

ST340 Assignment 2

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TODO Q1(b) needs code to load in data Q3

Q2 proof read/ clean up

Notes: cleaned up code for q2

Set Seed for reproducible results

```
set.seed(1123)
```

Question 1

1(a)

$$\begin{aligned} & \sum_{i=1}^n \sum_{n=1}^k \gamma_{in} \log(\prod_{j=1}^p \mu_{kj}^{x_{ij}} (1 - \mu_{kj})^{1-x_{ij}}) \\ &= \sum_{i=1}^n \sum_{n=1}^k \gamma_{in} \sum_{j=1}^p \log(\mu_{kj}^{x_{ij}} (1 - \mu_{kj})^{1-x_{ij}}) \\ &= \sum_{i=1}^n \sum_{n=1}^k \gamma_{in} \sum_{j=1}^p (x_{ij} \log(\mu_{kj}) + (1 - x_{ij}) \log(1 - \mu_{kj})) \end{aligned}$$

To maximise the sum over k we should maximise for each k . So fix k maximising

$$\sum_{i=1}^n \gamma_{in} \sum_{j=1}^p (x_{ij} \log(\mu_{kj}) + (1 - x_{ij}) \log(1 - \mu_{kj}))$$

To maximise the sum over j (as there is no interaction between different j) we can maximise for each j . So we fix j . We thus want to maximise $\sum_{i=1}^n \gamma_{in} (x_{ij} \log(\mu_{kj}) + (1 - x_{ij}) \log(1 - \mu_{kj}))$

We differentiate the sum with respect to μ_{kj} and we set it equal to 0 to find the maximum point.

$$\begin{aligned} & \sum_{i=1}^n \gamma_{in} \left(\frac{x_{ij}}{\mu_{kj}} - \frac{1-x_{ij}}{1-\mu_{kj}} \right) = 0 \\ \implies & \sum_{i=1}^n \gamma_{in} \left(\frac{x_{ij} - x_{ij} \mu_{kj} + x_{ij} \mu_{kj} - \mu_{kj}}{\mu_{kj}(1-\mu_{kj})} \right) = 0 \\ \implies & \frac{1}{\mu_{kj}(1-\mu_{kj})} \sum_{i=1}^n (\gamma_{ik} x_{ij} - \gamma_{ik} \mu_{kj}) = 0 \end{aligned}$$

Due to the expression above, $\mu_{kj} \neq 0$ and $\mu_{kj} \neq 1$

$$\begin{aligned} \implies & \sum_{i=1}^n \gamma_{ik} x_{ij} = \mu_{kj} \sum_{i=1}^n \gamma_{ik} \\ \implies & \mu_{kj} = \frac{\sum_{i=1}^n \gamma_{ik} x_{ij}}{\sum_{i=1}^n \gamma_{ik}} \\ \implies & \mu_k = \frac{\sum_{i=1}^n \gamma_{ik} x_i}{\sum_{i=1}^n \gamma_{ik}} \end{aligned}$$

1(b)

```
load("C:/Users/ricca/Dropbox/PC/Desktop/Uni/ST340/Assignment 2/20newsgroups.rdata")
bernoulli.mass.func=function(x,u){ #using that we assume each element is independent of the oth
```

```

h=vector(length=length(x)) #to get pmf of form given in 1a)
for(i in seq(from=1, to=length(h),by=1)){
  h[i]=(u[i]^x[i])*((1-u[i])^(1-x[i]))
}
return(prod(h))
}

compute_ll <- function(xs,mus,lws,gammas) {
  ll <- 0
  n <- dim(xs)[1]
  K <- dim(mus)[1]
  for (i in 1:n) {
    for (k in 1:K) {
      if (gammas[i,k] > 0) {
        ll <- ll + gammas[i,k]*(lws[k]+log(bernoulli.mass.func(xs[i,],mus[k,]))-log(gammas[i,k]))
      }
    }
  }
  return(ll)
}

logsumexp <- function(x){ return(log(sum(exp(x - max(x))))) + max(x)}
####
em_mix_bernoulli <- function(xs,K,max.numit=Inf) {
  p <- dim(xs)[2]
  n <- dim(xs)[1]

  # lws is log(ws)
  # we work with logs to keep the numbers stable
  # start off with ws all equal
  lws <- rep(log(1/K),K)

  ## start off with a random selection of cluster means
  mus <- matrix(rep(runif(K*p,0,1)),K,p)

  # gammas will be set in the first iteration
  gammas <- matrix(0,n,K)

  converged <- FALSE
  numit <- 0
  ll <- -Inf
  print("iteration : log-likelihood")
  while(!converged && numit < max.numit) {
    numit <- numit + 1
    mus.old <- mus
    ll.old <- ll

    ## E step - calculate gammas
    for (i in 1:n) {
      # the elements of lprs are log(w_k * p_k(x)) for each k in {1,...K}

```

```

lprs <- rep(0,K)
for (k in 1:K) {
  lprs[k] <- lws[k] + log(bernoulli.mass.func(xs[i,],mus[k,]))
}
# gammas[i,k] = w_k * p_k(x) / sum_j {w_j * p_j(x)}
gammas[i,] <- exp(lprs - logsumexp(lprs))
}

ll <- compute_ll(xs,mus,lws,gammas)

# M step - update ws, mus
Ns <- rep(0,K)
for (k in 1:K) {
  Ns[k] <- sum(gammas[,k])
  lws[k] <- log(Ns[k])-log(n)

  mus[k,] <- rep(0,p)

  for (i in 1:n) {
    mus[k,] <- mus[k,]+gammas[i,k]/Ns[k]*xs[i,]
  }
}
print(paste(numit,": ",ll))
# we stop once the increase in the log-likelihood is "small enough"
if (abs(ll-ll.old) < 1e-5) converged <- TRUE
}
return(list(lws=lws,mus=mus,gammas=gammas,ll=ll))
}
#####
Bernoulli.means=em_mix_bernoulli(xs=documents,K=4)

```

1(b)(i)

```

## [1] "iteration : log-likelihood"
## [1] "1 : -1483244.8715972"
## [1] "2 : -251225.204179432"
## [1] "3 : -244455.679554626"
## [1] "4 : -240509.432812035"
## [1] "5 : -238520.33629231"
## [1] "6 : -237498.698566241"
## [1] "7 : -236945.076691015"
## [1] "8 : -236625.285364691"
## [1] "9 : -236422.831255106"
## [1] "10 : -236294.589094426"
## [1] "11 : -236207.270235977"
## [1] "12 : -236149.426838007"
## [1] "13 : -236110.191025373"
## [1] "14 : -236081.652499356"
## [1] "15 : -236060.407690485"
## [1] "16 : -236044.253136473"
## [1] "17 : -236031.645297884"
## [1] "18 : -236021.501800305"
## [1] "19 : -236012.65621364"
## [1] "20 : -236004.73929384"

```

```

## [1] "21 : -235998.535439605"
## [1] "22 : -235993.34248508"
## [1] "23 : -235988.829798389"
## [1] "24 : -235984.835013491"
## [1] "25 : -235981.247524871"
## [1] "26 : -235977.992672898"
## [1] "27 : -235975.022602135"
## [1] "28 : -235972.307893092"
## [1] "29 : -235969.829982028"
## [1] "30 : -235967.573931854"
## [1] "31 : -235965.523721747"
## [1] "32 : -235963.661620982"
## [1] "33 : -235961.969633055"
## [1] "34 : -235960.430739121"
## [1] "35 : -235959.029425811"
## [1] "36 : -235957.751773342"
## [1] "37 : -235956.585354545"
## [1] "38 : -235955.519063066"
## [1] "39 : -235954.542922184"
## [1] "40 : -235953.647899337"
## [1] "41 : -235952.825741418"
## [1] "42 : -235952.068843359"
## [1] "43 : -235951.370167134"
## [1] "44 : -235950.723237471"
## [1] "45 : -235950.122248806"
## [1] "46 : -235949.562306769"
## [1] "47 : -235949.039764146"
## [1] "48 : -235948.552482665"
## [1] "49 : -235948.099747729"
## [1] "50 : -235947.68168328"
## [1] "51 : -235947.298391716"
## [1] "52 : -235946.949300735"
## [1] "53 : -235946.632997845"
## [1] "54 : -235946.347438316"
## [1] "55 : -235946.090257986"
## [1] "56 : -235945.85902133"
## [1] "57 : -235945.651367298"
## [1] "58 : -235945.465078"
## [1] "59 : -235945.298102874"
## [1] "60 : -235945.148561149"
## [1] "61 : -235945.014735042"
## [1] "62 : -235944.895059616"
## [1] "63 : -235944.78811177"
## [1] "64 : -235944.692598823"
## [1] "65 : -235944.607336761"
## [1] "66 : -235944.531043045"
## [1] "67 : -235944.458783287"
## [1] "68 : -235944.319476061"
## [1] "69 : -235943.413090724"
## [1] "70 : -235941.759233088"
## [1] "71 : -235941.328721585"
## [1] "72 : -235941.174708688"
## [1] "73 : -235941.064413625"
## [1] "74 : -235940.972146473"

```

```

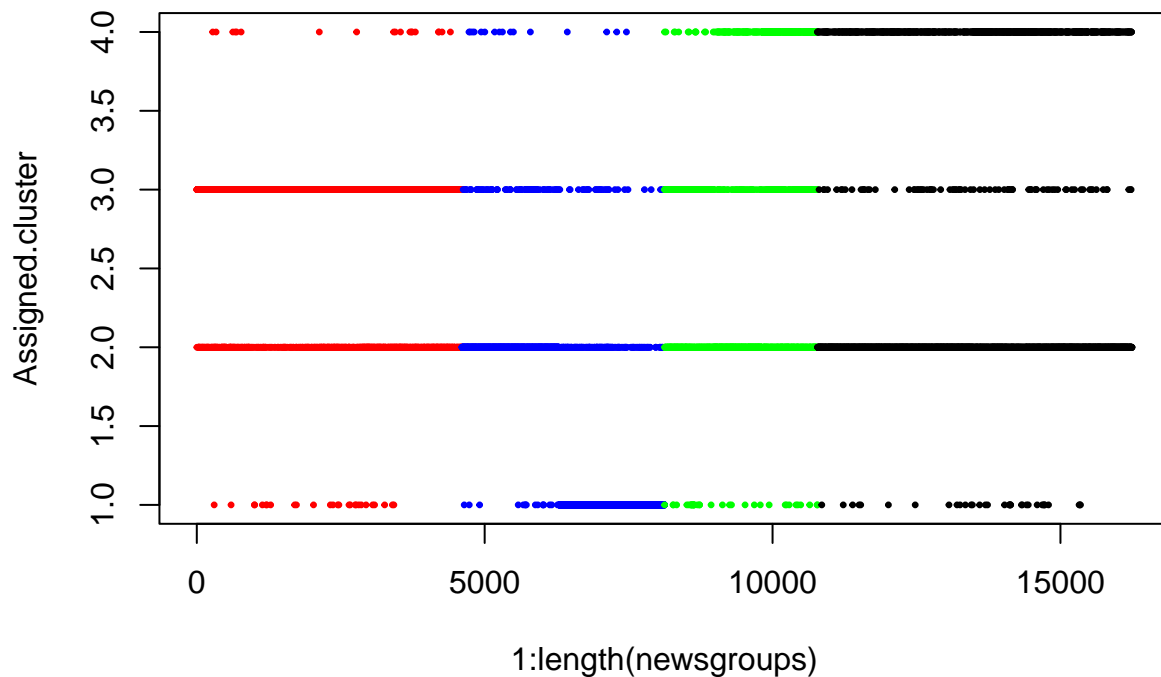
## [1] "75 : -235940.891916521"
## [1] "76 : -235940.821331413"
## [1] "77 : -235940.75898095"
## [1] "78 : -235940.703821753"
## [1] "79 : -235940.65499615"
## [1] "80 : -235940.61176739"
## [1] "81 : -235940.573490804"
## [1] "82 : -235940.539597865"
## [1] "83 : -235940.509585287"
## [1] "84 : -235940.483006744"
## [1] "85 : -235940.459466008"
## [1] "86 : -235940.438610929"
## [1] "87 : -235940.420128182"
## [1] "88 : -235940.403738525"
## [1] "89 : -235940.389192372"
## [1] "90 : -235940.376265771"
## [1] "91 : -235940.364756556"
## [1] "92 : -235940.354480557"
## [1] "93 : -235940.345267857"
## [1] "94 : -235940.336958954"
## [1] "95 : -235940.329400586"
## [1] "96 : -235940.322441298"
## [1] "97 : -235940.31592644"
## [1] "98 : -235940.30969258"
## [1] "99 : -235940.303561527"
## [1] "100 : -235940.297334065"
## [1] "101 : -235940.290784148"
## [1] "102 : -235940.283655074"
## [1] "103 : -235940.275659582"
## [1] "104 : -235940.266487577"
## [1] "105 : -235940.25582522"
## [1] "106 : -235940.243388983"
## [1] "107 : -235940.228975267"
## [1] "108 : -235940.21251909"
## [1] "109 : -235940.194146682"
## [1] "110 : -235940.174199548"
## [1] "111 : -235940.153208141"
## [1] "112 : -235940.131781339"
## [1] "113 : -235940.110026504"
## [1] "114 : -235940.081244372"
## [1] "115 : -235939.956582406"
## [1] "116 : -235939.12791143"
## [1] "117 : -235937.699395021"
## [1] "118 : -235937.302808899"
## [1] "119 : -235937.208052412"
## [1] "120 : -235937.162832703"
## [1] "121 : -235937.132146045"
## [1] "122 : -235937.108144429"
## [1] "123 : -235937.088214723"
## [1] "124 : -235937.071189571"
## [1] "125 : -235937.056427037"
## [1] "126 : -235937.043518267"
## [1] "127 : -235937.032173538"
## [1] "128 : -235937.022171284"

```

[1] "129 : -235937.013333043"
[1] "130 : -235937.005510162"
[1] "131 : -235936.998576058"
[1] "132 : -235936.992421495"
[1] "133 : -235936.986951275"
[1] "134 : -235936.982081849"
[1] "135 : -235936.977739459"
[1] "136 : -235936.973858635"
[1] "137 : -235936.970380949"
[1] "138 : -235936.967253913"
[1] "139 : -235936.964430039"
[1] "140 : -235936.961866095"
[1] "141 : -235936.959522324"
[1] "142 : -235936.957361878"
[1] "143 : -235936.955350304"
[1] "144 : -235936.953455126"
[1] "145 : -235936.951645577"
[1] "146 : -235936.949892487"
[1] "147 : -235936.948168301"
[1] "148 : -235936.946447328"
[1] "149 : -235936.944706283"
[1] "150 : -235936.942925026"
[1] "151 : -235936.941087596"
[1] "152 : -235936.939183382"
[1] "153 : -235936.937208426"
[1] "154 : -235936.935166561"
[1] "155 : -235936.933070125"
[1] "156 : -235936.930940079"
[1] "157 : -235936.928805054"
[1] "158 : -235936.9266995"
[1] "159 : -235936.924660809"
[1] "160 : -235936.922725769"
[1] "161 : -235936.920927124"
[1] "162 : -235936.919290451"
[1] "163 : -235936.917832295"
[1] "164 : -235936.916559389"
[1] "165 : -235936.915469372"
[1] "166 : -235936.914552267"
[1] "167 : -235936.913792749"
[1] "168 : -235936.913172248"
[1] "169 : -235936.912671095"
[1] "170 : -235936.912269934"
[1] "171 : -235936.911950988"
[1] "172 : -235936.911698482"
[1] "173 : -235936.911498987"
[1] "174 : -235936.911341379"
[1] "175 : -235936.91121659"
[1] "176 : -235936.911117421"
[1] "177 : -235936.911038194"
[1] "178 : -235936.910974475"
[1] "179 : -235936.910922861"
[1] "180 : -235936.910880701"
[1] "181 : -235936.91084598"
[1] "182 : -235936.910817153"

```
## [1] "183 : -235936.910793013"
## [1] "184 : -235936.910772643"
## [1] "185 : -235936.910755348"
## [1] "186 : -235936.910740551"
## [1] "187 : -235936.910727819"
## [1] "188 : -235936.910716805"
## [1] "189 : -235936.910707257"

Assigned.cluster=vector(length=dim(documents)[1])
for(i in 1:length(Assigned.cluster)){
  x=Bernoulli.means$gammas[i,]
  y=sort(x,decreasing=TRUE)
  Assigned.cluster[i]=which(x==y[1])
}
col.seq=vector(length=length(newsgroups))
for(i in 1:length(col.seq)){
  if(newsgroups[i]==1){col.seq[i]="red"}
  else{
    if(newsgroups[i]==2){col.seq[i]="blue"}
    else{
      if(newsgroups[i]==3){col.seq[i]="green"}
      else{col.seq[i]="black"}
    }
  }
}
}
plot(x=1:length(newsgroups),Assigned.cluster,col=col.seq,pch=20,cex=0.5)
```



```
Assigned.cluster.corrected=vector(length=length(Assigned.cluster))
for(i in 1:length(Assigned.cluster.corrected)){
  if(Assigned.cluster[i]==1){Assigned.cluster.corrected[i]=2}
  else{
    if(Assigned.cluster[i]==2){Assigned.cluster.corrected[i]=4}
    else{
      if(Assigned.cluster[i]==3){Assigned.cluster.corrected[i]=1}
      else{Assigned.cluster.corrected[i]=3}
    }
  }
}
}
proportion.correct=length(which(newsgroups==Assigned.cluster.corrected))/length(newsgroups)
proportion.correct
```

```
## [1] 0.6076222
```

1(b)(ii) The clustering provided by the algorithm is ok. It struggles to really distinguish between clusters and there is a lot of ‘mixing’ between assigned clusters and true labels. It does very well at certain things. For example, if the algorithm returns cluster 3 or 4 the we can be quite sure that the true label is not 1 (red). If it returns cluster 1 we can be quite sure the true label is not 1 (red). It looks like cluster 4 relates to label 3 sci. (green), cluster 1 relates to label 2 rec. (blue), cluster 2 relates to label 4 talk. (black) and cluster 3 relates to label 1 comp. (red). This then correctly assigns 60.8% of points, which is actually quite good accuracy and better than I expected just from looking at it. (I tried all ‘reasonable’ relationships between clusters and labels and this had the highest proportion of correctly assigned points. The next highest was cluster 1 = label 2, cluster 2 = label 4, cluster 3 = label 1, cluster 4 = label 3 with correct proportion of 48.5%. This also looks like it could be true from the diagram. All the other relationships gave proportions around 25% which is no better than randomly choosing. Note these best two both said that cluster 1 = rec. (blue) and cluster 3 = comp. (red) so we can be pretty sure that these are right but it is more difficult to decide which cluster is which label for the other two). Here, label refers to the topic of the posting. #####

1(b)(iii) The Output is quite sensitive to the intialisation mus. When I change these (by changing the seed or the distribution of them/ the way they are generated), but keep them random and quite similar then the output doesn’t change much and I still get the same sorts of clusters but the number of iterations does vary quite a bit. However, when any of the entries in any of the mus are 0 or 1, the algorithm fails as the likelihood can be 0 so we end up dividing by 0. Also, when I start all the mus to be identical (a matrix with the same entry in every position) the algorithm only does 3 iterations, and says that all the clusters are the same with each point coming from a cluster with probability 0.25! With the original mus being the equal, but the entries within each one being different the algorithm works as normal. Different runs will often ‘relabel’ the clusters that it returns but the actual clusters themselves are quite similar. It does then take a bit of examining to work out which cluster relates to which topic on different runs. For example, on another run of the algorithm it returned clusters which were very similar to the ones above, but cluster 1 of this run related to cluster 3 of the one above and other labels of clsuters were also changed. This is clearly wrong and shows that we need to start with a difference between clusters. Of course, we only find a local maximum and not necessarily a global maximum, so we need to be aware of this as different runs could provide different local maxima just by chance. Therefore in practice, it is probably a good idea to run the algorithm several times with random initialisation mus to check that what we get is quite similar. Small changes to the intialisation don’t appear to matter, as long as we keep them random and not to any extreme where we allow them to be 0 or 1. (In mine I used runif(0,1). This is fine as the probability of a 0 or 1 is zero and ?runif tells us that R will not return 0 or 1..)

