 'specificity' research because our paradigm included transfer targets that were novel and different from those encountered during training. An effective decision strategy in this task, therefore, required individuals to extrapolate information from the training set to predict the nature of the novel targets and detect the new targets based on prior knowledge, instead of merely recognizing the same targets observed during training. Given the variability in the stimuli used during training versus transfer in this task, it is more likely that training on higher base rates provides individuals with a better mental representation of what constitutes a "target". The resulting enhanced detection performance would transfer better to lower base rates compared to training under the same lower frequencies. The purpose of this study, therefore, was to examine the effects of training observers on varying levels of base rates and transferring them to a lower base rate in a simulated luggage screening task.

Purpose of the Present Study

This study was designed to test whether the number of times that the detection state occurs during practice leads to an improvement in the detection of novel targets at transfer. It is possible that a low number of detection searches would be beneficial during the acquisition phase but detrimental during transfer, because a lower "attention attracting tendency" developed during practice (Shiffrin & Schneider, 1984). In contrast, a higher number of detection searches could be more beneficial during transfer because it would increase the attention-attracting tendency of the signals. We hypothesized that larger base rates during training would lead to increased hit rates and faster response times at transfer, even with novel targets.

METHOD

Participants

Thirty-three students from Carnegie Mellon University completed all phases of the experiment. The duration of the experiment was approximately 1.5 hours and participants were paid a total of $15.

Tasks and Procedures

Participants completed a luggage screening task comprising of 5 blocks of 100 trials each. The first four blocks comprised the training phase and the fifth block constituted the transfer phase. Participants were assigned to one of three training conditions in the first 4 blocks: (i) 100% base rate, where all trials contained a signal (n = 11); (ii) 50% base rate, where half of the trials contained a signal (n = 11), or (iii) 20% base rate, where only 20 out of every 100 trials contained a signal (n = 11). In the transfer block, the base rate was 20% for all groups. Participants were not informed of the target base rate, in neither the training nor transfer blocks. In this paper, these conditions will be referred to as the *100% group*, *50%, group*, and *20% group*, respectively.

At the beginning of each training trial block, participants were asked to memorize a set of five targets drawn from five categories: guns, knives, scissors, sharp glass objects, and metal tools. Participants then observed a series of 100 two-color x-ray luggage-images cluttered with a variety of everyday objects (e.g., clothes, hair dryers, pill bottles) for a duration of 4 seconds per image. Participants were required to inspect each luggage image and click on the signal if it was present in the luggage.

During the transfer trial block, the targets consisted of unique objects drawn from different categories,) other than the ones used during training. Participants were also not shown the targets at the beginning of the trial block. Instead, participants were instructed to figure out what the targets could be, based on their knowledge and memory of the signals seen during the training session. Outcome feedback was provided at the end of each trial in the form of a text message on the screen.

The measures used to examine the effectiveness of transfer were: (1) hit rate, (2) false alarm rate, (3) sensitivity (*d'*) and (4) response time for correct detections. We also analyzed data for response criterion settings (*c*) but do not report them in this article due to lack of statistically significant differences among groups.

RESULTS

Multiple repeated measures ANOVAs revealed that higher base rates during training benefited initial skill acquisition more than lower base rates. The 100% group had the highest increase in hit rates and the greatest decrease in response times during the course of training, followed by the 50% and 20% groups, respectively.

The question that arises is - Would higher base rates during training result in similar benefits during transfer? This is particularly critical when (1) the signal probability during transfer might be significantly lower than that used during training, and, (2) when the transfer task requires recognition of unfamiliar targets not encountered previously during training. Both attributes are characteristic of a real luggage screening task. We discuss this transfer data below, where all groups transferred to a 20% base rate and detected novel signals. Alpha values less than .05 are reported as statistically significant.

Hit rate. A one-way ANOVA on hit rates during transfer revealed a significant difference between groups, F (2, 30) = 5.71, p <.05. The results for hit rates are illustrated in Figure 1.

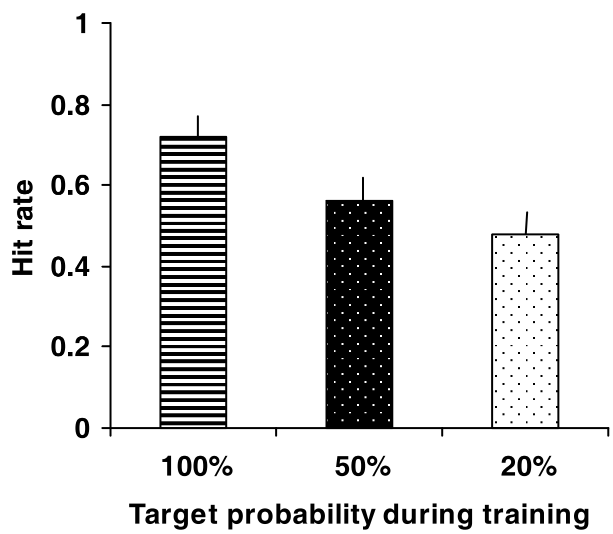

Figure 1. Hit rates during transfer.

