The Number of Trials with Target Affects the Low Prevalence Effect

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Abstract. Wolfe J M. et al found that subject's miss rate increased markedly when target prevalence decreased in simulated X-ray luggage screening task, which was so-called the low prevalence effect. He thought it was caused by shift of observer's decision criteria. But the number of trials with target (NTT) also affected the effect. The present study had two experiments, and there were two blocks in each experiment. Subjects in Exp 1 were in different NTT (20 vs. 100) but the same target prevalence (both 50%); In Exp 2, NTT was the same (both 20) but the target prevalence was different (50% vs. 5%). The results showed that subject's miss rate was mainly changed with NTT, and decision criteria was up to the target prevalence, Wolfe's conclusion was not completely correct.

Keywords: X-ray luggage screening, low prevalence effect, miss rate, visual search.

1 Introduction

The security of transport systems such as airport and subway has attracted more and more people's attention since 9/11 incident, but it is not always reliable, researchers were clear of security check of 15 airports with bombs and guns [1].

X-ray screening especially luggage screening is one of the most important processes in the security of transport systems. It was essentially a visual searching task, "and visual search was a ubiquitous target detection task [2]", but X-ray luggage screening was a little special, its target prevalence was very low, it was about only one time a month per an airport to detect knives or guns in passengers luggage [3]. And there maybe brought a serious problem, observer would miss some targets if the target was too rare. Wolfe J M. et al found that observer's miss error rate increased remarkably (from 7% to 30%) as target prevalence decreased (from 50% to 1%) [4], this was so-called the low prevalence effect, and he considered it was caused by shift of subject's decision criteria when target prevalence decreased. When the target prevalence was very low, the observer always responded with no target, and answering yes would more likely make mistake, he would be very cautious and his

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decision criteria were shifted to a strongly conservative position [5]; however, the observer could had more false alarms as the target prevalence was very high. And after then, Wolfe had done lots of experiments to cure the effect, but found that it was nearly impossible [5].

We know that the target prevalence is related to NTT and the number of all trials (see Equation 1, N is the number of all trials), and observer's miss rate is equal to the number of trials that targets are missed (Nm) divided NTT (see Equation 2), from Equation 1 and 2, we could get Equation 3. That is to say, observer's miss rate is related to Nm and NTT, or Nm, target prevalence and N. And among these variables, NTT, N and target prevalence can be controlled by experimenter; Nm is up to the observer (e.g., decision criteria) and stimulating materials (e.g., background) and so on. According to Equation 1, only two variables of NTT, N and target prevalence are independent, and the other one is dependent, for example, if N and target prevalence are given, NTT can be calculated. So we should keep NTT or N fixed when researching how target prevalence affects observer's miss rate.

$$\text{target prevalence} = \text{NTT} / \text{N} \tag{1}$$

$$\text{miss rate} = \text{Nm} / \text{NTT} \tag{2}$$

$$\text{miss rate} = \text{Nm} / (\text{target prevalence} * \text{N}) \tag{3}$$

However, Wolfe just mentioned the target prevalence but ignored NTT and N. in most of Wolfe's experiments about the low prevalence effect, there were 200 trials in high target prevalence (50%) block, NTT was 100; and 1000 trials in low target prevalence (2%) block, NTT was 20. In these two blocks, neither NTT nor N is the same. There would be a problem, if an observer misses both 18 targets in these two blocks, the miss rate in high target prevalence block will be 18%, but the miss rate in low target prevalence would be 90%! This experiment designing would magnify the low prevalence effect.

How NTT and target prevalence affected the miss rate and decision criteria was this study's aim.

2 Methods

2.1 Materials

X-ray pictures used in this study were created in laboratory. Each X-ray picture was in noisy background and contained 18 disturbing objects, which were ordinary things such as watches, cell phones, shoes, glasses, keys, tools (scissors, pincers, etc), toys (cars, tractors, tanks, etc), bottles, cameras and so on. And pictures with target of course had a target, which was a knife or gun. All disturbing objects and targets were black and white, partly transparent and in random rotation, and then overlapped randomly (see figure 1).

Exp 1 and Exp 2 used the same pictures.