Question 2

2(a)

Thompson sampling n is total number of runs x and y are success probabilities of arms


```

thompson = function(n, x, y, a.0, b.0) {
  i=1
  arm=rep(0, n)      # Vector representing which arm chosen
  reward=rep(0, n)    # Vector of rewards
  s.1 = 0
  f.1 = 0
  s.2 = 0
  f.2 = 0
  while(i <= n) {
    M.1 = rbeta(1, a.0 + s.1, b.0 + f.1)
    M.2 = rbeta(1, a.0 + s.2, b.0 + f.2)

    if(M.1 >= M.2) {
      arm[i] = 1
    } else {
      arm[i] = 2
    }

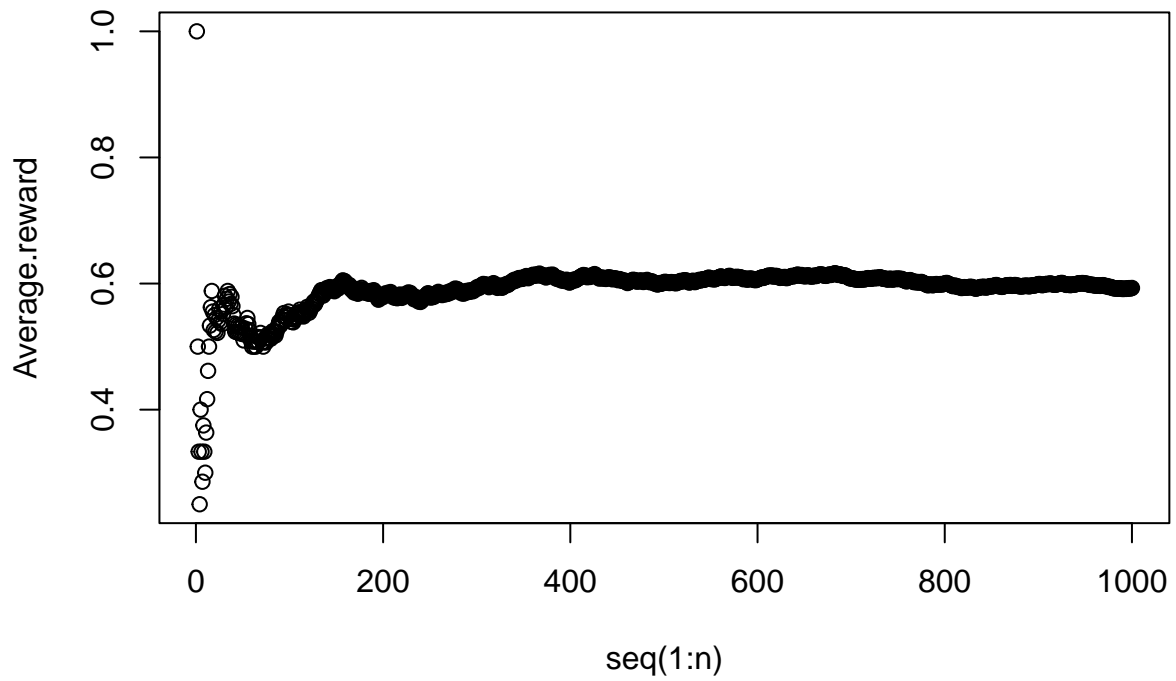
    if(arm[i] == 1) {
      reward[i] = rbinom(1, 1, x)
      s.1 = s.1 + reward[i]      # Update successes and failures so far for each arm
      f.1 = f.1 + 1 - reward[i]
    } else {
      reward[i] = rbinom(1,1,y)
      s.2 = s.2 + reward[i]
      f.2 = f.2 + 1 - reward[i]
    }

    i = i + 1
  }
  Average.reward=vector(length=n)
  for(i in 1:n){Average.reward[i]=sum(reward[1:i])/i}
  return(cbind(arm, reward,Average.reward, plot(seq(1:n),Average.reward)))
}

```

Thompson Sampling Test

```
thompson(1000, 0.6, 0.4, 10, 10)
```



##		arm	reward	Average.reward
##	[1,]	1	1	1.0000000
##	[2,]	2	0	0.5000000
##	[3,]	2	0	0.3333333
##	[4,]	1	0	0.2500000
##	[5,]	1	1	0.4000000
##	[6,]	2	0	0.3333333
##	[7,]	1	0	0.2857143
##	[8,]	2	1	0.3750000
##	[9,]	1	0	0.3333333
##	[10,]	2	0	0.3000000
##	[11,]	2	1	0.3636364
##	[12,]	1	1	0.4166667
##	[13,]	1	1	0.4615385
##	[14,]	1	1	0.5000000
##	[15,]	1	1	0.5333333
##	[16,]	1	1	0.5625000
##	[17,]	1	1	0.5882353
##	[18,]	1	0	0.5555556
##	[19,]	1	0	0.5263158
##	[20,]	1	1	0.5500000
##	[21,]	1	0	0.5238095
##	[22,]	2	1	0.5454545
##	[23,]	1	0	0.5217391
##	[24,]	1	1	0.5416667
##	[25,]	1	1	0.5600000

##	[26,]	1	0	0.5384615
##	[27,]	1	1	0.5555556
##	[28,]	1	0	0.5357143
##	[29,]	2	1	0.5517241
##	[30,]	1	1	0.5666667
##	[31,]	2	1	0.5806452
##	[32,]	1	0	0.5625000
##	[33,]	2	1	0.5757576
##	[34,]	1	1	0.5882353
##	[35,]	1	0	0.5714286
##	[36,]	2	1	0.5833333
##	[37,]	2	0	0.5675676
##	[38,]	2	1	0.5789474
##	[39,]	1	0	0.5641026
##	[40,]	1	0	0.5500000
##	[41,]	2	0	0.5365854
##	[42,]	2	0	0.5238095
##	[43,]	2	1	0.5348837
##	[44,]	2	0	0.5227273
##	[45,]	1	1	0.5333333
##	[46,]	2	0	0.5217391
##	[47,]	2	1	0.5319149
##	[48,]	2	0	0.5208333
##	[49,]	1	1	0.5306122
##	[50,]	2	0	0.5200000
##	[51,]	1	0	0.5098039
##	[52,]	1	1	0.5192308
##	[53,]	2	1	0.5283019
##	[54,]	1	1	0.5370370
##	[55,]	1	1	0.5454545
##	[56,]	2	0	0.5357143
##	[57,]	2	0	0.5263158
##	[58,]	2	0	0.5172414
##	[59,]	1	0	0.5084746
##	[60,]	2	0	0.5000000
##	[61,]	1	1	0.5081967
##	[62,]	1	0	0.5000000
##	[63,]	1	1	0.5079365
##	[64,]	1	0	0.5000000
##	[65,]	2	1	0.5076923
##	[66,]	1	1	0.5151515
##	[67,]	1	0	0.5074627
##	[68,]	1	1	0.5147059
##	[69,]	1	1	0.5217391
##	[70,]	1	0	0.5142857
##	[71,]	1	0	0.5070423
##	[72,]	1	0	0.5000000
##	[73,]	1	1	0.5068493
##	[74,]	1	1	0.5135135
##	[75,]	2	0	0.5066667
##	[76,]	1	1	0.5131579
##	[77,]	1	1	0.5194805
##	[78,]	1	0	0.5128205
##	[79,]	1	1	0.5189873

##	[80,]	2	0	0.5125000
##	[81,]	1	1	0.5185185
##	[82,]	1	1	0.5243902
##	[83,]	1	0	0.5180723
##	[84,]	1	1	0.5238095
##	[85,]	1	0	0.5176471
##	[86,]	1	1	0.5232558
##	[87,]	1	1	0.5287356
##	[88,]	1	1	0.5340909
##	[89,]	1	1	0.5393258
##	[90,]	1	0	0.5333333
##	[91,]	2	1	0.5384615
##	[92,]	1	1	0.5434783
##	[93,]	1	1	0.5483871
##	[94,]	1	1	0.5531915
##	[95,]	1	0	0.5473684
##	[96,]	1	0	0.5416667
##	[97,]	1	1	0.5463918
##	[98,]	1	1	0.5510204
##	[99,]	1	1	0.5555556
##	[100,]	1	0	0.5500000
##	[101,]	2	0	0.5445545
##	[102,]	1	0	0.5392157
##	[103,]	1	1	0.5436893
##	[104,]	1	0	0.5384615
##	[105,]	1	1	0.5428571
##	[106,]	1	1	0.5471698
##	[107,]	1	1	0.5514019
##	[108,]	1	0	0.5462963
##	[109,]	1	1	0.5504587
##	[110,]	1	1	0.5545455
##	[111,]	1	1	0.5585586
##	[112,]	1	0	0.5535714
##	[113,]	1	0	0.5486726
##	[114,]	1	1	0.5526316
##	[115,]	1	0	0.5478261
##	[116,]	1	1	0.5517241
##	[117,]	1	1	0.5555556
##	[118,]	1	1	0.5593220
##	[119,]	1	1	0.5630252
##	[120,]	1	0	0.5583333
##	[121,]	1	0	0.5537190
##	[122,]	1	1	0.5573770
##	[123,]	1	1	0.5609756
##	[124,]	1	1	0.5645161
##	[125,]	1	1	0.5680000
##	[126,]	1	1	0.5714286
##	[127,]	2	0	0.5669291
##	[128,]	1	1	0.5703125
##	[129,]	1	1	0.5736434
##	[130,]	1	1	0.5769231
##	[131,]	1	1	0.5801527
##	[132,]	1	1	0.5833333
##	[133,]	1	1	0.5864662

##	[134,]	1	1	0.5895522
##	[135,]	1	0	0.5851852
##	[136,]	1	0	0.5808824
##	[137,]	1	1	0.5839416
##	[138,]	1	1	0.5869565
##	[139,]	1	1	0.5899281
##	[140,]	1	1	0.5928571
##	[141,]	1	0	0.5886525
##	[142,]	1	1	0.5915493
##	[143,]	1	1	0.5944056
##	[144,]	1	0	0.5902778
##	[145,]	1	1	0.5931034
##	[146,]	1	0	0.5890411
##	[147,]	1	1	0.5918367
##	[148,]	1	0	0.5878378
##	[149,]	1	1	0.5906040
##	[150,]	1	1	0.5933333
##	[151,]	1	1	0.5960265
##	[152,]	1	0	0.5921053
##	[153,]	1	1	0.5947712
##	[154,]	1	1	0.5974026
##	[155,]	1	1	0.6000000
##	[156,]	1	1	0.6025641
##	[157,]	1	1	0.6050955
##	[158,]	1	0	0.6012658
##	[159,]	1	1	0.6037736
##	[160,]	1	0	0.6000000
##	[161,]	1	0	0.5962733
##	[162,]	1	1	0.5987654
##	[163,]	1	0	0.5950920
##	[164,]	1	1	0.5975610
##	[165,]	1	0	0.5939394
##	[166,]	1	0	0.5903614
##	[167,]	1	1	0.5928144
##	[168,]	1	0	0.5892857
##	[169,]	1	0	0.5857988
##	[170,]	1	1	0.5882353
##	[171,]	1	1	0.5906433
##	[172,]	1	0	0.5872093
##	[173,]	1	0	0.5838150
##	[174,]	1	1	0.5862069
##	[175,]	1	1	0.5885714
##	[176,]	1	1	0.5909091
##	[177,]	1	1	0.5932203
##	[178,]	1	0	0.5898876
##	[179,]	1	0	0.5865922
##	[180,]	1	1	0.5888889
##	[181,]	1	0	0.5856354
##	[182,]	1	1	0.5879121
##	[183,]	1	0	0.5846995
##	[184,]	1	1	0.5869565
##	[185,]	1	0	0.5837838
##	[186,]	1	1	0.5860215
##	[187,]	1	1	0.5882353

##	[188,]	1	0	0.5851064
##	[189,]	1	1	0.5873016
##	[190,]	1	1	0.5894737
##	[191,]	1	0	0.5863874
##	[192,]	1	0	0.5833333
##	[193,]	1	0	0.5803109
##	[194,]	1	0	0.5773196
##	[195,]	1	0	0.5743590
##	[196,]	1	1	0.5765306
##	[197,]	1	1	0.5786802
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##	[199,]	1	0	0.5778894
##	[200,]	1	1	0.5800000
##	[201,]	1	1	0.5820896
##	[202,]	1	1	0.5841584
##	[203,]	1	0	0.5812808
##	[204,]	1	1	0.5833333
##	[205,]	1	1	0.5853659
##	[206,]	1	0	0.5825243
##	[207,]	1	1	0.5845411
##	[208,]	1	1	0.5865385
##	[209,]	1	0	0.5837321
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##	[211,]	1	0	0.5781991
##	[212,]	1	1	0.5801887
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##	[222,]	1	1	0.5810811
##	[223,]	1	1	0.5829596
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##	[230,]	1	0	0.5826087
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##	[232,]	1	0	0.5775862
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##	[239,]	1	1	0.5732218
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##	[241,]	1	1	0.5726141

##	[242,]	1	1	0.5743802
##	[243,]	1	1	0.5761317
##	[244,]	1	1	0.5778689
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##	[247,]	1	1	0.5829960
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##	[251,]	1	0	0.5776892
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##	[273,]	1	0	0.5860806
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##	[276,]	1	1	0.5905797
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##	[302,]	1	0	0.5927152
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##	[305,]	1	1	0.5967213
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##	[332,]	1	1	0.5993976
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##	[503,]	1	1	0.6023857
##	[504,]	1	0	0.6011905
##	[505,]	1	1	0.6019802
##	[506,]	1	0	0.6007905
##	[507,]	1	1	0.6015779
##	[508,]	1	1	0.6023622
##	[509,]	1	0	0.6011788
##	[510,]	1	1	0.6019608
##	[511,]	1	0	0.6007828

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##	[513,]	1	0	0.6003899
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##	[516,]	1	1	0.6027132
##	[517,]	1	1	0.6034816
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##	[521,]	1	1	0.6046065
##	[522,]	1	1	0.6053640
##	[523,]	1	0	0.6042065
##	[524,]	1	1	0.6049618
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##	[526,]	1	0	0.6026616
##	[527,]	1	0	0.6015180
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##	[531,]	1	1	0.6045198
##	[532,]	1	0	0.6033835
##	[533,]	1	0	0.6022514
##	[534,]	1	1	0.6029963
##	[535,]	1	1	0.6037383
##	[536,]	1	1	0.6044776
##	[537,]	1	1	0.6052142
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##	[542,]	1	1	0.6070111
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##	[546,]	1	1	0.6080586
##	[547,]	1	1	0.6087751
##	[548,]	1	1	0.6094891
##	[549,]	1	0	0.6083789
##	[550,]	1	0	0.6072727
##	[551,]	1	1	0.6079855
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##	[553,]	1	1	0.6075949
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##	[562,]	1	0	0.6103203
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##	[947,]	1	1	0.6008448
##	[948,]	1	0	0.6002110
##	[949,]	1	1	0.6006322
##	[950,]	1	0	0.6000000
##	[951,]	1	0	0.5993691
##	[952,]	1	1	0.5997899
##	[953,]	1	0	0.5991605
##	[954,]	1	0	0.5985325
##	[955,]	1	0	0.5979058
##	[956,]	1	1	0.5983264
##	[957,]	1	0	0.5977011
##	[958,]	1	1	0.5981211
##	[959,]	1	0	0.5974974
##	[960,]	1	0	0.5968750
##	[961,]	1	1	0.5972945
##	[962,]	1	0	0.5966736
##	[963,]	1	1	0.5970924
##	[964,]	1	0	0.5964730
##	[965,]	1	1	0.5968912
##	[966,]	1	0	0.5962733
##	[967,]	1	1	0.5966908
##	[968,]	1	1	0.5971074
##	[969,]	1	1	0.5975232
##	[970,]	1	0	0.5969072
##	[971,]	1	0	0.5962925
##	[972,]	1	0	0.5956790
##	[973,]	1	1	0.5960946
##	[974,]	1	0	0.5954825
##	[975,]	1	0	0.5948718
##	[976,]	1	0	0.5942623
##	[977,]	1	1	0.5946776
##	[978,]	1	0	0.5940695
##	[979,]	1	0	0.5934627
##	[980,]	1	0	0.5928571
##	[981,]	1	0	0.5922528
##	[982,]	1	1	0.5926680
##	[983,]	1	0	0.5920651
##	[984,]	2	1	0.5924797
##	[985,]	1	0	0.5918782
##	[986,]	1	1	0.5922921
##	[987,]	1	1	0.5927052
##	[988,]	1	0	0.5921053
##	[989,]	1	0	0.5915066
##	[990,]	1	1	0.5919192
##	[991,]	1	0	0.5913219
##	[992,]	1	1	0.5917339
##	[993,]	1	1	0.5921450
##	[994,]	1	0	0.5915493
##	[995,]	1	1	0.5919598
##	[996,]	1	1	0.5923695
##	[997,]	1	1	0.5927783

```
## [998,] 1 0 0.5921844
## [999,] 1 1 0.5925926
## [1000,] 1 1 0.5930000
```

Epsilon-decreasing

```
epsilon.decreasing = function(n, x, y, e=vector(length=n)) {

  i = 3

  s.1 = 0    # Success rate so far for 1
  s.2 = 0    # Success rate so far for 2

  a = rep(0, n)    # Vector of which arm chosen
  r = rep(0, n)    # Vector of rewards

  a[1] = 1          #Begin by playing each arm once
  a[2] = 2

  random.arm=vector(length=n)    # For the purposes of 2b and 2c

  while(i <= n) {
    v = rbinom(1, 1, e[i])
    if(v == 1) {    #choose arm randomly with prob epsilon
      random.arm[i] = 1
      w = rbinom(1, 1, 0.5)

      if(w==1) {
        a[i]=1
      } else {
        a[i] = 2
      }
    } else {
      random.arm[i] = 0

      if(s.1 > s.2) {
        a[i] = 1
      } else {
        if(s.1 < s.2) {
          a[i] = 2
        } else {
          o = rbinom(1, 1, 0.5)
          if(o == 10) {
            a[i] = 1
          } else {
            a[i] = 2
          }
        }
      }    #if arm 1 better so far choose arm 1. If equal choose randomly
    }
  }

  if(a[i]==1) {
    r[i]=rbinom(1, 1, x)
  }
}
```

```

if(a[i]==2) {
  r[i]=rbinom(1, 1, y)
}

d = which(a == 1)

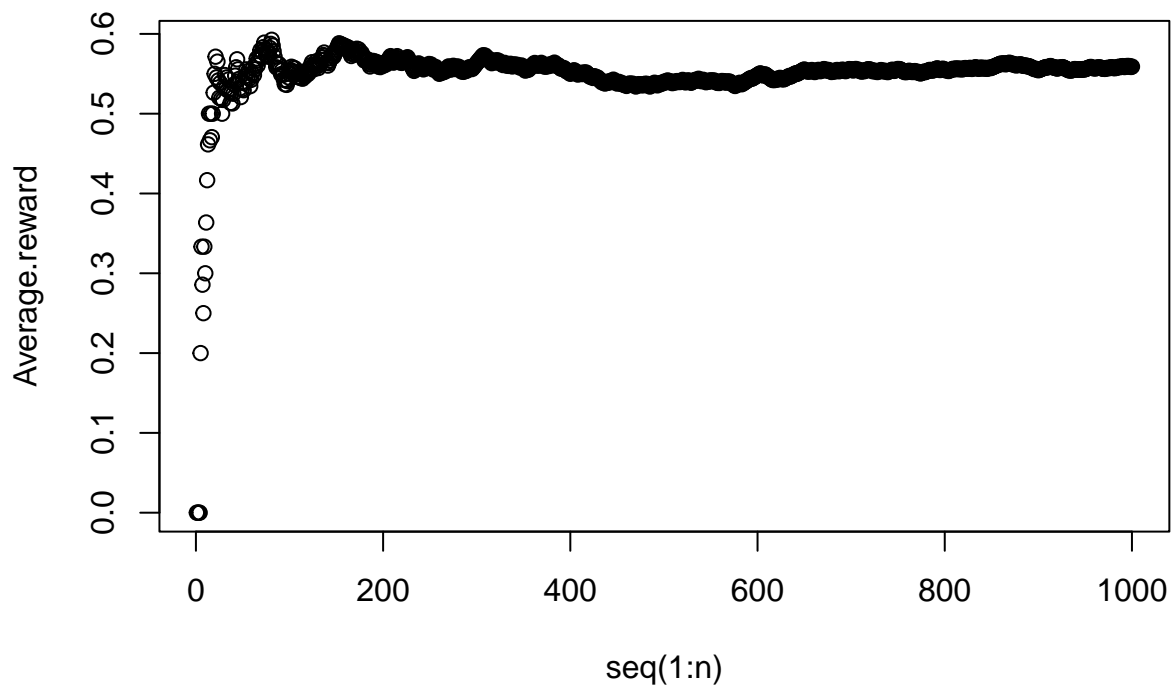
f = which(a == 2)

s.1 = sum(r[d])/length(d)  # Update success rates for arms. As arm chosen is originally set at 0 th
s.2 = sum(r[f])/length(f)
i=i+1  # iteration
}
Average.reward=vector(length=n)
for(i in 1:n){Average.reward[i]=sum(r[1:i])/i}

return(cbind(random.arm, a, r,Average.reward,plot(seq(1:n),Average.reward)))
}

n=1000
epsilon=vector(length=n)
for (i in 1:n){
  epsilon[i] = 0.5
}
epsilon.decreasing(1000, 0.6, 0.4, e=epsilon)