As seen in the figure, in keeping with expectations, the 100% group generated significantly more hits during transfer (M = .72, SD = .11) than the 50% group (M = .56, SD = .13), t (20) = 3.05, p < .05, and the 20% group, (M = .48, SD = .23), t (20) = 3.05, p < .05. However, the hit rates in the 50% group were not significantly different from the 20% group, t (20) = .95, p = .35. This suggests that the target base rate during training exerts a beneficial effect on transfer only when the training base rate is 'exceptionally high' (i.e., 100%). In other words, if the target rate during training is significantly higher than the transfer base rate, the probability of correctly detecting a novel target appears to be proportionately higher. However, the number of detection searches afforded by a 50% base rate during training was not sufficient to lead to accurate transfer to a lower base rate.

False alarm rate. A one-way ANOVA on false alarm rates during transfer revealed a significant difference between groups, F (2, 30) = 4.62, p < .05. The pattern of results for false alarm rates is illustrated in Figure 2. As predicted, the 100% group generated significantly more false alarms during transfer (M = .42, SD = .28) than the 50% group (M = .20, SD = .20), t (20) = 2.09, p = .05, and the 20% group (M = .17, SD = .11), t (20) = 2.73, p < .05. Similar to the pattern for hit rates, the false alarm rate in the 50% group was not significantly different from the 20% group, t (20) = .46, p = .65.

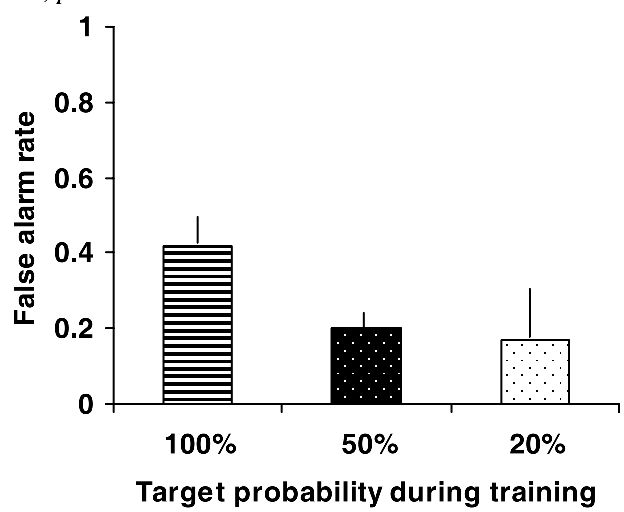

Figure 2. False alarm rates during transfer.

Sensitivity (d'). A one-way ANOVA on sensitivities revealed a significant difference between groups, F (2, 30) = 2.19, p < .05. The results are illustrated in Figure 3. As expected from the pattern of hit rates and false alarm rates discussed above, the 100% group demonstrated lower levels of sensitivity (M = .87, SD = .78) than the 50% group (M = 1.11, SD = .75), t (20) = 1.73, p < .057, but not significantly lower than the 20% group, (M = .96, SD = 1.11), t (20) = .21, p = .84. Unlike the pattern for hit rate and false alarm rates, and as evident in Figure 3, the sensitivity levels of the 50% group were also significantly higher than the 20% group, t (20) = 2.38, *p* < .05. This suggests that, after accounting for the tradeoff between hits and false alarms, a 'moderate' base rate (50%) during training has the most beneficial effects on detection sensitivity during transfer.

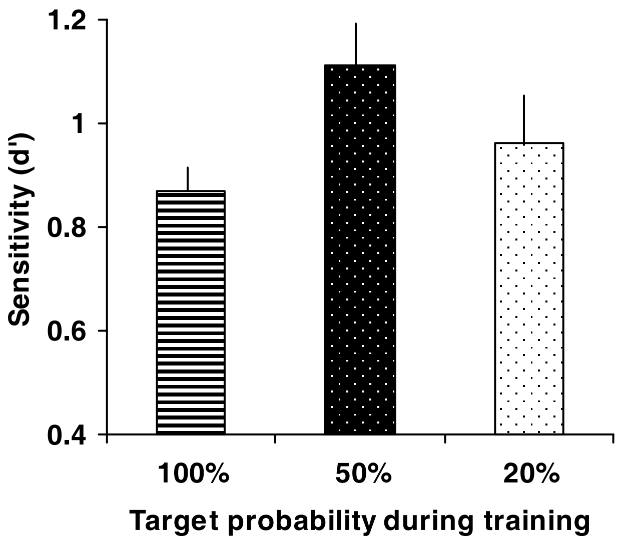

Figure 3. Sensitivities during transfer.

Response time for correct detections. Similar to the above analyses, a one-way ANOVA on response times during transfer revealed a significant difference between groups, F (2, 30) = 10.28, *p* < .05. The results are depicted in Figure 4.