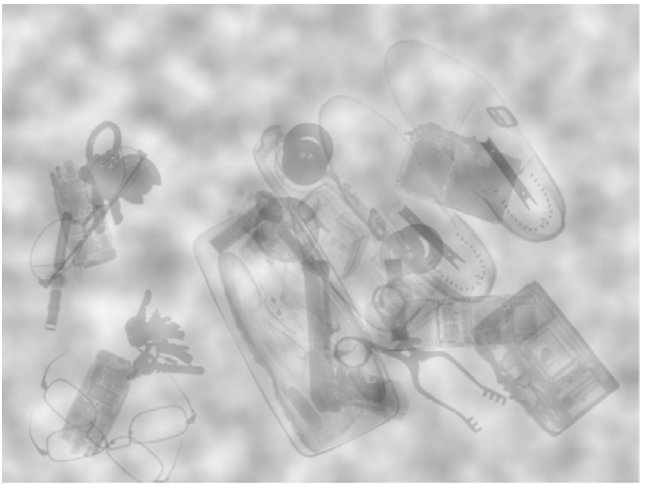

Fig. 1. A picture with a gun

2.2 Participants

15 college students (7 male, 8 female, ages were 18-26 years) were tested in this study, they all reported no history of eye or muscle disorders, and their visual acuity were normal or corrected to normal. 9 students (5 male, 4 female) participated in Exp 1, and 6 students (3 male, 3 female) participated in Exp 2.

2.3 Procedure

Exp 1 and 2 had similar procedure. Subjects were familiar with targets (guns and knives) at first, then practiced searching 10 times (the target prevalence was 50%), and at last, they had a formal screening task which concluded 2 blocks. Subjects were asked to have a rest for 2 minutes between the blocks.

And in Exp 1, the 2 blocks had different NTT (20 vs. 100) and N (40 vs. 200) but the same target prevalence (both 50%, it can be easily figured out by formula 1); however, the NTT were the same (both 20) in Exp 2, but N (40 vs. 400) and target prevalence (50% vs. 5%) were both different. And subjects rest twice in Exp 2, they also had 2 minutes rest in the half of the block with 400 trials besides the rest between blocks.

In each trial, the "+" was on the center of screen for 500 ms at first, and then a X-ray picture showed, subjects should press the key "1" when they found the target; otherwise press the key "2", their responses and reaction time (RT) were recorded. Feedback was given for right or wrong responses in practice, but no feedback in formal searching. And subjects were asked to response as soon as possible in condition of making sure their answers were correct.

2.4 Data Analysis

The trial with no response or that RT less than 200 ms was removed. And the subject that missed far too much times and responded extremely fast was also out of analysis. As a result, one subject's data were eliminated in each experiment, and 8 subjects (4 male, 4 female) were left in Exp 1, 5 subjects (2 male, 3 female) were left in Exp 2.

3 Result

Subjects' miss rates, decision criteria and RT were dependent variables and calculated after experiments. The three variables between blocks in each experiment were compared respectively by Paired-Samples T Test in SPSS 13.

Decision criteria is a psychology variable related to the subject, it increases means that subject becomes conservative, and more likely to consider that there is no target in the picture. The calculating formula in EXCEL 2003 is as follows, decision criteria =- (norminv(hit%)+norminv(false alarm%))/2 [5].

In Exp 1, the two blocks had different NTT (20 vs. 100), same target prevalence (both 50%), miss rate increased markedly ($t = 4.25$, $p = 0.004$) as NTT increased (see figure 2), it indicated that NTT also affected the low prevalence effect even the target prevalence didn't change. Subjects' decision criteria (see figure 3) had no difference ($t = -0.43$, $p = 0.681$), and RT (see figure 4) was also nearly the same ($t = 0.23$, $p = 0.826$).