```



```
##      random.arm a r Average.reward
```

##	[1,]	0 1 0	0.0000000
##	[2,]	0 2 0	0.0000000
##	[3,]	1 2 0	0.0000000
##	[4,]	0 2 0	0.0000000
##	[5,]	1 1 1	0.2000000
##	[6,]	0 1 1	0.3333333
##	[7,]	1 2 0	0.2857143
##	[8,]	0 1 0	0.2500000
##	[9,]	0 1 1	0.3333333
##	[10,]	1 1 0	0.3000000
##	[11,]	0 1 1	0.3636364
##	[12,]	1 1 1	0.4166667
##	[13,]	1 2 1	0.4615385
##	[14,]	0 1 1	0.5000000
##	[15,]	1 1 0	0.4666667
##	[16,]	0 1 1	0.5000000
##	[17,]	0 1 0	0.4705882
##	[18,]	0 1 1	0.5000000
##	[19,]	1 2 1	0.5263158
##	[20,]	1 2 1	0.5500000
##	[21,]	0 1 1	0.5714286
##	[22,]	0 1 0	0.5454545
##	[23,]	1 1 1	0.5652174
##	[24,]	1 2 0	0.5416667
##	[25,]	1 2 0	0.5200000
##	[26,]	0 1 1	0.5384615
##	[27,]	1 1 0	0.5185185
##	[28,]	1 2 0	0.5000000
##	[29,]	0 1 1	0.5172414
##	[30,]	0 1 1	0.5333333
##	[31,]	0 1 1	0.5483871
##	[32,]	0 1 0	0.5312500
##	[33,]	0 1 1	0.5454545
##	[34,]	1 1 0	0.5294118
##	[35,]	1 1 1	0.5428571
##	[36,]	1 1 0	0.5277778
##	[37,]	1 2 0	0.5135135
##	[38,]	0 1 1	0.5263158
##	[39,]	1 2 0	0.5128205
##	[40,]	0 1 1	0.5250000
##	[41,]	0 1 1	0.5365854
##	[42,]	0 1 1	0.5476190
##	[43,]	1 2 1	0.5581395
##	[44,]	0 1 1	0.5681818
##	[45,]	0 1 0	0.5555556
##	[46,]	0 1 0	0.5434783
##	[47,]	0 1 0	0.5319149
##	[48,]	0 1 0	0.5208333
##	[49,]	0 1 1	0.5306122
##	[50,]	1 2 1	0.5400000
##	[51,]	0 1 0	0.5294118
##	[52,]	0 1 1	0.5384615
##	[53,]	1 1 1	0.5471698
##	[54,]	1 1 1	0.5555556

##	[55,]	1 2 0	0.5454545
##	[56,]	1 2 1	0.5535714
##	[57,]	1 1 0	0.5438596
##	[58,]	0 1 0	0.5344828
##	[59,]	1 1 1	0.5423729
##	[60,]	1 1 1	0.5500000
##	[61,]	0 1 1	0.5573770
##	[62,]	0 1 0	0.5483871
##	[63,]	0 1 1	0.5555556
##	[64,]	0 1 1	0.5625000
##	[65,]	0 1 1	0.5692308
##	[66,]	1 2 0	0.5606061
##	[67,]	0 1 1	0.5671642
##	[68,]	0 1 1	0.5735294
##	[69,]	0 1 1	0.5797101
##	[70,]	1 1 0	0.5714286
##	[71,]	1 1 1	0.5774648
##	[72,]	0 1 1	0.5833333
##	[73,]	0 1 1	0.5890411
##	[74,]	1 2 0	0.5810811
##	[75,]	1 2 0	0.5733333
##	[76,]	0 1 1	0.5789474
##	[77,]	1 2 0	0.5714286
##	[78,]	1 2 1	0.5769231
##	[79,]	1 1 1	0.5822785
##	[80,]	1 1 1	0.5875000
##	[81,]	0 1 1	0.5925926
##	[82,]	1 1 0	0.5853659
##	[83,]	1 2 0	0.5783133
##	[84,]	0 1 0	0.5714286
##	[85,]	0 1 0	0.5647059
##	[86,]	1 2 0	0.5581395
##	[87,]	1 1 1	0.5632184
##	[88,]	1 1 0	0.5568182
##	[89,]	1 1 1	0.5617978
##	[90,]	1 1 0	0.5555556
##	[91,]	1 2 0	0.5494505
##	[92,]	1 1 1	0.5543478
##	[93,]	0 1 0	0.5483871
##	[94,]	1 2 0	0.5425532
##	[95,]	0 1 0	0.5368421
##	[96,]	0 1 1	0.5416667
##	[97,]	1 1 0	0.5360825
##	[98,]	0 1 1	0.5408163
##	[99,]	1 1 1	0.5454545
##	[100,]	1 1 1	0.5500000
##	[101,]	0 1 1	0.5544554
##	[102,]	1 1 1	0.5588235
##	[103,]	1 1 0	0.5533981
##	[104,]	1 1 1	0.5576923
##	[105,]	1 1 0	0.5523810
##	[106,]	0 1 1	0.5566038
##	[107,]	1 2 0	0.5514019
##	[108,]	0 1 0	0.5462963

##	[109,]	1 1 1	0.5504587
##	[110,]	0 1 0	0.5454545
##	[111,]	0 1 1	0.5495495
##	[112,]	1 2 0	0.5446429
##	[113,]	0 1 1	0.5486726
##	[114,]	0 1 0	0.5438596
##	[115,]	1 1 1	0.5478261
##	[116,]	1 1 1	0.5517241
##	[117,]	0 1 0	0.5470085
##	[118,]	0 1 1	0.5508475
##	[119,]	1 1 1	0.5546218
##	[120,]	0 1 0	0.5500000
##	[121,]	1 2 1	0.5537190
##	[122,]	0 1 1	0.5573770
##	[123,]	0 1 1	0.5609756
##	[124,]	0 1 1	0.5645161
##	[125,]	0 1 0	0.5600000
##	[126,]	1 1 0	0.5555556
##	[127,]	0 1 1	0.5590551
##	[128,]	0 1 1	0.5625000
##	[129,]	0 1 1	0.5658915
##	[130,]	0 1 0	0.5615385
##	[131,]	0 1 0	0.5572519
##	[132,]	0 1 1	0.5606061
##	[133,]	0 1 1	0.5639098
##	[134,]	1 2 1	0.5671642
##	[135,]	0 1 1	0.5703704
##	[136,]	1 1 1	0.5735294
##	[137,]	0 1 1	0.5766423
##	[138,]	1 2 0	0.5724638
##	[139,]	0 1 0	0.5683453
##	[140,]	1 1 0	0.5642857
##	[141,]	1 2 0	0.5602837
##	[142,]	1 1 1	0.5633803
##	[143,]	1 2 1	0.5664336
##	[144,]	0 1 1	0.5694444
##	[145,]	0 1 1	0.5724138
##	[146,]	1 1 1	0.5753425
##	[147,]	1 2 0	0.5714286
##	[148,]	1 1 1	0.5743243
##	[149,]	0 1 1	0.5771812
##	[150,]	1 1 1	0.5800000
##	[151,]	0 1 1	0.5827815
##	[152,]	1 2 1	0.5855263
##	[153,]	0 1 1	0.5882353
##	[154,]	1 2 0	0.5844156
##	[155,]	1 1 1	0.5870968
##	[156,]	0 1 0	0.5833333
##	[157,]	0 1 1	0.5859873
##	[158,]	1 2 0	0.5822785
##	[159,]	0 1 1	0.5849057
##	[160,]	1 2 0	0.5812500
##	[161,]	1 2 1	0.5838509
##	[162,]	1 2 0	0.5802469

##	[163,]	0 1 1	0.5828221
##	[164,]	0 1 0	0.5792683
##	[165,]	1 2 0	0.5757576
##	[166,]	1 1 0	0.5722892
##	[167,]	1 2 1	0.5748503
##	[168,]	1 1 1	0.5773810
##	[169,]	1 1 0	0.5739645
##	[170,]	1 2 1	0.5764706
##	[171,]	0 1 1	0.5789474
##	[172,]	0 1 1	0.5813953
##	[173,]	1 2 0	0.5780347
##	[174,]	0 1 1	0.5804598
##	[175,]	0 1 0	0.5771429
##	[176,]	0 1 0	0.5738636
##	[177,]	0 1 1	0.5762712
##	[178,]	0 1 0	0.5730337
##	[179,]	0 1 0	0.5698324
##	[180,]	0 1 0	0.5666667
##	[181,]	0 1 1	0.5690608
##	[182,]	1 2 0	0.5659341
##	[183,]	1 1 1	0.5683060
##	[184,]	1 1 0	0.5652174
##	[185,]	0 1 0	0.5621622
##	[186,]	0 1 0	0.5591398
##	[187,]	0 1 1	0.5614973
##	[188,]	1 2 1	0.5638298
##	[189,]	0 1 1	0.5661376
##	[190,]	0 1 0	0.5631579
##	[191,]	1 1 1	0.5654450
##	[192,]	1 2 0	0.5625000
##	[193,]	0 1 1	0.5647668
##	[194,]	1 1 0	0.5618557
##	[195,]	0 1 0	0.5589744
##	[196,]	1 1 1	0.5612245
##	[197,]	1 1 0	0.5583756
##	[198,]	0 1 1	0.5606061
##	[199,]	1 1 1	0.5628141
##	[200,]	0 1 0	0.5600000
##	[201,]	1 1 1	0.5621891
##	[202,]	0 1 1	0.5643564
##	[203,]	0 1 0	0.5615764
##	[204,]	1 1 1	0.5637255
##	[205,]	0 1 1	0.5658537
##	[206,]	0 1 1	0.5679612
##	[207,]	1 1 1	0.5700483
##	[208,]	1 1 1	0.5721154
##	[209,]	0 1 0	0.5693780
##	[210,]	1 2 0	0.5666667
##	[211,]	1 1 0	0.5639810
##	[212,]	1 1 1	0.5660377
##	[213,]	1 1 1	0.5680751
##	[214,]	1 2 1	0.5700935
##	[215,]	0 1 1	0.5720930
##	[216,]	1 2 0	0.5694444

##	[217,]	0 1 0	0.5668203
##	[218,]	0 1 0	0.5642202
##	[219,]	0 1 1	0.5662100
##	[220,]	0 1 0	0.5636364
##	[221,]	1 1 1	0.5656109
##	[222,]	0 1 1	0.5675676
##	[223,]	1 1 0	0.5650224
##	[224,]	1 2 1	0.5669643
##	[225,]	1 2 1	0.5688889
##	[226,]	1 2 1	0.5707965
##	[227,]	0 1 0	0.5682819
##	[228,]	1 1 0	0.5657895
##	[229,]	1 2 0	0.5633188
##	[230,]	1 2 0	0.5608696
##	[231,]	0 1 0	0.5584416
##	[232,]	0 1 0	0.5560345
##	[233,]	0 1 0	0.5536481
##	[234,]	1 1 1	0.5555556
##	[235,]	0 1 1	0.5574468
##	[236,]	1 1 1	0.5593220
##	[237,]	0 1 1	0.5611814
##	[238,]	1 1 1	0.5630252
##	[239,]	1 2 0	0.5606695
##	[240,]	1 2 0	0.5583333
##	[241,]	0 1 1	0.5601660
##	[242,]	0 1 0	0.5578512
##	[243,]	0 1 0	0.5555556
##	[244,]	0 1 1	0.5573770
##	[245,]	1 1 1	0.5591837
##	[246,]	0 1 0	0.5569106
##	[247,]	0 1 1	0.5587045
##	[248,]	1 2 1	0.5604839
##	[249,]	1 1 1	0.5622490
##	[250,]	0 1 0	0.5600000
##	[251,]	0 1 1	0.5617530
##	[252,]	1 2 0	0.5595238
##	[253,]	1 2 0	0.5573123
##	[254,]	1 2 0	0.5551181
##	[255,]	0 1 1	0.5568627
##	[256,]	1 1 1	0.5585938
##	[257,]	1 1 0	0.5564202
##	[258,]	0 1 0	0.5542636
##	[259,]	0 1 0	0.5521236
##	[260,]	0 1 0	0.5500000
##	[261,]	0 1 1	0.5517241
##	[262,]	0 1 1	0.5534351
##	[263,]	0 1 0	0.5513308
##	[264,]	1 2 1	0.5530303
##	[265,]	0 1 1	0.5547170
##	[266,]	0 1 0	0.5526316
##	[267,]	0 1 1	0.5543071
##	[268,]	0 1 1	0.5559701
##	[269,]	0 1 1	0.5576208
##	[270,]	0 1 1	0.5592593

##	[271,]	0 1 0	0.5571956
##	[272,]	0 1 0	0.5551471
##	[273,]	0 1 1	0.5567766
##	[274,]	0 1 1	0.5583942
##	[275,]	1 1 1	0.5600000
##	[276,]	1 1 0	0.5579710
##	[277,]	1 2 0	0.5559567
##	[278,]	0 1 1	0.5575540
##	[279,]	0 1 1	0.5591398
##	[280,]	0 1 0	0.5571429
##	[281,]	1 2 1	0.5587189
##	[282,]	0 1 0	0.5567376
##	[283,]	0 1 0	0.5547703
##	[284,]	0 1 0	0.5528169
##	[285,]	0 1 1	0.5543860
##	[286,]	0 1 0	0.5524476
##	[287,]	0 1 1	0.5540070
##	[288,]	0 1 1	0.5555556
##	[289,]	0 1 0	0.5536332
##	[290,]	0 1 1	0.5551724
##	[291,]	1 2 1	0.5567010
##	[292,]	1 2 1	0.5582192
##	[293,]	0 1 0	0.5563140
##	[294,]	1 2 1	0.5578231
##	[295,]	1 1 0	0.5559322
##	[296,]	1 2 1	0.5574324
##	[297,]	1 2 1	0.5589226
##	[298,]	0 1 1	0.5604027
##	[299,]	1 1 1	0.5618729
##	[300,]	0 1 1	0.5633333
##	[301,]	1 2 1	0.5647841
##	[302,]	1 1 1	0.5662252
##	[303,]	1 1 1	0.5676568
##	[304,]	1 2 1	0.5690789
##	[305,]	1 2 1	0.5704918
##	[306,]	1 1 1	0.5718954
##	[307,]	1 1 1	0.5732899
##	[308,]	1 2 0	0.5714286
##	[309,]	1 2 1	0.5728155
##	[310,]	0 1 0	0.5709677
##	[311,]	1 2 0	0.5691318
##	[312,]	0 1 0	0.5673077
##	[313,]	1 2 1	0.5686901
##	[314,]	0 1 0	0.5668790
##	[315,]	1 1 0	0.5650794
##	[316,]	0 1 0	0.5632911
##	[317,]	0 1 1	0.5646688
##	[318,]	0 1 1	0.5660377
##	[319,]	0 1 0	0.5642633
##	[320,]	1 2 1	0.5656250
##	[321,]	1 1 1	0.5669782
##	[322,]	0 1 0	0.5652174
##	[323,]	1 2 1	0.5665635
##	[324,]	1 1 0	0.5648148

##	[325,]	0 1 0	0.5630769
##	[326,]	1 1 1	0.5644172
##	[327,]	1 2 0	0.5626911
##	[328,]	0 1 0	0.5609756
##	[329,]	0 1 1	0.5623100
##	[330,]	1 2 1	0.5636364
##	[331,]	1 2 0	0.5619335
##	[332,]	0 1 0	0.5602410
##	[333,]	1 2 1	0.5615616
##	[334,]	1 2 0	0.5598802
##	[335,]	1 1 1	0.5611940
##	[336,]	1 2 1	0.5625000
##	[337,]	0 1 0	0.5608309
##	[338,]	0 1 0	0.5591716
##	[339,]	1 2 1	0.5604720
##	[340,]	0 1 1	0.5617647
##	[341,]	1 1 0	0.5601173
##	[342,]	0 1 1	0.5614035
##	[343,]	1 2 0	0.5597668
##	[344,]	1 1 1	0.5610465
##	[345,]	0 1 0	0.5594203
##	[346,]	1 1 0	0.5578035
##	[347,]	0 1 1	0.5590778
##	[348,]	1 1 1	0.5603448
##	[349,]	0 1 0	0.5587393
##	[350,]	1 1 0	0.5571429
##	[351,]	0 1 0	0.5555556
##	[352,]	0 1 0	0.5539773
##	[353,]	0 1 1	0.5552408
##	[354,]	0 1 1	0.5564972
##	[355,]	0 1 0	0.5549296
##	[356,]	0 1 1	0.5561798
##	[357,]	1 1 1	0.5574230
##	[358,]	0 1 1	0.5586592
##	[359,]	0 1 1	0.5598886
##	[360,]	1 2 1	0.5611111
##	[361,]	0 1 1	0.5623269
##	[362,]	0 1 1	0.5635359
##	[363,]	1 2 0	0.5619835
##	[364,]	1 1 0	0.5604396
##	[365,]	1 1 1	0.5616438
##	[366,]	0 1 0	0.5601093
##	[367,]	0 1 1	0.5613079
##	[368,]	0 1 1	0.5625000
##	[369,]	0 1 1	0.5636856
##	[370,]	1 2 0	0.5621622
##	[371,]	0 1 0	0.5606469
##	[372,]	0 1 0	0.5591398
##	[373,]	1 1 1	0.5603217
##	[374,]	1 2 0	0.5588235
##	[375,]	1 2 1	0.5600000
##	[376,]	0 1 1	0.5611702
##	[377,]	0 1 0	0.5596817
##	[378,]	0 1 1	0.5608466

##	[379,]	1 1 1	0.5620053
##	[380,]	0 1 0	0.5605263
##	[381,]	1 2 1	0.5616798
##	[382,]	0 1 1	0.5628272
##	[383,]	0 1 1	0.5639687
##	[384,]	1 2 0	0.5625000
##	[385,]	0 1 0	0.5610390
##	[386,]	0 1 0	0.5595855
##	[387,]	0 1 1	0.5607235
##	[388,]	1 2 0	0.5592784
##	[389,]	0 1 0	0.5578406
##	[390,]	0 1 0	0.5564103
##	[391,]	1 2 1	0.5575448
##	[392,]	1 2 0	0.5561224
##	[393,]	0 1 1	0.5572519
##	[394,]	1 2 0	0.5558376
##	[395,]	0 1 0	0.5544304
##	[396,]	0 1 0	0.5530303
##	[397,]	0 1 1	0.5541562
##	[398,]	0 1 0	0.5527638
##	[399,]	1 1 0	0.5513784
##	[400,]	1 2 0	0.5500000
##	[401,]	1 2 1	0.5511222
##	[402,]	0 1 1	0.5522388
##	[403,]	1 2 1	0.5533499
##	[404,]	0 1 1	0.5544554
##	[405,]	0 1 0	0.5530864
##	[406,]	0 1 0	0.5517241
##	[407,]	0 1 0	0.5503686
##	[408,]	1 1 0	0.5490196
##	[409,]	0 1 1	0.5501222
##	[410,]	1 1 1	0.5512195
##	[411,]	0 1 0	0.5498783
##	[412,]	1 1 1	0.5509709
##	[413,]	1 2 0	0.5496368
##	[414,]	1 1 1	0.5507246
##	[415,]	1 1 1	0.5518072
##	[416,]	1 1 0	0.5504808
##	[417,]	1 1 1	0.5515588
##	[418,]	1 1 0	0.5502392
##	[419,]	1 2 0	0.5489260
##	[420,]	1 2 0	0.5476190
##	[421,]	0 1 0	0.5463183
##	[422,]	0 1 1	0.5473934
##	[423,]	0 1 0	0.5460993
##	[424,]	0 1 0	0.5448113
##	[425,]	0 1 1	0.5458824
##	[426,]	1 2 1	0.5469484
##	[427,]	1 1 0	0.5456674
##	[428,]	0 1 0	0.5443925
##	[429,]	1 2 1	0.5454545
##	[430,]	1 2 0	0.5441860
##	[431,]	1 1 0	0.5429234
##	[432,]	0 1 0	0.5416667