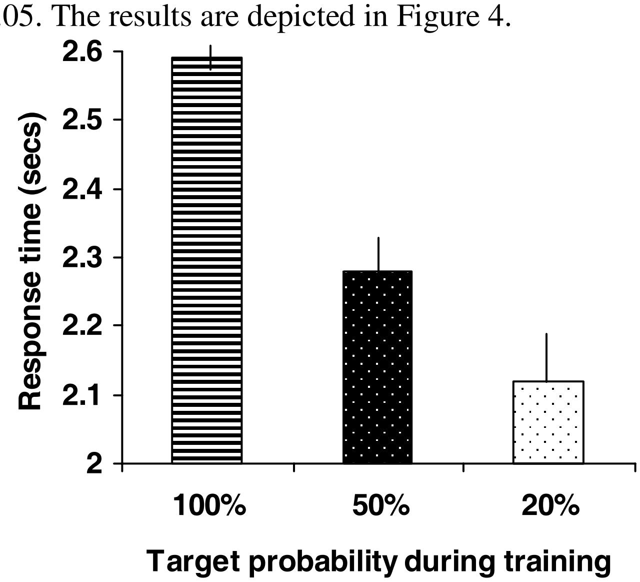

Figure 4. Response times for correct detections during transfer.

Contrary to the pattern for hit rates, participants in the 100% group responded significantly slower during transfer (M = 2.59 sec, SD = .28) than the 50% group (M = 2.28 sec, SD = .18), t (20) = 3.13, *p* < .05 and the 20% group, (M = 2.12 sec, SD = .27), t (20) = 4.00, *p* < .05. The response time of participants in the 50% group did not differ from the 20% group, t (20) = 1.56, *p* = .14.

DISCUSSION

Schneider and Fisk (unpublished) examined improvements in signal detection performance in a simple visual search as a function of the ratio of detection and non-detection searches. They found that the number of non-detection searches decreases detection accuracy and influences the transfer to either low or high base rate situations. In the current research we utilized a practice-test paradigm wherein the transfer condition involved novel targets and all the training conditions transferred to the same reduced base rate (20%). This design allows for specific conclusions about the effect of the diversity of search states during training in detecting novel items at test.

Our findings show an advantage of training on the highest base rate condition (100%) with respect to the hit rate during transfer to novel targets. This result can be interpreted by the "attention attracting tendency" that is developed during practice (Shiffrin & Schneider, 1984). In this experiment, practice increased the 'attention-attracting tendency' of signals and provided participants in the 100% group with a more accurate mental representation of what constituted a "target", relative to the 50% and the 20%groups. This finding, however, did not hold true for false alarm rates, sensitivities and response time. Reasons for this are discussed below.

Contrary to the data for hit rates, results revealed that training on a very high base rate led to a higher incidence of false alarms, thereby negatively impacting sensitivities. It is possible that a very high base rate led to a higher expectation of signals being present, which led participants in the 100% group to generate more "target present" responses during transfer. This increased their false alarm rate relative to the groups that trained on lower base rates and hence had lower expectations of the target being present. The large number of false alarms generated during transfer led to a drop in sensitivity levels for the 100% group, despite their high hit rate.

Similar to the negative pattern for false alarms, the 100% group also demonstrated the slowest response times during transfer. It appears that the higher expectation of a target being present led participants to spend more time scanning each image, thereby slowing their response time. It is also possible that participants in the 100% group slowed their responses by attempting to inhibit the attention attraction when exposed to the 20% transfer base rate with novel signals.

Training with a base rate of 50% led to a more optimal balance between hits and false alarms as well as succeeded in achieving the lowest response time, compared to a 100% or a 20% base rate. On the one hand, a 50% base rate sufficiently increased the 'attention attracting tendency' (Shiffrin & Schneider, 1984) of targets during training, leading to a better hit rate relative to the 20% group. On the other hand, a moderate base rate of 50% during training likely led to lower expectations of target probability during transfer, thereby circumventing the problems associated with frequent false alarms and slower response times demonstrated by the 100% group. Overall, a low base rate of 20% was the least effective when transferring to novel targets, despite the fact that the base rate for this condition was identical during training and transfer.

Conclusions and Implications

The results of the present study have implications for developing training solutions for security personnel in differentiating targets from distractors under time pressure. As indicated by the results of the present study, methods of training that include moderate to high base rates (i.e., showing operators several instances/examples of a target and thereby increasing the number of detection searches), will likely lead to better transfer of detection skills than very low base rates. These observations hold true even under conditions where the targets encountered during transfer are different than those used during training.

Whether the training interventions suggested above will indeed lead to better transfer of knowledge in situations involving increased workload, time pressure, and actual consequences remains to be examined. Therefore, further research is required before concrete suggestions can be made toward developing training solutions for airline luggage screening.

ACKNOWLEDGEMENTS

This research was supported by the Multidisciplinary University Research Initiative Program (MURI), grant number N00014–01–1-677 to Cleotilde Gonzalez. We thank Polina Vanyukov for helping in data collection, and Jack Lim for programming the tool used in this experiment.

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