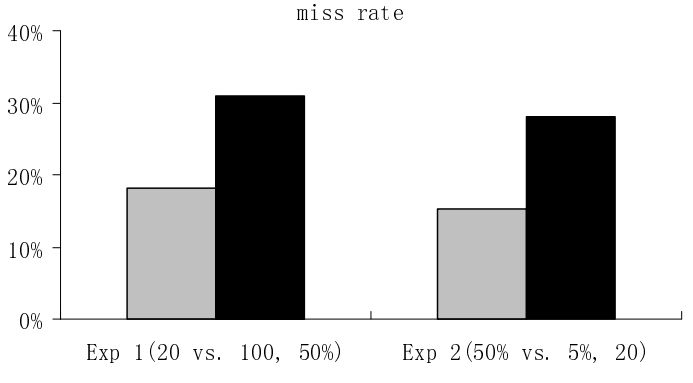

Fig. 2. Subject's miss rate in different NTT or target prevalence

And in Exp 2, target prevalence was different (50% vs. 5%) and NTT was the same (both 20) between the two blocks, the difference of miss rate was not very remarkable ($t = -2.6$, $p = 0.06$), which indicated that target prevalence didn't influence on miss rate very much, the low prevalence effect was not very obvious. And subject's decision criteria ($t = 24.19$, $p < 0.001$) and RT ($t = -3.229$, $p = 0.032$) were remarkable different, the result of Exp 2 was similar with Wolfe's experiments.

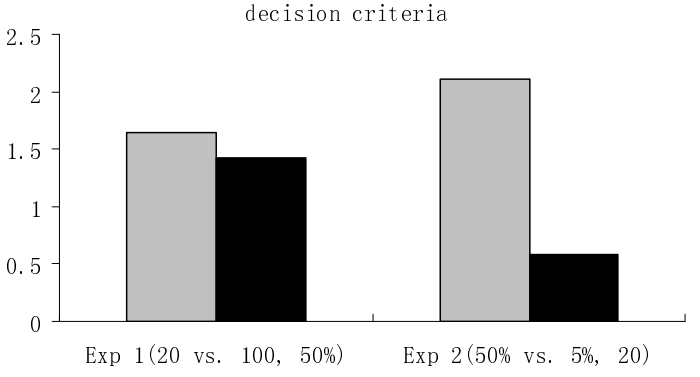

Fig. 3. Subject's decision criteria in different experiment

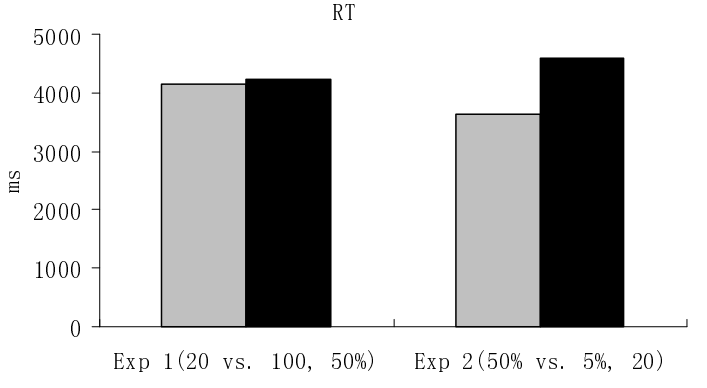

Fig. 4. Subject's RT in different experiment

The detailed data about mean value and standard deviation (SD) of miss rate, decision criteria and RT was in table 1.

Table 1. Mean and SD of miss rate, decision criteria and RT

	Exp 1 NTT = 20 Mean (SD)	Exp 1 NTT = 100 Mean (SD)	Exp 2 50% Mean (SD)	Exp 2 5% Mean (SD)
Miss rate	18.22% (0.08)	30.83% (0.08)	15.24% (0.09)	28% (0.18)
Decision criteria	1.65 (0.98)	1.42 (0.99)	2.16 (0.23)	0.79 (0.56)
RT (ms)	4151 (906)	4215 (474)	3558 (527)	4297 (907)

The results indicated that NTT had more influence on miss rate than target prevalence, but less influence on decision criteria and RT than target prevalence.

4 Discussion

According to formula 2 and 3, miss rate was affected by NTT or the product of target prevalence and N, maybe this was partly the reason that NTT had more influence on miss rate than target prevalence.

The difference of miss rate between blocks in Exp 2 was marginal notable ($p=0.06$), maybe it will be remarkable if adding more subjects. However, comparing Exp 2 with Wolfe's experiments, equal NTT between different target prevalence blocks would weaken the low prevalence effect. Making NTT the same in different target prevalence blocks, the change of miss rate will be more objective and correct.

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