##	[433,]	1 2 0	0.5404157
##	[434,]	0 1 0	0.5391705
##	[435,]	1 1 1	0.5402299
##	[436,]	1 1 0	0.5389908
##	[437,]	0 1 0	0.5377574
##	[438,]	0 1 1	0.5388128
##	[439,]	0 1 1	0.5398633
##	[440,]	1 2 0	0.5386364
##	[441,]	1 1 1	0.5396825
##	[442,]	1 2 1	0.5407240
##	[443,]	0 1 0	0.5395034
##	[444,]	1 1 1	0.5405405
##	[445,]	0 1 1	0.5415730
##	[446,]	0 1 1	0.5426009
##	[447,]	1 2 0	0.5413870
##	[448,]	0 1 0	0.5401786
##	[449,]	0 1 0	0.5389755
##	[450,]	1 2 0	0.5377778
##	[451,]	1 2 1	0.5388027
##	[452,]	1 1 1	0.5398230
##	[453,]	0 1 0	0.5386313
##	[454,]	1 1 0	0.5374449
##	[455,]	0 1 1	0.5384615
##	[456,]	0 1 0	0.5372807
##	[457,]	1 2 0	0.5361050
##	[458,]	0 1 1	0.5371179
##	[459,]	1 2 0	0.5359477
##	[460,]	0 1 0	0.5347826
##	[461,]	0 1 1	0.5357918
##	[462,]	1 1 1	0.5367965
##	[463,]	0 1 1	0.5377970
##	[464,]	1 1 0	0.5366379
##	[465,]	0 1 1	0.5376344
##	[466,]	1 2 0	0.5364807
##	[467,]	1 1 1	0.5374732
##	[468,]	1 1 0	0.5363248
##	[469,]	1 2 0	0.5351812
##	[470,]	0 1 0	0.5340426
##	[471,]	1 1 1	0.5350318
##	[472,]	1 2 1	0.5360169
##	[473,]	1 1 1	0.5369979
##	[474,]	0 1 0	0.5358650
##	[475,]	0 1 1	0.5368421
##	[476,]	1 2 0	0.5357143
##	[477,]	0 1 1	0.5366876
##	[478,]	0 1 0	0.5355649
##	[479,]	0 1 1	0.5365344
##	[480,]	1 1 1	0.5375000
##	[481,]	1 1 0	0.5363825
##	[482,]	0 1 1	0.5373444
##	[483,]	1 2 0	0.5362319
##	[484,]	0 1 0	0.5351240
##	[485,]	0 1 0	0.5340206
##	[486,]	1 1 1	0.5349794

##	[487,]	0 1 1	0.5359343
##	[488,]	1 2 1	0.5368852
##	[489,]	0 1 1	0.5378323
##	[490,]	0 1 1	0.5387755
##	[491,]	0 1 0	0.5376782
##	[492,]	1 1 0	0.5365854
##	[493,]	0 1 0	0.5354970
##	[494,]	1 1 1	0.5364372
##	[495,]	0 1 1	0.5373737
##	[496,]	1 2 1	0.5383065
##	[497,]	1 2 0	0.5372233
##	[498,]	0 1 1	0.5381526
##	[499,]	0 1 1	0.5390782
##	[500,]	0 1 1	0.5400000
##	[501,]	1 2 0	0.5389222
##	[502,]	1 2 1	0.5398406
##	[503,]	1 1 1	0.5407555
##	[504,]	0 1 1	0.5416667
##	[505,]	0 1 0	0.5405941
##	[506,]	0 1 0	0.5395257
##	[507,]	0 1 1	0.5404339
##	[508,]	0 1 0	0.5393701
##	[509,]	1 1 0	0.5383104
##	[510,]	1 1 1	0.5392157
##	[511,]	0 1 1	0.5401174
##	[512,]	1 1 0	0.5390625
##	[513,]	0 1 1	0.5399610
##	[514,]	1 1 1	0.5408560
##	[515,]	1 1 0	0.5398058
##	[516,]	0 1 1	0.5406977
##	[517,]	1 2 0	0.5396518
##	[518,]	1 1 1	0.5405405
##	[519,]	0 1 1	0.5414258
##	[520,]	0 1 1	0.5423077
##	[521,]	0 1 0	0.5412668
##	[522,]	0 1 0	0.5402299
##	[523,]	1 2 0	0.5391969
##	[524,]	1 1 1	0.5400763
##	[525,]	0 1 1	0.5409524
##	[526,]	0 1 1	0.5418251
##	[527,]	0 1 0	0.5407970
##	[528,]	0 1 0	0.5397727
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##	[530,]	0 1 1	0.5396226
##	[531,]	0 1 1	0.5404896
##	[532,]	0 1 1	0.5413534
##	[533,]	1 2 1	0.5422139
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##	[535,]	1 2 1	0.5420561
##	[536,]	1 1 1	0.5429104
##	[537,]	0 1 1	0.5437616
##	[538,]	1 2 0	0.5427509
##	[539,]	1 2 0	0.5417440
##	[540,]	0 1 0	0.5407407

##	[541,]	0 1 1	0.5415896
##	[542,]	0 1 1	0.5424354
##	[543,]	0 1 0	0.5414365
##	[544,]	0 1 0	0.5404412
##	[545,]	0 1 0	0.5394495
##	[546,]	0 1 1	0.5402930
##	[547,]	1 1 1	0.5411335
##	[548,]	0 1 0	0.5401460
##	[549,]	0 1 1	0.5409836
##	[550,]	1 2 1	0.5418182
##	[551,]	0 1 0	0.5408348
##	[552,]	0 1 1	0.5416667
##	[553,]	1 2 0	0.5406872
##	[554,]	1 2 1	0.5415162
##	[555,]	0 1 0	0.5405405
##	[556,]	1 2 0	0.5395683
##	[557,]	0 1 0	0.5385996
##	[558,]	1 1 1	0.5394265
##	[559,]	0 1 0	0.5384615
##	[560,]	0 1 1	0.5392857
##	[561,]	1 2 1	0.5401070
##	[562,]	0 1 1	0.5409253
##	[563,]	0 1 0	0.5399645
##	[564,]	1 1 1	0.5407801
##	[565,]	1 1 0	0.5398230
##	[566,]	1 1 0	0.5388693
##	[567,]	0 1 1	0.5396825
##	[568,]	1 1 1	0.5404930
##	[569,]	0 1 0	0.5395431
##	[570,]	0 1 1	0.5403509
##	[571,]	1 1 0	0.5394046
##	[572,]	1 1 0	0.5384615
##	[573,]	0 1 0	0.5375218
##	[574,]	1 2 0	0.5365854
##	[575,]	0 1 0	0.5356522
##	[576,]	1 2 0	0.5347222
##	[577,]	1 1 1	0.5355286
##	[578,]	0 1 1	0.5363322
##	[579,]	1 2 1	0.5371330
##	[580,]	1 1 1	0.5379310
##	[581,]	0 1 1	0.5387263
##	[582,]	0 1 0	0.5378007
##	[583,]	1 1 0	0.5368782
##	[584,]	1 1 1	0.5376712
##	[585,]	1 1 1	0.5384615
##	[586,]	0 1 1	0.5392491
##	[587,]	1 2 1	0.5400341
##	[588,]	0 1 1	0.5408163
##	[589,]	1 1 1	0.5415959
##	[590,]	0 1 1	0.5423729
##	[591,]	1 1 1	0.5431472
##	[592,]	0 1 1	0.5439189
##	[593,]	0 1 1	0.5446880
##	[594,]	1 2 0	0.5437710

##	[595,]	1 2 1	0.5445378
##	[596,]	1 1 1	0.5453020
##	[597,]	0 1 1	0.5460637
##	[598,]	0 1 1	0.5468227
##	[599,]	1 2 1	0.5475793
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##	[601,]	1 2 1	0.5490849
##	[602,]	0 1 1	0.5498339
##	[603,]	0 1 1	0.5505804
##	[604,]	1 2 0	0.5496689
##	[605,]	0 1 0	0.5487603
##	[606,]	0 1 0	0.5478548
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##	[608,]	1 1 1	0.5493421
##	[609,]	1 1 0	0.5484401
##	[610,]	0 1 0	0.5475410
##	[611,]	1 1 0	0.5466448
##	[612,]	0 1 0	0.5457516
##	[613,]	1 2 0	0.5448613
##	[614,]	1 1 0	0.5439739
##	[615,]	1 2 0	0.5430894
##	[616,]	1 1 0	0.5422078
##	[617,]	0 1 1	0.5429498
##	[618,]	0 1 0	0.5420712
##	[619,]	0 1 1	0.5428110
##	[620,]	0 1 1	0.5435484
##	[621,]	0 1 0	0.5426731
##	[622,]	1 1 1	0.5434084
##	[623,]	1 2 1	0.5441413
##	[624,]	0 1 1	0.5448718
##	[625,]	1 2 0	0.5440000
##	[626,]	0 1 0	0.5431310
##	[627,]	1 1 1	0.5438596
##	[628,]	1 2 0	0.5429936
##	[629,]	0 1 1	0.5437202
##	[630,]	1 2 1	0.5444444
##	[631,]	1 2 1	0.5451664
##	[632,]	0 1 1	0.5458861
##	[633,]	0 1 1	0.5466035
##	[634,]	1 1 1	0.5473186
##	[635,]	0 1 0	0.5464567
##	[636,]	1 1 1	0.5471698
##	[637,]	1 2 1	0.5478807
##	[638,]	1 2 1	0.5485893
##	[639,]	0 1 1	0.5492958
##	[640,]	0 1 1	0.5500000
##	[641,]	1 1 1	0.5507020
##	[642,]	0 1 0	0.5498442
##	[643,]	0 1 1	0.5505443
##	[644,]	0 1 1	0.5512422
##	[645,]	0 1 1	0.5519380
##	[646,]	1 1 1	0.5526316
##	[647,]	1 1 1	0.5533230
##	[648,]	0 1 1	0.5540123

##	[649,]	0 1 1	0.5546995
##	[650,]	0 1 1	0.5553846
##	[651,]	1 2 0	0.5545315
##	[652,]	0 1 0	0.5536810
##	[653,]	1 2 0	0.5528331
##	[654,]	0 1 1	0.5535168
##	[655,]	1 2 0	0.5526718
##	[656,]	0 1 1	0.5533537
##	[657,]	1 1 1	0.5540335
##	[658,]	0 1 1	0.5547112
##	[659,]	0 1 0	0.5538695
##	[660,]	1 2 0	0.5530303
##	[661,]	0 1 0	0.5521936
##	[662,]	0 1 1	0.5528701
##	[663,]	1 2 1	0.5535445
##	[664,]	1 1 1	0.5542169
##	[665,]	0 1 1	0.5548872
##	[666,]	1 1 0	0.5540541
##	[667,]	1 1 0	0.5532234
##	[668,]	1 2 1	0.5538922
##	[669,]	0 1 1	0.5545590
##	[670,]	0 1 1	0.5552239
##	[671,]	0 1 1	0.5558867
##	[672,]	1 1 0	0.5550595
##	[673,]	1 1 0	0.5542348
##	[674,]	1 2 1	0.5548961
##	[675,]	1 2 0	0.5540741
##	[676,]	1 1 1	0.5547337
##	[677,]	1 2 0	0.5539143
##	[678,]	1 1 0	0.5530973
##	[679,]	0 1 0	0.5522828
##	[680,]	1 1 1	0.5529412
##	[681,]	1 2 1	0.5535977
##	[682,]	0 1 0	0.5527859
##	[683,]	1 1 1	0.5534407
##	[684,]	1 2 1	0.5540936
##	[685,]	1 2 1	0.5547445
##	[686,]	1 1 0	0.5539359
##	[687,]	1 2 0	0.5531295
##	[688,]	1 1 1	0.5537791
##	[689,]	0 1 1	0.5544267
##	[690,]	1 1 1	0.5550725
##	[691,]	0 1 0	0.5542692
##	[692,]	1 2 1	0.5549133
##	[693,]	1 2 0	0.5541126
##	[694,]	1 2 0	0.5533141
##	[695,]	0 1 1	0.5539568
##	[696,]	0 1 1	0.5545977
##	[697,]	0 1 1	0.5552367
##	[698,]	0 1 1	0.5558739
##	[699,]	0 1 0	0.5550787
##	[700,]	0 1 1	0.5557143
##	[701,]	0 1 0	0.5549215
##	[702,]	1 2 0	0.5541311

##	[703,]	1 1 1	0.5547653
##	[704,]	1 1 1	0.5553977
##	[705,]	0 1 1	0.5560284
##	[706,]	1 1 0	0.5552408
##	[707,]	1 2 0	0.5544554
##	[708,]	0 1 1	0.5550847
##	[709,]	1 2 0	0.5543018
##	[710,]	1 2 0	0.5535211
##	[711,]	1 2 0	0.5527426
##	[712,]	0 1 1	0.5533708
##	[713,]	0 1 1	0.5539972
##	[714,]	0 1 0	0.5532213
##	[715,]	0 1 1	0.5538462
##	[716,]	0 1 1	0.5544693
##	[717,]	1 2 1	0.5550907
##	[718,]	0 1 1	0.5557103
##	[719,]	1 2 0	0.5549374
##	[720,]	0 1 1	0.5555556
##	[721,]	1 2 0	0.5547850
##	[722,]	0 1 0	0.5540166
##	[723,]	0 1 0	0.5532503
##	[724,]	0 1 1	0.5538674
##	[725,]	0 1 0	0.5531034
##	[726,]	1 1 1	0.5537190
##	[727,]	1 1 0	0.5529574
##	[728,]	1 2 0	0.5521978
##	[729,]	1 2 1	0.5528121
##	[730,]	0 1 1	0.5534247
##	[731,]	0 1 1	0.5540356
##	[732,]	1 1 1	0.5546448
##	[733,]	0 1 0	0.5538881
##	[734,]	1 1 0	0.5531335
##	[735,]	1 2 1	0.5537415
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##	[738,]	1 2 0	0.5528455
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##	[740,]	1 2 1	0.5527027
##	[741,]	0 1 1	0.5533063
##	[742,]	1 1 1	0.5539084
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##	[744,]	0 1 1	0.5551075
##	[745,]	0 1 0	0.5543624
##	[746,]	0 1 0	0.5536193
##	[747,]	1 1 1	0.5542169
##	[748,]	0 1 1	0.5548128
##	[749,]	0 1 1	0.5554072
##	[750,]	1 1 1	0.5560000
##	[751,]	1 1 0	0.5552597
##	[752,]	0 1 1	0.5558511
##	[753,]	1 2 0	0.5551129
##	[754,]	0 1 0	0.5543767
##	[755,]	1 1 0	0.5536424
##	[756,]	0 1 0	0.5529101

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##	[758,]	0 1 1	0.5527704
##	[759,]	1 2 0	0.5520422
##	[760,]	0 1 1	0.5526316
##	[761,]	0 1 1	0.5532194
##	[762,]	1 1 1	0.5538058
##	[763,]	1 2 0	0.5530799
##	[764,]	1 2 0	0.5523560
##	[765,]	1 1 1	0.5529412
##	[766,]	0 1 0	0.5522193
##	[767,]	0 1 1	0.5528031
##	[768,]	0 1 1	0.5533854
##	[769,]	0 1 0	0.5526658
##	[770,]	0 1 0	0.5519481
##	[771,]	0 1 1	0.5525292
##	[772,]	1 1 0	0.5518135
##	[773,]	1 2 0	0.5510996
##	[774,]	0 1 0	0.5503876
##	[775,]	0 1 1	0.5509677
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##	[785,]	1 2 0	0.5541401
##	[786,]	0 1 1	0.5547074
##	[787,]	1 2 0	0.5540025
##	[788,]	1 1 1	0.5545685
##	[789,]	0 1 1	0.5551331
##	[790,]	1 2 1	0.5556962
##	[791,]	1 1 1	0.5562579
##	[792,]	0 1 1	0.5568182
##	[793,]	0 1 0	0.5561160
##	[794,]	1 2 0	0.5554156
##	[795,]	0 1 0	0.5547170
##	[796,]	1 1 1	0.5552764
##	[797,]	1 1 1	0.5558344
##	[798,]	0 1 1	0.5563910
##	[799,]	1 2 0	0.5556946
##	[800,]	0 1 0	0.5550000
##	[801,]	1 2 0	0.5543071
##	[802,]	1 2 1	0.5548628
##	[803,]	0 1 0	0.5541719
##	[804,]	0 1 0	0.5534826
##	[805,]	1 1 1	0.5540373
##	[806,]	0 1 1	0.5545906
##	[807,]	1 1 1	0.5551425
##	[808,]	0 1 1	0.5556931
##	[809,]	0 1 1	0.5562423
##	[810,]	1 2 0	0.5555556

##	[811,]	0 1 1	0.5561036
##	[812,]	1 1 1	0.5566502
##	[813,]	1 1 0	0.5559656
##	[814,]	1 1 1	0.5565111
##	[815,]	0 1 0	0.5558282
##	[816,]	0 1 1	0.5563725
##	[817,]	0 1 0	0.5556916
##	[818,]	0 1 1	0.5562347
##	[819,]	1 2 0	0.5555556
##	[820,]	1 1 1	0.5560976
##	[821,]	1 2 1	0.5566382
##	[822,]	1 1 1	0.5571776
##	[823,]	0 1 0	0.5565006
##	[824,]	1 2 1	0.5570388
##	[825,]	0 1 0	0.5563636
##	[826,]	1 1 1	0.5569007
##	[827,]	1 2 1	0.5574365
##	[828,]	1 1 0	0.5567633
##	[829,]	1 1 0	0.5560917
##	[830,]	1 2 1	0.5566265
##	[831,]	0 1 1	0.5571600
##	[832,]	1 1 1	0.5576923
##	[833,]	1 2 1	0.5582233
##	[834,]	1 1 0	0.5575540
##	[835,]	1 2 0	0.5568862
##	[836,]	1 2 0	0.5562201
##	[837,]	0 1 1	0.5567503
##	[838,]	1 1 1	0.5572792
##	[839,]	1 2 1	0.5578069
##	[840,]	0 1 0	0.5571429
##	[841,]	1 1 0	0.5564804
##	[842,]	1 1 1	0.5570071
##	[843,]	0 1 1	0.5575326
##	[844,]	0 1 0	0.5568720
##	[845,]	1 2 0	0.5562130
##	[846,]	1 2 1	0.5567376
##	[847,]	0 1 1	0.5572609
##	[848,]	1 1 1	0.5577830
##	[849,]	1 1 0	0.5571260
##	[850,]	0 1 1	0.5576471
##	[851,]	0 1 1	0.5581669
##	[852,]	0 1 1	0.5586854
##	[853,]	1 2 1	0.5592028
##	[854,]	0 1 1	0.5597190
##	[855,]	1 1 1	0.5602339
##	[856,]	0 1 1	0.5607477
##	[857,]	1 1 1	0.5612602
##	[858,]	0 1 1	0.5617716
##	[859,]	0 1 1	0.5622817
##	[860,]	1 1 1	0.5627907
##	[861,]	0 1 0	0.5621370
##	[862,]	0 1 1	0.5626450
##	[863,]	0 1 1	0.5631518
##	[864,]	1 2 0	0.5625000

##	[865,]	0 1 0	0.5618497
##	[866,]	0 1 1	0.5623557
##	[867,]	0 1 1	0.5628604
##	[868,]	0 1 1	0.5633641
##	[869,]	0 1 1	0.5638665
##	[870,]	0 1 0	0.5632184
##	[871,]	1 2 0	0.5625718
##	[872,]	0 1 0	0.5619266
##	[873,]	1 1 1	0.5624284
##	[874,]	0 1 0	0.5617849
##	[875,]	1 2 0	0.5611429
##	[876,]	1 2 0	0.5605023
##	[877,]	1 2 1	0.5610034
##	[878,]	0 1 1	0.5615034
##	[879,]	0 1 0	0.5608646
##	[880,]	0 1 1	0.5613636
##	[881,]	0 1 1	0.5618615
##	[882,]	0 1 0	0.5612245
##	[883,]	0 1 0	0.5605889
##	[884,]	1 2 0	0.5599548
##	[885,]	1 1 1	0.5604520
##	[886,]	1 2 0	0.5598194
##	[887,]	1 1 1	0.5603157
##	[888,]	0 1 0	0.5596847
##	[889,]	0 1 0	0.5590551
##	[890,]	0 1 1	0.5595506
##	[891,]	1 2 0	0.5589226
##	[892,]	0 1 0	0.5582960
##	[893,]	0 1 0	0.5576708
##	[894,]	1 1 0	0.5570470
##	[895,]	1 2 0	0.5564246
##	[896,]	1 2 0	0.5558036
##	[897,]	0 1 1	0.5562988
##	[898,]	1 1 0	0.5556793
##	[899,]	1 1 0	0.5550612
##	[900,]	0 1 0	0.5544444
##	[901,]	0 1 1	0.5549390
##	[902,]	1 1 1	0.5554324
##	[903,]	1 1 1	0.5559247
##	[904,]	1 1 1	0.5564159
##	[905,]	0 1 1	0.5569061
##	[906,]	0 1 1	0.5573951
##	[907,]	1 2 1	0.5578831
##	[908,]	1 2 1	0.5583700
##	[909,]	1 1 0	0.5577558
##	[910,]	0 1 1	0.5582418
##	[911,]	0 1 1	0.5587267
##	[912,]	0 1 1	0.5592105
##	[913,]	0 1 1	0.5596933
##	[914,]	1 1 0	0.5590810
##	[915,]	0 1 0	0.5584699
##	[916,]	1 2 0	0.5578603
##	[917,]	1 1 1	0.5583424
##	[918,]	1 2 0	0.5577342

##	[919,]	1 2 0	0.5571273
##	[920,]	1 2 0	0.5565217
##	[921,]	0 1 1	0.5570033
##	[922,]	0 1 1	0.5574837
##	[923,]	1 1 1	0.5579632
##	[924,]	1 2 0	0.5573593
##	[925,]	0 1 1	0.5578378
##	[926,]	0 1 1	0.5583153
##	[927,]	1 1 0	0.5577131
##	[928,]	0 1 0	0.5571121
##	[929,]	0 1 0	0.5565124
##	[930,]	0 1 0	0.5559140
##	[931,]	1 2 0	0.5553169
##	[932,]	0 1 0	0.5547210
##	[933,]	1 2 0	0.5541265
##	[934,]	1 1 1	0.5546039
##	[935,]	0 1 0	0.5540107
##	[936,]	1 2 1	0.5544872
##	[937,]	0 1 1	0.5549626
##	[938,]	1 1 1	0.5554371
##	[939,]	0 1 1	0.5559105
##	[940,]	1 1 0	0.5553191
##	[941,]	0 1 1	0.5557917
##	[942,]	1 2 0	0.5552017
##	[943,]	0 1 1	0.5556734
##	[944,]	1 1 0	0.5550847
##	[945,]	0 1 1	0.5555556
##	[946,]	1 2 0	0.5549683
##	[947,]	0 1 1	0.5554382
##	[948,]	0 1 1	0.5559072
##	[949,]	1 2 0	0.5553214
##	[950,]	0 1 1	0.5557895
##	[951,]	0 1 1	0.5562566
##	[952,]	0 1 1	0.5567227
##	[953,]	0 1 1	0.5571878
##	[954,]	0 1 1	0.5576520
##	[955,]	0 1 1	0.5581152
##	[956,]	0 1 1	0.5585774
##	[957,]	0 1 0	0.5579937
##	[958,]	1 1 0	0.5574113
##	[959,]	1 1 0	0.5568300
##	[960,]	0 1 1	0.5572917
##	[961,]	1 2 0	0.5567118
##	[962,]	0 1 1	0.5571726
##	[963,]	0 1 1	0.5576324
##	[964,]	0 1 1	0.5580913
##	[965,]	1 2 0	0.5575130
##	[966,]	1 1 1	0.5579710
##	[967,]	1 2 0	0.5573940
##	[968,]	0 1 0	0.5568182
##	[969,]	1 1 0	0.5562436
##	[970,]	1 2 1	0.5567010
##	[971,]	0 1 0	0.5561277
##	[972,]	1 2 1	0.5565844

##	[973,]	1 1 1	0.5570401
##	[974,]	0 1 1	0.5574949
##	[975,]	0 1 0	0.5569231
##	[976,]	0 1 1	0.5573770
##	[977,]	0 1 1	0.5578301
##	[978,]	1 2 1	0.5582822
##	[979,]	0 1 0	0.5577120
##	[980,]	0 1 0	0.5571429
##	[981,]	1 2 1	0.5575943
##	[982,]	0 1 0	0.5570265
##	[983,]	1 1 1	0.5574771
##	[984,]	0 1 1	0.5579268
##	[985,]	1 1 1	0.5583756
##	[986,]	0 1 1	0.5588235
##	[987,]	0 1 0	0.5582573
##	[988,]	0 1 1	0.5587045
##	[989,]	1 1 1	0.5591507
##	[990,]	0 1 1	0.5595960
##	[991,]	1 2 0	0.5590313
##	[992,]	1 1 0	0.5584677
##	[993,]	0 1 1	0.5589124
##	[994,]	0 1 1	0.5593561
##	[995,]	1 1 1	0.5597990
##	[996,]	0 1 0	0.5592369
##	[997,]	0 1 1	0.5596790
##	[998,]	0 1 0	0.5591182
##	[999,]	0 1 0	0.5585586
##	[1000,]	1 2 1	0.5590000

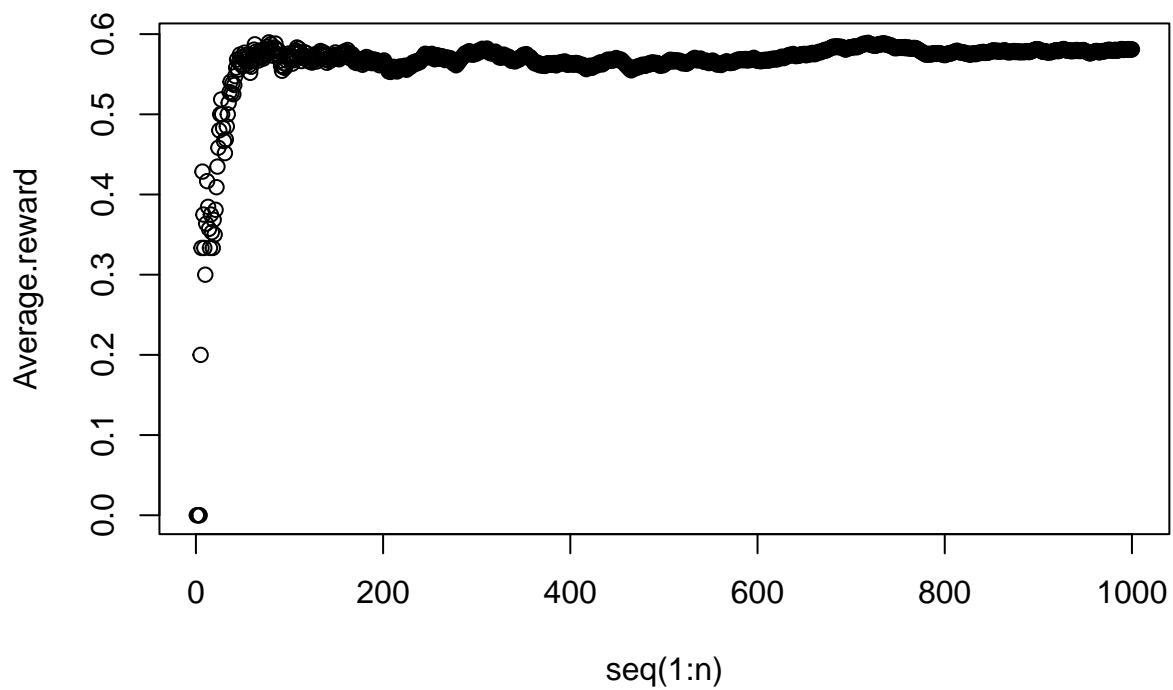
2(b)

$\epsilon = \min\{1, C \cdot n^{-1}\}$

$\lim_{n \rightarrow \infty} \epsilon = 0$ as n tends to infinity. Hence as n increases with higher probability we play the arm with the best success rate so far. This relates to relying on the actual success rate so far, as time goes on because it's more likely to reflect the true probability of success. By Borel-Cantelli we play a random arm infinitely many times so we won't ever get 'stuck' on the wrong arm. Given arbitrary C value > 1 . A random arm is played for floor of C since $\min\{1, C \cdot n^{-1}\}$ would still be 1. If C is less than 1 then random arm is chosen with probability $[C \cdot n^{-1}]$. As you can see from our run of the function, we choose a random arm less frequently as time goes on and we end up choosing arm 1 which is the better arm, which is what we want to do.

```
C = 5
n=1000
epsilon=vector(length=n)
for (i in 1:n){
  epsilon[i] = min(1, C/i)
}

sample.1=epsilon.decreasing(n, 0.6, 0.4, e=epsilon)
```



sample.1

##		random.arm	a	r	Average.reward
##	[1,]	0	1	0	0.0000000
##	[2,]	0	2	0	0.0000000
##	[3,]	1	2	0	0.0000000
##	[4,]	1	1	0	0.0000000
##	[5,]	1	1	1	0.2000000
##	[6,]	1	1	1	0.3333333
##	[7,]	1	2	1	0.4285714
##	[8,]	0	1	0	0.3750000
##	[9,]	0	1	0	0.3333333
##	[10,]	0	2	0	0.3000000
##	[11,]	0	1	1	0.3636364
##	[12,]	0	1	1	0.4166667
##	[13,]	0	1	0	0.3846154
##	[14,]	0	1	0	0.3571429
##	[15,]	1	2	0	0.3333333
##	[16,]	0	1	1	0.3750000
##	[17,]	0	1	0	0.3529412
##	[18,]	1	2	0	0.3333333
##	[19,]	0	1	1	0.3684211
##	[20,]	0	1	0	0.3500000
##	[21,]	0	1	1	0.3809524
##	[22,]	0	1	1	0.4090909
##	[23,]	0	1	1	0.4347826

##	[24,]	0 1 1	0.4583333
##	[25,]	0 1 1	0.4800000
##	[26,]	0 1 1	0.5000000
##	[27,]	0 1 1	0.5185185
##	[28,]	0 1 0	0.5000000
##	[29,]	0 1 0	0.4827586
##	[30,]	0 1 0	0.4666667
##	[31,]	1 2 0	0.4516129
##	[32,]	0 1 1	0.4687500
##	[33,]	1 2 1	0.4848485
##	[34,]	0 1 1	0.5000000
##	[35,]	0 1 1	0.5142857
##	[36,]	0 1 1	0.5277778
##	[37,]	0 1 1	0.5405405
##	[38,]	1 2 0	0.5263158
##	[39,]	0 1 1	0.5384615
##	[40,]	1 2 0	0.5250000
##	[41,]	0 1 1	0.5365854
##	[42,]	0 1 1	0.5476190
##	[43,]	0 1 1	0.5581395
##	[44,]	0 1 1	0.5681818
##	[45,]	0 1 0	0.5555556
##	[46,]	0 1 1	0.5652174
##	[47,]	0 1 1	0.5744681
##	[48,]	0 1 0	0.5625000
##	[49,]	0 1 1	0.5714286
##	[50,]	1 2 0	0.5600000
##	[51,]	0 1 1	0.5686275
##	[52,]	0 1 1	0.5769231
##	[53,]	0 1 0	0.5660377
##	[54,]	0 1 1	0.5740741
##	[55,]	0 1 0	0.5636364
##	[56,]	1 2 1	0.5714286
##	[57,]	0 1 0	0.5614035
##	[58,]	0 1 0	0.5517241
##	[59,]	0 1 1	0.5593220
##	[60,]	0 1 1	0.5666667
##	[61,]	0 1 1	0.5737705
##	[62,]	0 1 1	0.5806452
##	[63,]	0 1 1	0.5873016
##	[64,]	0 1 0	0.5781250
##	[65,]	0 1 0	0.5692308
##	[66,]	0 1 1	0.5757576
##	[67,]	0 1 0	0.5671642
##	[68,]	0 1 1	0.5735294
##	[69,]	0 1 1	0.5797101
##	[70,]	0 1 0	0.5714286
##	[71,]	0 1 1	0.5774648
##	[72,]	1 2 0	0.5694444
##	[73,]	0 1 1	0.5753425
##	[74,]	0 1 1	0.5810811
##	[75,]	0 1 0	0.5733333
##	[76,]	0 1 1	0.5789474
##	[77,]	0 1 1	0.5844156

##	[78,]	0 1 1	0.5897436
##	[79,]	1 2 0	0.5822785
##	[80,]	0 1 1	0.5875000
##	[81,]	1 2 0	0.5802469
##	[82,]	0 1 0	0.5731707
##	[83,]	0 1 1	0.5783133
##	[84,]	0 1 1	0.5833333
##	[85,]	0 1 1	0.5882353
##	[86,]	0 1 0	0.5813953
##	[87,]	0 1 0	0.5747126
##	[88,]	0 1 1	0.5795455
##	[89,]	0 1 0	0.5730337
##	[90,]	0 1 0	0.5666667
##	[91,]	0 1 0	0.5604396
##	[92,]	0 1 0	0.5543478
##	[93,]	0 1 1	0.5591398
##	[94,]	0 1 1	0.5638298
##	[95,]	0 1 0	0.5578947
##	[96,]	0 1 1	0.5625000
##	[97,]	0 1 1	0.5670103
##	[98,]	0 1 1	0.5714286
##	[99,]	0 1 1	0.5757576
##	[100,]	0 1 0	0.5700000
##	[101,]	0 1 1	0.5742574
##	[102,]	0 1 0	0.5686275
##	[103,]	0 1 0	0.5631068
##	[104,]	0 1 1	0.5673077
##	[105,]	0 1 1	0.5714286
##	[106,]	0 1 1	0.5754717
##	[107,]	0 1 1	0.5794393
##	[108,]	0 1 1	0.5833333
##	[109,]	0 1 0	0.5779817
##	[110,]	0 1 1	0.5818182
##	[111,]	0 1 0	0.5765766
##	[112,]	0 1 0	0.5714286
##	[113,]	0 1 0	0.5663717
##	[114,]	0 1 1	0.5701754
##	[115,]	0 1 1	0.5739130
##	[116,]	0 1 1	0.5775862
##	[117,]	0 1 0	0.5726496
##	[118,]	0 1 1	0.5762712
##	[119,]	0 1 0	0.5714286
##	[120,]	0 1 0	0.5666667
##	[121,]	0 1 1	0.5702479
##	[122,]	0 1 0	0.5655738
##	[123,]	0 1 1	0.5691057
##	[124,]	0 1 0	0.5645161
##	[125,]	0 1 1	0.5680000
##	[126,]	0 1 1	0.5714286
##	[127,]	0 1 1	0.5748031
##	[128,]	0 1 0	0.5703125
##	[129,]	0 1 0	0.5658915
##	[130,]	0 1 1	0.5692308
##	[131,]	0 1 1	0.5725191

##	[132,]	0 1 1	0.5757576
##	[133,]	0 1 1	0.5789474
##	[134,]	0 1 0	0.5746269
##	[135,]	0 1 1	0.5777778
##	[136,]	0 1 0	0.5735294
##	[137,]	0 1 1	0.5766423
##	[138,]	0 1 0	0.5724638
##	[139,]	0 1 0	0.5683453
##	[140,]	0 1 0	0.5642857
##	[141,]	0 1 1	0.5673759
##	[142,]	0 1 1	0.5704225
##	[143,]	0 1 0	0.5664336
##	[144,]	0 1 1	0.5694444
##	[145,]	0 1 1	0.5724138
##	[146,]	0 1 0	0.5684932
##	[147,]	0 1 1	0.5714286
##	[148,]	0 1 1	0.5743243
##	[149,]	0 1 1	0.5771812
##	[150,]	0 1 0	0.5733333
##	[151,]	0 1 0	0.5695364
##	[152,]	0 1 1	0.5723684
##	[153,]	0 1 0	0.5686275
##	[154,]	0 1 1	0.5714286
##	[155,]	0 1 1	0.5741935
##	[156,]	0 1 1	0.5769231
##	[157,]	0 1 0	0.5732484
##	[158,]	0 1 1	0.5759494
##	[159,]	1 2 1	0.5786164
##	[160,]	0 1 0	0.5750000
##	[161,]	0 1 1	0.5776398
##	[162,]	0 1 1	0.5802469
##	[163,]	0 1 0	0.5766871
##	[164,]	0 1 0	0.5731707
##	[165,]	0 1 0	0.5696970
##	[166,]	0 1 1	0.5722892
##	[167,]	0 1 1	0.5748503
##	[168,]	0 1 0	0.5714286
##	[169,]	0 1 0	0.5680473
##	[170,]	0 1 0	0.5647059
##	[171,]	0 1 1	0.5672515
##	[172,]	0 1 0	0.5639535
##	[173,]	0 1 1	0.5664740
##	[174,]	0 1 1	0.5689655
##	[175,]	0 1 0	0.5657143
##	[176,]	0 1 1	0.5681818
##	[177,]	0 1 0	0.5649718
##	[178,]	0 1 0	0.5617978
##	[179,]	0 1 1	0.5642458
##	[180,]	0 1 1	0.5666667
##	[181,]	0 1 1	0.5690608
##	[182,]	0 1 1	0.5714286
##	[183,]	0 1 0	0.5683060
##	[184,]	0 1 1	0.5706522
##	[185,]	0 1 0	0.5675676

##	[186,]	0 1 0	0.5645161
##	[187,]	0 1 1	0.5668449
##	[188,]	0 1 0	0.5638298
##	[189,]	0 1 1	0.5661376
##	[190,]	0 1 1	0.5684211
##	[191,]	0 1 0	0.5654450
##	[192,]	0 1 1	0.5677083
##	[193,]	0 1 0	0.5647668
##	[194,]	0 1 1	0.5670103
##	[195,]	0 1 0	0.5641026
##	[196,]	0 1 0	0.5612245
##	[197,]	0 1 1	0.5634518
##	[198,]	0 1 1	0.5656566
##	[199,]	1 1 0	0.5628141
##	[200,]	0 1 1	0.5650000
##	[201,]	0 1 1	0.5671642
##	[202,]	0 1 0	0.5643564
##	[203,]	0 1 0	0.5615764
##	[204,]	0 1 0	0.5588235
##	[205,]	0 1 0	0.5560976
##	[206,]	0 1 0	0.5533981
##	[207,]	0 1 1	0.5555556
##	[208,]	0 1 0	0.5528846
##	[209,]	0 1 1	0.5550239
##	[210,]	0 1 1	0.5571429
##	[211,]	1 1 1	0.5592417
##	[212,]	0 1 0	0.5566038
##	[213,]	0 1 0	0.5539906
##	[214,]	0 1 1	0.5560748
##	[215,]	0 1 0	0.5534884
##	[216,]	0 1 1	0.5555556
##	[217,]	0 1 1	0.5576037
##	[218,]	0 1 1	0.5596330
##	[219,]	0 1 0	0.5570776
##	[220,]	0 1 1	0.5590909
##	[221,]	0 1 0	0.5565611
##	[222,]	0 1 1	0.5585586
##	[223,]	0 1 1	0.5605381
##	[224,]	0 1 0	0.5580357
##	[225,]	0 1 0	0.5555556
##	[226,]	0 1 1	0.5575221
##	[227,]	0 1 1	0.5594714
##	[228,]	0 1 1	0.5614035
##	[229,]	0 1 0	0.5589520
##	[230,]	0 1 1	0.5608696
##	[231,]	1 2 1	0.5627706
##	[232,]	0 1 1	0.5646552
##	[233,]	0 1 0	0.5622318
##	[234,]	0 1 1	0.5641026
##	[235,]	0 1 1	0.5659574
##	[236,]	0 1 0	0.5635593
##	[237,]	0 1 1	0.5654008
##	[238,]	0 1 1	0.5672269
##	[239,]	0 1 0	0.5648536

##	[240,]	0 1 1	0.5666667
##	[241,]	0 1 1	0.5684647
##	[242,]	0 1 1	0.5702479
##	[243,]	0 1 1	0.5720165
##	[244,]	0 1 1	0.5737705
##	[245,]	0 1 1	0.5755102
##	[246,]	1 2 0	0.5731707
##	[247,]	0 1 0	0.5708502
##	[248,]	0 1 1	0.5725806
##	[249,]	1 1 1	0.5742972
##	[250,]	0 1 0	0.5720000
##	[251,]	0 1 1	0.5737052
##	[252,]	0 1 1	0.5753968
##	[253,]	0 1 0	0.5731225
##	[254,]	0 1 0	0.5708661
##	[255,]	0 1 0	0.5686275
##	[256,]	0 1 1	0.5703125
##	[257,]	0 1 1	0.5719844
##	[258,]	0 1 1	0.5736434
##	[259,]	0 1 0	0.5714286
##	[260,]	0 1 0	0.5692308
##	[261,]	0 1 1	0.5708812
##	[262,]	0 1 1	0.5725191
##	[263,]	0 1 0	0.5703422
##	[264,]	0 1 1	0.5719697
##	[265,]	0 1 0	0.5698113
##	[266,]	0 1 0	0.5676692
##	[267,]	0 1 1	0.5692884
##	[268,]	0 1 1	0.5708955
##	[269,]	0 1 0	0.5687732
##	[270,]	0 1 1	0.5703704
##	[271,]	0 1 0	0.5682657
##	[272,]	0 1 1	0.5698529
##	[273,]	0 1 0	0.5677656
##	[274,]	0 1 0	0.5656934
##	[275,]	0 1 0	0.5636364
##	[276,]	0 1 1	0.5652174
##	[277,]	0 1 0	0.5631769
##	[278,]	0 1 0	0.5611511
##	[279,]	0 1 1	0.5627240
##	[280,]	0 1 1	0.5642857
##	[281,]	0 1 1	0.5658363
##	[282,]	0 1 1	0.5673759
##	[283,]	0 1 1	0.5689046
##	[284,]	0 1 1	0.5704225
##	[285,]	0 1 1	0.5719298
##	[286,]	0 1 1	0.5734266
##	[287,]	0 1 1	0.5749129
##	[288,]	0 1 1	0.5763889
##	[289,]	0 1 0	0.5743945
##	[290,]	0 1 1	0.5758621
##	[291,]	0 1 1	0.5773196
##	[292,]	0 1 1	0.5787671
##	[293,]	0 1 0	0.5767918

##	[294,]	0 1 0	0.5748299
##	[295,]	0 1 1	0.5762712
##	[296,]	0 1 0	0.5743243
##	[297,]	0 1 1	0.5757576
##	[298,]	0 1 1	0.5771812
##	[299,]	0 1 0	0.5752508
##	[300,]	0 1 1	0.5766667
##	[301,]	0 1 1	0.5780731
##	[302,]	0 1 1	0.5794702
##	[303,]	0 1 0	0.5775578
##	[304,]	0 1 1	0.5789474
##	[305,]	0 1 1	0.5803279
##	[306,]	0 1 1	0.5816993
##	[307,]	0 1 0	0.5798046
##	[308,]	0 1 1	0.5811688
##	[309,]	0 1 0	0.5792880
##	[310,]	0 1 1	0.5806452
##	[311,]	0 1 1	0.5819936
##	[312,]	0 1 0	0.5801282
##	[313,]	0 1 0	0.5782748
##	[314,]	0 1 0	0.5764331
##	[315,]	0 1 1	0.5777778
##	[316,]	0 1 0	0.5759494
##	[317,]	0 1 1	0.5772871
##	[318,]	0 1 0	0.5754717
##	[319,]	0 1 1	0.5768025
##	[320,]	0 1 1	0.5781250
##	[321,]	0 1 0	0.5763240
##	[322,]	0 1 0	0.5745342
##	[323,]	0 1 0	0.5727554
##	[324,]	0 1 0	0.5709877
##	[325,]	0 1 1	0.5723077
##	[326,]	0 1 0	0.5705521
##	[327,]	0 1 1	0.5718654
##	[328,]	0 1 1	0.5731707
##	[329,]	0 1 1	0.5744681
##	[330,]	0 1 0	0.5727273
##	[331,]	0 1 0	0.5709970
##	[332,]	0 1 1	0.5722892
##	[333,]	0 1 0	0.5705706
##	[334,]	0 1 1	0.5718563
##	[335,]	0 1 0	0.5701493
##	[336,]	0 1 0	0.5684524
##	[337,]	0 1 0	0.5667656
##	[338,]	0 1 1	0.5680473
##	[339,]	0 1 0	0.5663717
##	[340,]	0 1 1	0.5676471
##	[341,]	0 1 0	0.5659824
##	[342,]	0 1 1	0.5672515
##	[343,]	0 1 1	0.5685131
##	[344,]	0 1 1	0.5697674
##	[345,]	0 1 0	0.5681159
##	[346,]	0 1 1	0.5693642
##	[347,]	0 1 1	0.5706052

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##	[349,]	0 1 1	0.5730659
##	[350,]	0 1 1	0.5742857
##	[351,]	0 1 0	0.5726496
##	[352,]	0 1 1	0.5738636
##	[353,]	0 1 1	0.5750708
##	[354,]	0 1 0	0.5734463
##	[355,]	0 1 0	0.5718310
##	[356,]	0 1 0	0.5702247
##	[357,]	0 1 1	0.5714286
##	[358,]	0 1 0	0.5698324
##	[359,]	0 1 0	0.5682451
##	[360,]	0 1 0	0.5666667
##	[361,]	0 1 0	0.5650970
##	[362,]	0 1 0	0.5635359
##	[363,]	0 1 1	0.5647383
##	[364,]	0 1 0	0.5631868
##	[365,]	0 1 1	0.5643836
##	[366,]	0 1 0	0.5628415
##	[367,]	0 1 0	0.5613079
##	[368,]	0 1 1	0.5625000
##	[369,]	0 1 0	0.5609756
##	[370,]	0 1 1	0.5621622
##	[371,]	0 1 0	0.5606469
##	[372,]	0 1 1	0.5618280
##	[373,]	0 1 0	0.5603217
##	[374,]	0 1 1	0.5614973
##	[375,]	0 1 1	0.5626667
##	[376,]	0 1 1	0.5638298
##	[377,]	0 1 0	0.5623342
##	[378,]	0 1 1	0.5634921
##	[379,]	0 1 0	0.5620053
##	[380,]	0 1 1	0.5631579
##	[381,]	0 1 0	0.5616798
##	[382,]	0 1 1	0.5628272
##	[383,]	0 1 1	0.5639687
##	[384,]	1 2 0	0.5625000
##	[385,]	0 1 0	0.5610390
##	[386,]	0 1 1	0.5621762
##	[387,]	0 1 1	0.5633075
##	[388,]	0 1 1	0.5644330
##	[389,]	0 1 0	0.5629820
##	[390,]	0 1 1	0.5641026
##	[391,]	0 1 1	0.5652174
##	[392,]	0 1 0	0.5637755
##	[393,]	0 1 1	0.5648855
##	[394,]	0 1 1	0.5659898
##	[395,]	0 1 0	0.5645570
##	[396,]	0 1 0	0.5631313
##	[397,]	0 1 0	0.5617128
##	[398,]	0 1 1	0.5628141
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##	[403,]	0 1 1	0.5632754
##	[404,]	0 1 0	0.5618812
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##	[411,]	0 1 1	0.5620438
##	[412,]	0 1 0	0.5606796
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##	[414,]	0 1 0	0.5603865
##	[415,]	0 1 0	0.5590361
##	[416,]	0 1 0	0.5576923
##	[417,]	0 1 0	0.5563549
##	[418,]	0 1 1	0.5574163
##	[419,]	0 1 1	0.5584726
##	[420,]	0 1 1	0.5595238
##	[421,]	0 1 1	0.5605701
##	[422,]	0 1 0	0.5592417
##	[423,]	0 1 0	0.5579196
##	[424,]	0 1 1	0.5589623
##	[425,]	0 1 1	0.5600000
##	[426,]	0 1 1	0.5610329
##	[427,]	0 1 1	0.5620609
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##	[435,]	0 1 1	0.5632184
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##	[437,]	0 1 1	0.5652174
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##	[439,]	0 1 1	0.5671982
##	[440,]	0 1 1	0.5681818
##	[441,]	0 1 0	0.5668934
##	[442,]	0 1 1	0.5678733
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##	[444,]	0 1 1	0.5675676
##	[445,]	0 1 1	0.5685393
##	[446,]	0 1 0	0.5672646
##	[447,]	0 1 1	0.5682327
##	[448,]	0 1 1	0.5691964
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##	[452,]	0 1 1	0.5685841
##	[453,]	0 1 0	0.5673289
##	[454,]	0 1 1	0.5682819
##	[455,]	0 1 0	0.5670330

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##	[457,]	0 1 0	0.5645514
##	[458,]	0 1 0	0.5633188
##	[459,]	0 1 0	0.5620915
##	[460,]	0 1 0	0.5608696
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##	[462,]	0 1 0	0.5584416
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##	[464,]	0 1 0	0.5560345
##	[465,]	0 1 0	0.5548387
##	[466,]	0 1 1	0.5557940
##	[467,]	0 1 1	0.5567452
##	[468,]	0 1 1	0.5576923
##	[469,]	0 1 1	0.5586354
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##	[477,]	0 1 1	0.5618449
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##	[480,]	0 1 0	0.5604167
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##	[482,]	0 1 1	0.5622407
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##	[493,]	0 1 1	0.5638945
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##	[502,]	0 1 1	0.5637450
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##	[506,]	0 1 1	0.5671937
##	[507,]	0 1 1	0.5680473
##	[508,]	0 1 0	0.5669291
##	[509,]	0 1 0	0.5658153

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##	[512,]	0 1 0	0.5664062
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##	[515,]	0 1 1	0.5669903
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##	[520,]	0 1 0	0.5634615
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##	[522,]	0 1 1	0.5651341
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##	[526,]	0 1 1	0.5646388
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##	[541,]	0 1 0	0.5674677
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##	[546,]	0 1 0	0.5659341
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##	[555,]	0 1 0	0.5639640
##	[556,]	0 1 0	0.5629496
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##	[558,]	0 1 1	0.5627240
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##	[561,]	0 1 0	0.5614973
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##	[563,]	0 1 1	0.5630551

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##	[574,]	0 1 0	0.5644599
##	[575,]	0 1 1	0.5652174
##	[576,]	0 1 1	0.5659722
##	[577,]	0 1 1	0.5667244
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##	[581,]	0 1 1	0.5679862
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##	[588,]	0 1 0	0.5680272
##	[589,]	0 1 0	0.5670628
##	[590,]	0 1 1	0.5677966
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##	[623,]	0 1 1	0.5698234
##	[624,]	0 1 1	0.5705128
##	[625,]	0 1 1	0.5712000
##	[626,]	0 1 1	0.5718850
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##	[629,]	0 1 1	0.5707472
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##	[634,]	0 1 1	0.5741325
##	[635,]	0 1 0	0.5732283
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##	[638,]	0 1 1	0.5752351
##	[639,]	0 1 0	0.5743349
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##	[644,]	0 1 0	0.5729814
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##	[660,]	0 1 0	0.5757576
##	[661,]	1 2 0	0.5748865
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##	[664,]	0 1 1	0.5768072
##	[665,]	0 1 1	0.5774436
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##	[678,]	0 1 1	0.5825959
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##	[680,]	0 1 1	0.5838235
##	[681,]	0 1 1	0.5844347
##	[682,]	0 1 0	0.5835777
##	[683,]	0 1 1	0.5841874
##	[684,]	0 1 1	0.5847953
##	[685,]	0 1 0	0.5839416
##	[686,]	0 1 1	0.5845481
##	[687,]	0 1 0	0.5836972
##	[688,]	0 1 1	0.5843023
##	[689,]	0 1 0	0.5834543
##	[690,]	0 1 1	0.5840580
##	[691,]	0 1 0	0.5832127
##	[692,]	0 1 0	0.5823699
##	[693,]	0 1 0	0.5815296
##	[694,]	0 1 0	0.5806916
##	[695,]	0 1 1	0.5812950
##	[696,]	0 1 1	0.5818966
##	[697,]	0 1 1	0.5824964
##	[698,]	0 1 1	0.5830946
##	[699,]	0 1 1	0.5836910
##	[700,]	0 1 0	0.5828571
##	[701,]	0 1 1	0.5834522
##	[702,]	0 1 1	0.5840456
##	[703,]	0 1 1	0.5846373
##	[704,]	0 1 0	0.5838068
##	[705,]	0 1 1	0.5843972
##	[706,]	0 1 0	0.5835694
##	[707,]	0 1 1	0.5841584
##	[708,]	0 1 1	0.5847458
##	[709,]	0 1 1	0.5853315
##	[710,]	0 1 1	0.5859155
##	[711,]	0 1 1	0.5864979
##	[712,]	0 1 1	0.5870787
##	[713,]	0 1 1	0.5876578
##	[714,]	0 1 1	0.5882353
##	[715,]	0 1 0	0.5874126
##	[716,]	0 1 1	0.5879888
##	[717,]	0 1 1	0.5885635
##	[718,]	0 1 1	0.5891365
##	[719,]	0 1 0	0.5883171
##	[720,]	0 1 0	0.5875000
##	[721,]	0 1 0	0.5866852
##	[722,]	0 1 1	0.5872576
##	[723,]	0 1 0	0.5864454
##	[724,]	0 1 0	0.5856354
##	[725,]	0 1 1	0.5862069

##	[726,]	0 1 0	0.5853994
##	[727,]	0 1 1	0.5859697
##	[728,]	0 1 1	0.5865385
##	[729,]	0 1 1	0.5871056
##	[730,]	0 1 1	0.5876712
##	[731,]	0 1 0	0.5868673
##	[732,]	0 1 1	0.5874317
##	[733,]	0 1 1	0.5879945
##	[734,]	0 1 1	0.5885559
##	[735,]	0 1 0	0.5877551
##	[736,]	0 1 1	0.5883152
##	[737,]	0 1 0	0.5875170
##	[738,]	0 1 0	0.5867209
##	[739,]	0 1 1	0.5872801
##	[740,]	0 1 0	0.5864865
##	[741,]	0 1 0	0.5856950
##	[742,]	0 1 1	0.5862534
##	[743,]	0 1 0	0.5854643
##	[744,]	0 1 0	0.5846774
##	[745,]	0 1 0	0.5838926
##	[746,]	0 1 0	0.5831099
##	[747,]	0 1 0	0.5823293
##	[748,]	0 1 1	0.5828877
##	[749,]	0 1 1	0.5834446
##	[750,]	0 1 0	0.5826667
##	[751,]	0 1 1	0.5832224
##	[752,]	0 1 1	0.5837766
##	[753,]	0 1 0	0.5830013
##	[754,]	0 1 1	0.5835544
##	[755,]	0 1 0	0.5827815
##	[756,]	0 1 1	0.5833333
##	[757,]	0 1 1	0.5838838
##	[758,]	0 1 0	0.5831135
##	[759,]	0 1 0	0.5823452
##	[760,]	0 1 1	0.5828947
##	[761,]	0 1 1	0.5834428
##	[762,]	0 1 0	0.5826772
##	[763,]	0 1 0	0.5819135
##	[764,]	0 1 1	0.5824607
##	[765,]	0 1 0	0.5816993
##	[766,]	0 1 1	0.5822454
##	[767,]	0 1 1	0.5827901
##	[768,]	0 1 0	0.5820312
##	[769,]	0 1 1	0.5825748
##	[770,]	0 1 0	0.5818182
##	[771,]	0 1 0	0.5810636
##	[772,]	0 1 0	0.5803109
##	[773,]	0 1 0	0.5795602
##	[774,]	0 1 0	0.5788114
##	[775,]	0 1 0	0.5780645
##	[776,]	0 1 0	0.5773196
##	[777,]	0 1 0	0.5765766
##	[778,]	0 1 0	0.5758355
##	[779,]	0 1 0	0.5750963

##	[780,]	0 1 0	0.5743590
##	[781,]	0 1 1	0.5749040
##	[782,]	0 1 1	0.5754476
##	[783,]	0 1 0	0.5747126
##	[784,]	0 1 1	0.5752551
##	[785,]	0 1 0	0.5745223
##	[786,]	0 1 1	0.5750636
##	[787,]	0 1 1	0.5756036
##	[788,]	0 1 1	0.5761421
##	[789,]	0 1 0	0.5754119
##	[790,]	0 1 1	0.5759494
##	[791,]	0 1 0	0.5752212
##	[792,]	0 1 1	0.5757576
##	[793,]	0 1 1	0.5762926
##	[794,]	0 1 0	0.5755668
##	[795,]	0 1 1	0.5761006
##	[796,]	0 1 0	0.5753769
##	[797,]	0 1 0	0.5746550
##	[798,]	0 1 1	0.5751880
##	[799,]	0 1 0	0.5744681
##	[800,]	0 1 0	0.5737500
##	[801,]	0 1 1	0.5742821
##	[802,]	0 1 1	0.5748130
##	[803,]	0 1 1	0.5753425
##	[804,]	0 1 1	0.5758706
##	[805,]	0 1 1	0.5763975
##	[806,]	0 1 0	0.5756824
##	[807,]	0 1 1	0.5762082
##	[808,]	0 1 1	0.5767327
##	[809,]	0 1 1	0.5772559
##	[810,]	0 1 1	0.5777778
##	[811,]	1 2 1	0.5782984
##	[812,]	0 1 1	0.5788177
##	[813,]	0 1 1	0.5793358
##	[814,]	0 1 0	0.5786241
##	[815,]	0 1 0	0.5779141
##	[816,]	0 1 0	0.5772059
##	[817,]	0 1 1	0.5777234
##	[818,]	0 1 0	0.5770171
##	[819,]	0 1 1	0.5775336
##	[820,]	0 1 0	0.5768293
##	[821,]	0 1 0	0.5761267
##	[822,]	0 1 1	0.5766423
##	[823,]	0 1 0	0.5759417
##	[824,]	0 1 0	0.5752427
##	[825,]	0 1 1	0.5757576
##	[826,]	0 1 0	0.5750605
##	[827,]	0 1 0	0.5743652
##	[828,]	0 1 1	0.5748792
##	[829,]	0 1 1	0.5753920
##	[830,]	0 1 1	0.5759036
##	[831,]	0 1 0	0.5752106
##	[832,]	0 1 1	0.5757212
##	[833,]	0 1 0	0.5750300

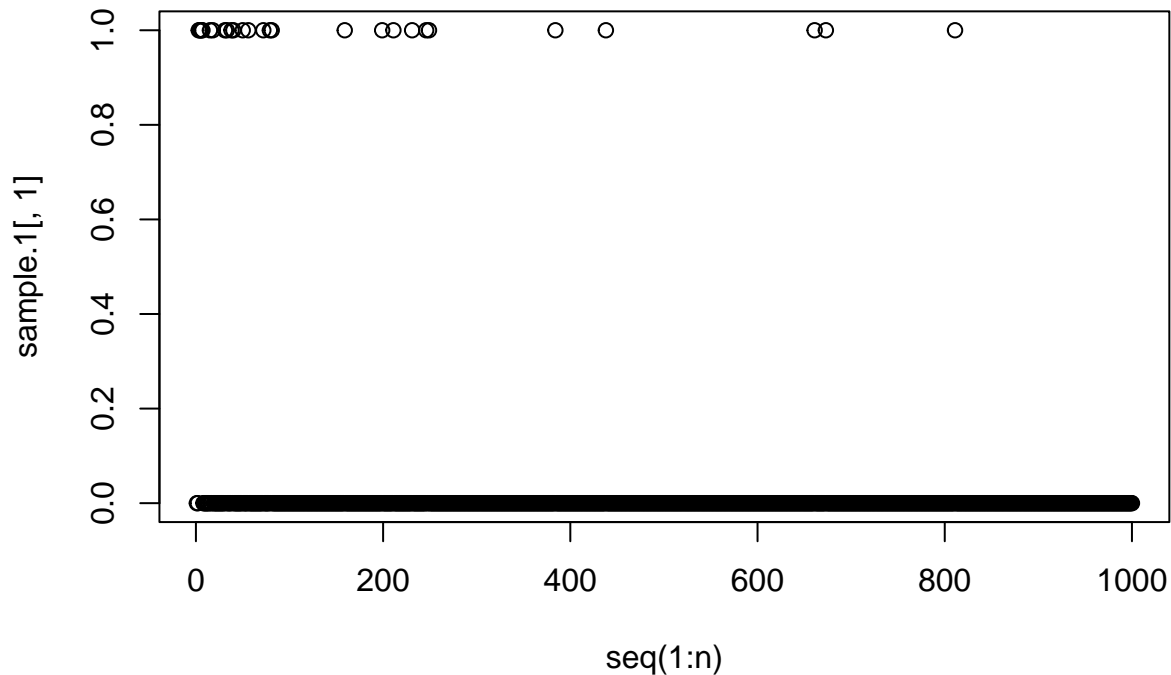
##	[834,]	0 1 1	0.5755396
##	[835,]	0 1 1	0.5760479
##	[836,]	0 1 1	0.5765550
##	[837,]	0 1 1	0.5770609
##	[838,]	0 1 0	0.5763723
##	[839,]	0 1 1	0.5768772
##	[840,]	0 1 1	0.5773810
##	[841,]	0 1 1	0.5778835
##	[842,]	0 1 0	0.5771971
##	[843,]	0 1 0	0.5765125
##	[844,]	0 1 1	0.5770142
##	[845,]	0 1 1	0.5775148
##	[846,]	0 1 0	0.5768322
##	[847,]	0 1 1	0.5773318
##	[848,]	0 1 1	0.5778302
##	[849,]	0 1 1	0.5783274
##	[850,]	0 1 1	0.5788235
##	[851,]	0 1 1	0.5793184
##	[852,]	0 1 1	0.5798122
##	[853,]	0 1 0	0.5791325
##	[854,]	0 1 0	0.5784543
##	[855,]	0 1 1	0.5789474
##	[856,]	0 1 1	0.5794393
##	[857,]	0 1 0	0.5787631
##	[858,]	0 1 0	0.5780886
##	[859,]	0 1 1	0.5785797
##	[860,]	0 1 1	0.5790698
##	[861,]	0 1 0	0.5783972
##	[862,]	0 1 1	0.5788863
##	[863,]	0 1 1	0.5793743
##	[864,]	0 1 1	0.5798611
##	[865,]	0 1 0	0.5791908
##	[866,]	0 1 0	0.5785219
##	[867,]	0 1 0	0.5778547
##	[868,]	0 1 0	0.5771889
##	[869,]	0 1 1	0.5776755
##	[870,]	0 1 1	0.5781609
##	[871,]	0 1 0	0.5774971
##	[872,]	0 1 1	0.5779817
##	[873,]	0 1 1	0.5784651
##	[874,]	0 1 1	0.5789474
##	[875,]	0 1 0	0.5782857
##	[876,]	0 1 0	0.5776256
##	[877,]	0 1 1	0.5781072
##	[878,]	0 1 1	0.5785877
##	[879,]	0 1 0	0.5779295
##	[880,]	0 1 0	0.5772727
##	[881,]	0 1 1	0.5777526
##	[882,]	0 1 1	0.5782313
##	[883,]	0 1 0	0.5775764
##	[884,]	0 1 1	0.5780543
##	[885,]	0 1 0	0.5774011
##	[886,]	0 1 1	0.5778781
##	[887,]	0 1 1	0.5783540

##	[888,]	0 1 1	0.5788288
##	[889,]	0 1 0	0.5781777
##	[890,]	0 1 0	0.5775281
##	[891,]	0 1 1	0.5780022
##	[892,]	0 1 1	0.5784753
##	[893,]	0 1 1	0.5789474
##	[894,]	0 1 1	0.5794183
##	[895,]	0 1 1	0.5798883
##	[896,]	0 1 1	0.5803571
##	[897,]	0 1 1	0.5808250
##	[898,]	0 1 1	0.5812918
##	[899,]	0 1 0	0.5806452
##	[900,]	0 1 1	0.5811111
##	[901,]	0 1 0	0.5804661
##	[902,]	0 1 0	0.5798226
##	[903,]	0 1 0	0.5791805
##	[904,]	0 1 0	0.5785398
##	[905,]	0 1 0	0.5779006
##	[906,]	0 1 1	0.5783664
##	[907,]	0 1 1	0.5788313
##	[908,]	0 1 0	0.5781938
##	[909,]	0 1 0	0.5775578
##	[910,]	0 1 0	0.5769231
##	[911,]	0 1 1	0.5773875
##	[912,]	0 1 1	0.5778509
##	[913,]	0 1 0	0.5772180
##	[914,]	0 1 1	0.5776805
##	[915,]	0 1 1	0.5781421
##	[916,]	0 1 1	0.5786026
##	[917,]	0 1 1	0.5790622
##	[918,]	0 1 1	0.5795207
##	[919,]	0 1 1	0.5799782
##	[920,]	0 1 0	0.5793478
##	[921,]	0 1 0	0.5787188
##	[922,]	0 1 1	0.5791757
##	[923,]	0 1 1	0.5796316
##	[924,]	0 1 1	0.5800866
##	[925,]	0 1 1	0.5805405
##	[926,]	0 1 1	0.5809935
##	[927,]	0 1 1	0.5814455
##	[928,]	0 1 0	0.5808190
##	[929,]	0 1 0	0.5801938
##	[930,]	0 1 0	0.5795699
##	[931,]	0 1 1	0.5800215
##	[932,]	0 1 0	0.5793991
##	[933,]	0 1 1	0.5798499
##	[934,]	0 1 0	0.5792291
##	[935,]	0 1 0	0.5786096
##	[936,]	0 1 1	0.5790598
##	[937,]	0 1 1	0.5795091
##	[938,]	0 1 0	0.5788913
##	[939,]	0 1 1	0.5793397
##	[940,]	0 1 1	0.5797872
##	[941,]	0 1 1	0.5802338

##	[942,]	0 1 0	0.5796178
##	[943,]	0 1 0	0.5790032
##	[944,]	0 1 1	0.5794492
##	[945,]	0 1 0	0.5788360
##	[946,]	0 1 1	0.5792812
##	[947,]	0 1 1	0.5797254
##	[948,]	0 1 1	0.5801688
##	[949,]	0 1 0	0.5795574
##	[950,]	0 1 0	0.5789474
##	[951,]	0 1 0	0.5783386
##	[952,]	0 1 0	0.5777311
##	[953,]	0 1 0	0.5771249
##	[954,]	0 1 0	0.5765199
##	[955,]	0 1 0	0.5759162
##	[956,]	0 1 1	0.5763598
##	[957,]	0 1 1	0.5768025
##	[958,]	0 1 1	0.5772443
##	[959,]	0 1 1	0.5776851
##	[960,]	0 1 1	0.5781250
##	[961,]	0 1 1	0.5785640
##	[962,]	0 1 1	0.5790021
##	[963,]	0 1 0	0.5784008
##	[964,]	0 1 0	0.5778008
##	[965,]	0 1 0	0.5772021
##	[966,]	0 1 1	0.5776398
##	[967,]	0 1 1	0.5780765
##	[968,]	0 1 1	0.5785124
##	[969,]	0 1 1	0.5789474
##	[970,]	0 1 0	0.5783505
##	[971,]	0 1 1	0.5787848
##	[972,]	0 1 1	0.5792181
##	[973,]	0 1 1	0.5796506
##	[974,]	0 1 1	0.5800821
##	[975,]	0 1 1	0.5805128
##	[976,]	0 1 0	0.5799180
##	[977,]	0 1 1	0.5803480
##	[978,]	0 1 0	0.5797546
##	[979,]	0 1 0	0.5791624
##	[980,]	0 1 1	0.5795918
##	[981,]	0 1 1	0.5800204
##	[982,]	0 1 1	0.5804481
##	[983,]	0 1 0	0.5798576
##	[984,]	0 1 0	0.5792683
##	[985,]	0 1 1	0.5796954
##	[986,]	0 1 1	0.5801217
##	[987,]	0 1 1	0.5805471
##	[988,]	0 1 1	0.5809717
##	[989,]	0 1 1	0.5813953
##	[990,]	0 1 0	0.5808081
##	[991,]	0 1 0	0.5802220
##	[992,]	0 1 1	0.5806452
##	[993,]	0 1 1	0.5810675
##	[994,]	0 1 0	0.5804829
##	[995,]	0 1 1	0.5809045

```
## [996,]      0 1 1      0.5813253
## [997,]      0 1 0      0.5807422
## [998,]      0 1 1      0.5811623
## [999,]      0 1 0      0.5805806
## [1000,]     0 1 1      0.5810000
```

```
plot(seq(1:n),sample.1[,1])
```



2(c)

$\epsilon = \min\{1, C \cdot n^{-2}\}$

$\lim_{\epsilon \rightarrow 0} n \rightarrow \infty$ Hence as n increases with higher probability we play the arm with the best success rate so far. This relates to relying on the actual success rate so far, as time goes on because it's more likely to reflect the true probability of success. By Borel-Cantelli we will only play a random arm finitely many times so eventually rely only on the success rates so far. However, this is risky because if we choose the wrong arm originally it is more likely than in 2b) that we never get back to the good arm. For example when we repeated this we occasionally got 'stuck' on arm 2, as can be seen below with the seed as 15, but get on arm 1 with seed 1123. This happens a lot faster than in 2b) as it tends to zero faster, so we put more emphasis on what we have actually seen so far rather than testing out different arms. We spend more time in exploitation than exploration than we did in 2b). As you can see from our run of the function, we choose a random arm less frequently as time goes on and we end up choosing arm 1 which is the better arm, which is what we want to do. Again, this is a lot faster than in 2b). However, as mentioned we also have an example where it goes wrong.

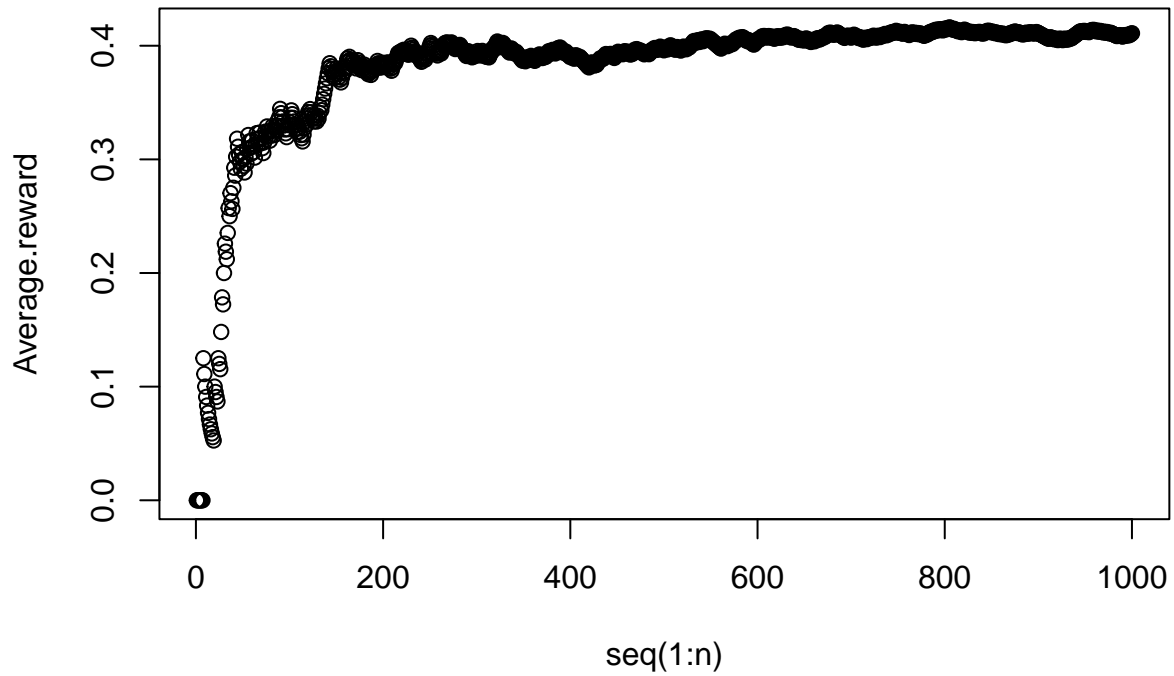
```
C = 5
n=1000
epsilon=vector(length=n)
```

```

for (i in 1:n){
  epsilon[i] = min(1, C/i^(2))
}

sample.2=epsilon.decreasing(n, 0.6, 0.4, e=epsilon)

```



```
sample.2
```

##	random.arm	a	r	Average.reward	
##	[1,]	0	1	0	0.00000000
##	[2,]	0	2	0	0.00000000
##	[3,]	1	1	0	0.00000000
##	[4,]	0	2	0	0.00000000
##	[5,]	0	2	0	0.00000000
##	[6,]	0	2	0	0.00000000
##	[7,]	0	2	0	0.00000000
##	[8,]	0	2	1	0.12500000
##	[9,]	1	2	0	0.11111111
##	[10,]	0	2	0	0.10000000
##	[11,]	0	2	0	0.09090909
##	[12,]	0	2	0	0.08333333
##	[13,]	0	2	0	0.07692308
##	[14,]	0	2	0	0.07142857
##	[15,]	0	2	0	0.06666667
##	[16,]	0	2	0	0.06250000
##	[17,]	0	2	0	0.05882353

##	[18,]	0 2 0	0.05555556
##	[19,]	0 2 0	0.05263158
##	[20,]	0 2 1	0.10000000
##	[21,]	0 2 0	0.09523810
##	[22,]	0 2 0	0.09090909
##	[23,]	0 2 0	0.08695652
##	[24,]	0 2 1	0.12500000
##	[25,]	0 2 0	0.12000000
##	[26,]	0 2 0	0.11538462
##	[27,]	0 2 1	0.14814815
##	[28,]	0 2 1	0.17857143
##	[29,]	0 2 0	0.17241379
##	[30,]	0 2 1	0.20000000
##	[31,]	0 2 1	0.22580645
##	[32,]	0 2 0	0.21875000
##	[33,]	0 2 0	0.21212121
##	[34,]	0 2 1	0.23529412
##	[35,]	0 2 1	0.25714286
##	[36,]	0 2 0	0.25000000
##	[37,]	0 2 1	0.27027027
##	[38,]	0 2 0	0.26315789
##	[39,]	0 2 0	0.25641026
##	[40,]	0 2 1	0.27500000
##	[41,]	0 2 1	0.29268293
##	[42,]	0 2 0	0.28571429
##	[43,]	0 2 1	0.30232558
##	[44,]	0 2 1	0.31818182
##	[45,]	0 2 0	0.31111111
##	[46,]	0 2 0	0.30434783
##	[47,]	0 2 0	0.29787234
##	[48,]	0 2 0	0.29166667
##	[49,]	0 2 1	0.30612245
##	[50,]	0 2 0	0.30000000
##	[51,]	0 2 0	0.29411765
##	[52,]	0 2 0	0.28846154
##	[53,]	0 2 1	0.30188679
##	[54,]	0 2 0	0.29629630
##	[55,]	0 2 1	0.30909091
##	[56,]	0 2 1	0.32142857
##	[57,]	0 2 0	0.31578947
##	[58,]	0 2 0	0.31034483
##	[59,]	0 2 0	0.30508475
##	[60,]	0 2 1	0.31666667
##	[61,]	0 2 0	0.31147541
##	[62,]	0 2 0	0.30645161
##	[63,]	0 2 0	0.30158730
##	[64,]	0 2 1	0.31250000
##	[65,]	0 2 1	0.32307692
##	[66,]	0 2 0	0.31818182
##	[67,]	0 2 0	0.31343284
##	[68,]	0 2 1	0.32352941
##	[69,]	0 2 0	0.31884058
##	[70,]	0 2 0	0.31428571
##	[71,]	0 2 0	0.30985915

##	[72,]	0 2 0	0.30555556
##	[73,]	0 2 1	0.31506849
##	[74,]	0 2 1	0.32432432
##	[75,]	0 2 0	0.32000000
##	[76,]	0 2 1	0.32894737
##	[77,]	0 2 0	0.32467532
##	[78,]	0 2 0	0.32051282
##	[79,]	0 2 0	0.31645570
##	[80,]	0 2 1	0.32500000
##	[81,]	0 2 0	0.32098765
##	[82,]	0 2 1	0.32926829
##	[83,]	0 2 0	0.32530120
##	[84,]	0 2 0	0.32142857
##	[85,]	0 2 1	0.32941176
##	[86,]	0 2 0	0.32558140
##	[87,]	0 2 1	0.33333333
##	[88,]	0 2 0	0.32954545
##	[89,]	0 2 1	0.33707865
##	[90,]	0 2 1	0.34444444
##	[91,]	0 2 0	0.34065934
##	[92,]	0 2 0	0.33695652
##	[93,]	0 2 0	0.33333333
##	[94,]	0 2 0	0.32978723
##	[95,]	0 2 0	0.32631579
##	[96,]	0 2 0	0.32291667
##	[97,]	0 2 0	0.31958763
##	[98,]	0 2 1	0.32653061
##	[99,]	0 2 1	0.33333333
##	[100,]	0 2 0	0.33000000
##	[101,]	0 2 1	0.33663366
##	[102,]	0 2 1	0.34313725
##	[103,]	0 2 0	0.33980583
##	[104,]	0 2 0	0.33653846
##	[105,]	0 2 0	0.33333333
##	[106,]	0 2 0	0.33018868
##	[107,]	0 2 0	0.32710280
##	[108,]	0 2 0	0.32407407
##	[109,]	0 2 1	0.33027523
##	[110,]	0 2 0	0.32727273
##	[111,]	0 2 0	0.32432432
##	[112,]	0 2 0	0.32142857
##	[113,]	0 2 0	0.31858407
##	[114,]	0 2 0	0.31578947
##	[115,]	0 2 1	0.32173913
##	[116,]	0 2 1	0.32758621
##	[117,]	0 2 1	0.33333333
##	[118,]	0 2 0	0.33050847
##	[119,]	0 2 1	0.33613445
##	[120,]	0 2 1	0.34166667
##	[121,]	0 2 0	0.33884298
##	[122,]	0 2 1	0.34426230
##	[123,]	0 2 0	0.34146341
##	[124,]	0 2 0	0.33870968
##	[125,]	0 2 0	0.33600000

##	[126,]	0 2 0	0.33333333
##	[127,]	0 2 1	0.33858268
##	[128,]	0 2 0	0.33593750
##	[129,]	0 2 0	0.33333333
##	[130,]	0 2 1	0.33846154
##	[131,]	0 2 0	0.33587786
##	[132,]	0 2 1	0.34090909
##	[133,]	0 2 1	0.34586466
##	[134,]	0 2 0	0.34328358
##	[135,]	0 2 1	0.34814815
##	[136,]	0 2 1	0.35294118
##	[137,]	0 2 1	0.35766423
##	[138,]	0 2 1	0.36231884
##	[139,]	0 2 1	0.36690647
##	[140,]	0 2 1	0.37142857
##	[141,]	0 2 1	0.37588652
##	[142,]	0 2 1	0.38028169
##	[143,]	0 2 1	0.38461538
##	[144,]	0 2 0	0.38194444
##	[145,]	0 2 0	0.37931034
##	[146,]	0 2 0	0.37671233
##	[147,]	0 2 0	0.37414966
##	[148,]	0 2 0	0.37162162
##	[149,]	0 2 1	0.37583893
##	[150,]	0 2 1	0.38000000
##	[151,]	0 2 0	0.37748344
##	[152,]	0 2 0	0.37500000
##	[153,]	0 2 0	0.37254902
##	[154,]	0 2 0	0.37012987
##	[155,]	0 2 0	0.36774194
##	[156,]	0 2 1	0.37179487
##	[157,]	0 2 1	0.37579618
##	[158,]	0 2 1	0.37974684
##	[159,]	0 2 0	0.37735849
##	[160,]	0 2 1	0.38125000
##	[161,]	0 2 1	0.38509317
##	[162,]	0 2 1	0.38888889
##	[163,]	0 2 0	0.38650307
##	[164,]	0 2 1	0.39024390
##	[165,]	0 2 0	0.38787879
##	[166,]	0 2 0	0.38554217
##	[167,]	0 2 0	0.38323353
##	[168,]	0 2 1	0.38690476
##	[169,]	0 2 0	0.38461538
##	[170,]	0 2 0	0.38235294
##	[171,]	0 2 0	0.38011696
##	[172,]	0 2 1	0.38372093
##	[173,]	0 2 1	0.38728324
##	[174,]	0 2 0	0.38505747
##	[175,]	0 2 0	0.38285714
##	[176,]	0 2 0	0.38068182
##	[177,]	0 2 0	0.37853107
##	[178,]	0 2 1	0.38202247
##	[179,]	0 2 0	0.37988827

##	[180,]	0 2 1	0.38333333
##	[181,]	0 2 0	0.38121547
##	[182,]	0 2 0	0.37912088
##	[183,]	0 2 0	0.37704918
##	[184,]	0 2 0	0.37500000
##	[185,]	0 2 1	0.37837838
##	[186,]	0 2 0	0.37634409
##	[187,]	0 2 0	0.37433155
##	[188,]	0 2 1	0.37765957
##	[189,]	0 2 1	0.38095238
##	[190,]	0 2 0	0.37894737
##	[191,]	0 2 1	0.38219895
##	[192,]	0 2 0	0.38020833
##	[193,]	0 2 1	0.38341969
##	[194,]	0 2 1	0.38659794
##	[195,]	0 2 0	0.38461538
##	[196,]	0 2 0	0.38265306
##	[197,]	0 2 0	0.38071066
##	[198,]	0 2 1	0.38383838
##	[199,]	0 2 0	0.38190955
##	[200,]	0 2 1	0.38500000
##	[201,]	0 2 0	0.38308458
##	[202,]	0 2 0	0.38118812
##	[203,]	0 2 1	0.38423645
##	[204,]	0 2 0	0.38235294
##	[205,]	0 2 1	0.38536585
##	[206,]	0 2 0	0.38349515
##	[207,]	0 2 0	0.38164251
##	[208,]	0 2 0	0.37980769
##	[209,]	0 2 0	0.37799043
##	[210,]	0 2 1	0.38095238
##	[211,]	0 2 1	0.38388626
##	[212,]	0 2 1	0.38679245
##	[213,]	0 2 0	0.38497653
##	[214,]	0 2 1	0.38785047
##	[215,]	0 2 1	0.39069767
##	[216,]	0 2 1	0.39351852
##	[217,]	0 2 0	0.39170507
##	[218,]	0 2 1	0.39449541
##	[219,]	0 2 0	0.39269406
##	[220,]	0 2 1	0.39545455
##	[221,]	0 2 0	0.39366516
##	[222,]	0 2 1	0.39639640
##	[223,]	0 2 0	0.39461883
##	[224,]	0 2 0	0.39285714
##	[225,]	0 2 1	0.39555556
##	[226,]	0 2 0	0.39380531
##	[227,]	0 2 0	0.39207048
##	[228,]	0 2 1	0.39473684
##	[229,]	0 2 1	0.39737991
##	[230,]	0 2 1	0.40000000
##	[231,]	0 2 0	0.39826840
##	[232,]	0 2 0	0.39655172
##	[233,]	0 2 0	0.39484979

##	[234,]	0 2 0	0.39316239
##	[235,]	0 2 0	0.39148936
##	[236,]	0 2 1	0.39406780
##	[237,]	0 2 0	0.39240506
##	[238,]	0 2 0	0.39075630
##	[239,]	0 2 0	0.38912134
##	[240,]	0 2 0	0.38750000
##	[241,]	0 2 0	0.38589212
##	[242,]	0 2 1	0.38842975
##	[243,]	0 2 1	0.39094650
##	[244,]	0 2 0	0.38934426
##	[245,]	0 2 0	0.38775510
##	[246,]	0 2 1	0.39024390
##	[247,]	0 2 1	0.39271255
##	[248,]	0 2 1	0.39516129
##	[249,]	0 2 1	0.39759036
##	[250,]	0 2 1	0.40000000
##	[251,]	0 2 1	0.40239044
##	[252,]	0 2 0	0.40079365
##	[253,]	0 2 0	0.39920949
##	[254,]	0 2 0	0.39763780
##	[255,]	0 2 0	0.39607843
##	[256,]	0 2 0	0.39453125
##	[257,]	0 2 0	0.39299611
##	[258,]	0 2 0	0.39147287
##	[259,]	0 2 1	0.39382239
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##	[270,]	0 2 0	0.40000000
##	[271,]	0 2 1	0.40221402
##	[272,]	0 2 0	0.40073529
##	[273,]	0 2 1	0.40293040
##	[274,]	0 2 0	0.40145985
##	[275,]	0 2 0	0.40000000
##	[276,]	0 2 0	0.39855072
##	[277,]	0 2 0	0.39711191
##	[278,]	0 2 1	0.39928058
##	[279,]	0 2 0	0.39784946
##	[280,]	0 2 1	0.40000000
##	[281,]	0 2 0	0.39857651
##	[282,]	0 2 1	0.40070922
##	[283,]	0 2 0	0.39929329
##	[284,]	0 2 0	0.39788732
##	[285,]	0 2 0	0.39649123
##	[286,]	0 2 0	0.39510490
##	[287,]	0 2 0	0.39372822

##	[288,]	0 2 0	0.39236111
##	[289,]	0 2 0	0.39100346
##	[290,]	0 2 1	0.39310345
##	[291,]	0 2 1	0.39518900
##	[292,]	0 2 0	0.39383562
##	[293,]	0 2 0	0.39249147
##	[294,]	0 2 0	0.39115646
##	[295,]	0 2 0	0.38983051
##	[296,]	0 2 1	0.39189189
##	[297,]	0 2 0	0.39057239
##	[298,]	0 2 1	0.39261745
##	[299,]	0 2 0	0.39130435
##	[300,]	0 2 1	0.39333333
##	[301,]	0 2 1	0.39534884
##	[302,]	0 2 0	0.39403974
##	[303,]	0 2 0	0.39273927
##	[304,]	0 2 0	0.39144737
##	[305,]	0 2 1	0.39344262
##	[306,]	0 2 1	0.39542484
##	[307,]	0 2 0	0.39413681
##	[308,]	0 2 0	0.39285714
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##	[311,]	0 2 1	0.39228296
##	[312,]	0 2 0	0.39102564
##	[313,]	0 2 0	0.38977636
##	[314,]	0 2 1	0.39171975
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##	[331,]	0 2 0	0.39879154
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##	[333,]	0 2 0	0.39639640
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##	[336,]	0 2 1	0.39583333
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##	[338,]	0 2 0	0.39644970
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##	[340,]	0 2 0	0.39411765
##	[341,]	0 2 0	0.39296188

##	[342,]	0 2 1	0.39473684
##	[343,]	0 2 0	0.39358601
##	[344,]	0 2 0	0.39244186
##	[345,]	0 2 0	0.39130435
##	[346,]	0 2 0	0.39017341
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##	[353,]	0 2 1	0.38810198
##	[354,]	0 2 1	0.38983051
##	[355,]	0 2 0	0.38873239
##	[356,]	0 2 0	0.38764045
##	[357,]	0 2 1	0.38935574
##	[358,]	0 2 1	0.39106145
##	[359,]	0 2 0	0.38997214
##	[360,]	0 2 0	0.38888889
##	[361,]	0 2 0	0.38781163
##	[362,]	0 2 0	0.38674033
##	[363,]	0 2 1	0.38842975
##	[364,]	0 2 1	0.39010989
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##	[368,]	0 2 0	0.39130435
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##	[375,]	0 2 1	0.39200000
##	[376,]	0 2 1	0.39361702
##	[377,]	0 2 1	0.39522546
##	[378,]	0 2 0	0.39417989
##	[379,]	0 2 0	0.39313984
##	[380,]	0 2 1	0.39473684
##	[381,]	0 2 1	0.39632546
##	[382,]	0 2 0	0.39528796
##	[383,]	0 2 0	0.39425587
##	[384,]	0 2 0	0.39322917
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##	[387,]	0 2 1	0.39793282
##	[388,]	0 2 0	0.39690722
##	[389,]	0 2 1	0.39845758
##	[390,]	0 2 0	0.39743590
##	[391,]	0 2 0	0.39641944
##	[392,]	0 2 0	0.39540816
##	[393,]	0 2 0	0.39440204
##	[394,]	0 2 0	0.39340102
##	[395,]	0 2 1	0.39493671

##	[396,]	0 2 0	0.39393939
##	[397,]	0 2 0	0.39294710
##	[398,]	0 2 0	0.39195980
##	[399,]	0 2 0	0.39097744
##	[400,]	0 2 0	0.39000000
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##	[402,]	0 2 0	0.39054726
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##	[406,]	0 2 1	0.39162562
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##	[432,]	0 2 1	0.38888889
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##	[444,]	0 2 0	0.39189189
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##	[446,]	0 2 0	0.39013453
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##	[449,]	0 2 1	0.39198218

##	[450,]	0 2 1	0.39333333
##	[451,]	0 2 1	0.39467849
##	[452,]	0 2 0	0.39380531
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##	[454,]	0 2 1	0.39427313
##	[455,]	0 2 0	0.39340659
##	[456,]	0 2 0	0.39254386
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##	[472,]	0 2 0	0.39618644
##	[473,]	0 2 0	0.39534884
##	[474,]	0 2 0	0.39451477
##	[475,]	0 2 1	0.39578947
##	[476,]	0 2 0	0.39495798
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##	[479,]	0 2 0	0.39248434
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##	[493,]	0 2 1	0.39756592
##	[494,]	0 2 0	0.39676113
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##	[500,]	0 2 0	0.39600000
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##	[504,]	0 2 0	0.39682540
##	[505,]	0 2 1	0.39801980
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##	[508,]	0 2 0	0.39960630
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##	[525,]	0 2 1	0.39809524
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##	[527,]	0 2 0	0.39848197
##	[528,]	0 2 1	0.39962121
##	[529,]	0 2 1	0.40075614
##	[530,]	0 2 1	0.40188679
##	[531,]	0 2 1	0.40301318
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##	[562,]	0 2 1	0.39857651
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##	[575,]	0 2 1	0.40347826
##	[576,]	0 2 1	0.40451389
##	[577,]	0 2 1	0.40554593
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##	[579,]	0 2 1	0.40587219
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##	[582,]	0 2 1	0.40721649
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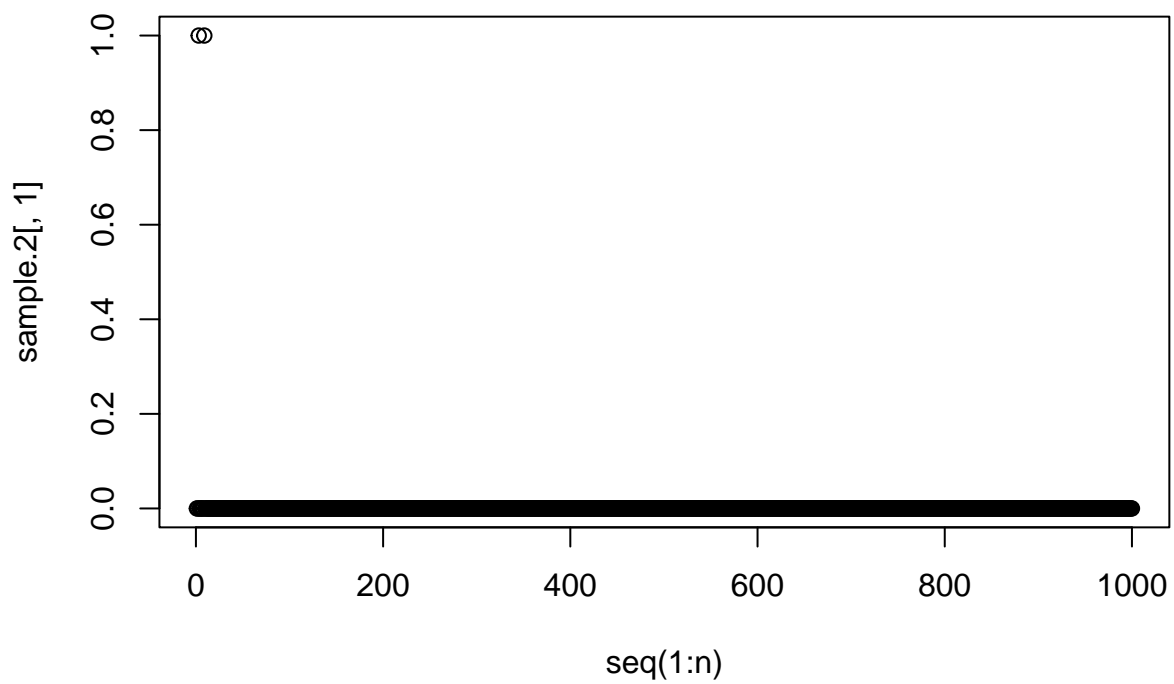
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##	[964,]	0 2 0	0.41286307
##	[965,]	0 2 0	0.41243523
##	[966,]	0 2 1	0.41304348
##	[967,]	0 2 0	0.41261634
##	[968,]	0 2 0	0.41219008
##	[969,]	0 2 0	0.41176471
##	[970,]	0 2 1	0.41237113
##	[971,]	0 2 0	0.41194645
##	[972,]	0 2 0	0.41152263
##	[973,]	0 2 1	0.41212744
##	[974,]	0 2 0	0.41170431
##	[975,]	0 2 0	0.41128205
##	[976,]	0 2 0	0.41086066
##	[977,]	0 2 1	0.41146366
##	[978,]	0 2 0	0.41104294
##	[979,]	0 2 0	0.41062308
##	[980,]	0 2 0	0.41020408
##	[981,]	0 2 0	0.40978593
##	[982,]	0 2 0	0.40936864
##	[983,]	0 2 0	0.40895219
##	[984,]	0 2 0	0.40853659
##	[985,]	0 2 1	0.40913706
##	[986,]	0 2 0	0.40872211
##	[987,]	0 2 1	0.40932118
##	[988,]	0 2 0	0.40890688
##	[989,]	0 2 0	0.40849343

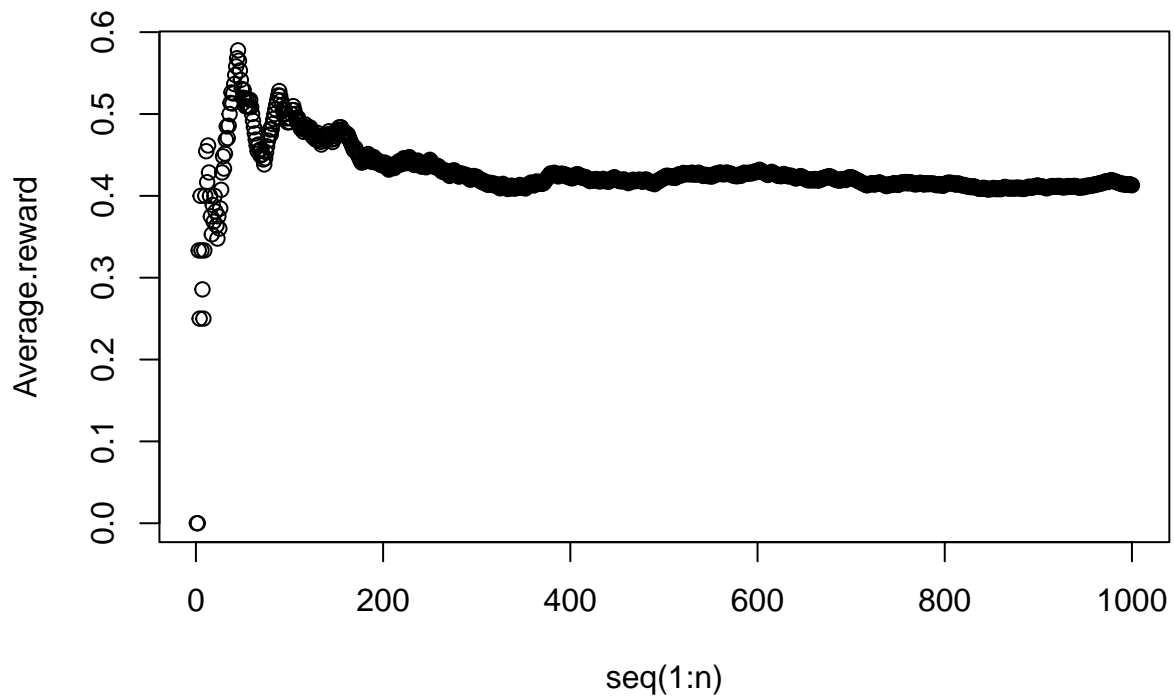

```
## [990,]      0 2 0      0.40808081
## [991,]      0 2 1      0.40867810
## [992,]      0 2 1      0.40927419
## [993,]      0 2 0      0.40886203
## [994,]      0 2 1      0.40945674
## [995,]      0 2 0      0.40904523
## [996,]      0 2 1      0.40963855
## [997,]      0 2 0      0.40922768
## [998,]      0 2 1      0.40981964
## [999,]      0 2 1      0.41041041
## [1000,]     0 2 1      0.41100000
```

```
plot(seq(1:n),sample.2[,1])
```



```
set.seed(15)
C = 5
n=1000
epsilon=vector(length=n)
for (i in 1:n){
  epsilon[i] = min(1, C/i^(2))
}

sample.3=epsilon.decreasing(n, 0.6, 0.4, e=epsilon)
```



sample.3

##	random.arm	a	r	Average.reward	
##	[1,]	0	1	0	0.0000000
##	[2,]	0	2	0	0.0000000
##	[3,]	0	2	1	0.3333333
##	[4,]	0	2	0	0.2500000
##	[5,]	1	1	1	0.4000000
##	[6,]	0	1	0	0.3333333
##	[7,]	0	2	0	0.2857143
##	[8,]	0	1	0	0.2500000
##	[9,]	0	2	1	0.3333333
##	[10,]	0	2	1	0.4000000
##	[11,]	0	2	1	0.4545455
##	[12,]	0	2	0	0.4166667
##	[13,]	0	2	1	0.4615385
##	[14,]	0	2	0	0.4285714
##	[15,]	0	2	0	0.4000000
##	[16,]	0	2	0	0.3750000
##	[17,]	0	2	0	0.3529412
##	[18,]	0	2	1	0.3888889
##	[19,]	0	2	0	0.3684211
##	[20,]	0	2	1	0.4000000
##	[21,]	0	2	0	0.3809524
##	[22,]	0	2	0	0.3636364
##	[23,]	0	2	0	0.3478261

##	[24,]	0 2 1	0.3750000
##	[25,]	0 2 0	0.3600000
##	[26,]	0 2 1	0.3846154
##	[27,]	0 2 1	0.4074074
##	[28,]	0 2 1	0.4285714
##	[29,]	0 2 1	0.4482759
##	[30,]	0 2 0	0.4333333
##	[31,]	0 2 1	0.4516129
##	[32,]	0 2 1	0.4687500
##	[33,]	0 2 1	0.4848485
##	[34,]	0 2 0	0.4705882
##	[35,]	0 2 1	0.4857143
##	[36,]	0 2 1	0.5000000
##	[37,]	0 2 1	0.5135135
##	[38,]	0 2 1	0.5263158
##	[39,]	0 2 0	0.5128205
##	[40,]	0 2 1	0.5250000
##	[41,]	0 2 1	0.5365854
##	[42,]	0 2 1	0.5476190
##	[43,]	0 2 1	0.5581395
##	[44,]	0 2 1	0.5681818
##	[45,]	0 2 1	0.5777778
##	[46,]	0 2 0	0.5652174
##	[47,]	0 2 0	0.5531915
##	[48,]	0 2 0	0.5416667
##	[49,]	0 2 0	0.5306122
##	[50,]	0 2 0	0.5200000
##	[51,]	0 2 1	0.5294118
##	[52,]	0 2 0	0.5192308
##	[53,]	0 2 0	0.5094340
##	[54,]	0 2 1	0.5185185
##	[55,]	0 2 0	0.5090909
##	[56,]	0 2 1	0.5178571
##	[57,]	0 2 0	0.5087719
##	[58,]	0 2 1	0.5172414
##	[59,]	0 2 0	0.5084746
##	[60,]	0 2 0	0.5000000
##	[61,]	0 2 0	0.4918033
##	[62,]	0 2 0	0.4838710
##	[63,]	0 2 0	0.4761905
##	[64,]	0 2 0	0.4687500
##	[65,]	0 2 0	0.4615385
##	[66,]	0 2 0	0.4545455
##	[67,]	0 2 1	0.4626866
##	[68,]	0 2 0	0.4558824
##	[69,]	0 2 0	0.4492754
##	[70,]	0 2 1	0.4571429
##	[71,]	0 2 0	0.4507042
##	[72,]	0 2 0	0.4444444
##	[73,]	0 2 0	0.4383562
##	[74,]	0 2 1	0.4459459
##	[75,]	0 2 1	0.4533333
##	[76,]	0 2 1	0.4605263
##	[77,]	0 2 1	0.4675325

##	[78,]	0 2 1	0.4743590
##	[79,]	0 2 1	0.4810127
##	[80,]	0 2 0	0.4750000
##	[81,]	0 2 1	0.4814815
##	[82,]	0 2 1	0.4878049
##	[83,]	0 2 1	0.4939759
##	[84,]	0 2 1	0.5000000
##	[85,]	0 2 1	0.5058824
##	[86,]	0 2 1	0.5116279
##	[87,]	0 2 1	0.5172414
##	[88,]	0 2 1	0.5227273
##	[89,]	0 2 1	0.5280899
##	[90,]	0 2 0	0.5222222
##	[91,]	0 2 0	0.5164835
##	[92,]	0 2 0	0.5108696
##	[93,]	0 2 0	0.5053763
##	[94,]	0 2 0	0.5000000
##	[95,]	0 2 1	0.5052632
##	[96,]	0 2 0	0.5000000
##	[97,]	0 2 0	0.4948454
##	[98,]	0 2 0	0.4897959
##	[99,]	0 2 1	0.4949495
##	[100,]	0 2 0	0.4900000
##	[101,]	0 2 1	0.4950495
##	[102,]	0 2 1	0.5000000
##	[103,]	0 2 1	0.5048544
##	[104,]	0 2 1	0.5096154
##	[105,]	0 2 0	0.5047619
##	[106,]	0 2 0	0.5000000
##	[107,]	0 2 0	0.4953271
##	[108,]	0 2 0	0.4907407
##	[109,]	0 2 1	0.4954128
##	[110,]	0 2 0	0.4909091
##	[111,]	0 2 0	0.4864865
##	[112,]	0 2 0	0.4821429
##	[113,]	0 2 1	0.4867257
##	[114,]	0 2 0	0.4824561
##	[115,]	0 2 0	0.4782609
##	[116,]	0 2 1	0.4827586
##	[117,]	0 2 1	0.4871795
##	[118,]	0 2 0	0.4830508
##	[119,]	0 2 0	0.4789916
##	[120,]	0 2 1	0.4833333
##	[121,]	0 2 0	0.4793388
##	[122,]	0 2 1	0.4836066
##	[123,]	0 2 0	0.4796748
##	[124,]	0 2 0	0.4758065
##	[125,]	0 2 0	0.4720000
##	[126,]	0 2 1	0.4761905
##	[127,]	0 2 0	0.4724409
##	[128,]	0 2 0	0.4687500
##	[129,]	0 2 1	0.4728682
##	[130,]	0 2 1	0.4769231
##	[131,]	0 2 0	0.4732824

##	[132,]	0 2 0	0.4696970
##	[133,]	0 2 0	0.4661654
##	[134,]	0 2 0	0.4626866
##	[135,]	0 2 1	0.4666667
##	[136,]	0 2 1	0.4705882
##	[137,]	0 2 1	0.4744526
##	[138,]	0 2 0	0.4710145
##	[139,]	0 2 0	0.4676259
##	[140,]	0 2 1	0.4714286
##	[141,]	0 2 1	0.4751773
##	[142,]	0 2 1	0.4788732
##	[143,]	0 2 0	0.4755245
##	[144,]	0 2 0	0.4722222
##	[145,]	0 2 0	0.4689655
##	[146,]	0 2 0	0.4657534
##	[147,]	0 2 1	0.4693878
##	[148,]	0 2 1	0.4729730
##	[149,]	0 2 1	0.4765101
##	[150,]	0 2 1	0.4800000
##	[151,]	0 2 0	0.4768212
##	[152,]	0 2 1	0.4802632
##	[153,]	0 2 1	0.4836601
##	[154,]	0 2 0	0.4805195
##	[155,]	0 2 1	0.4838710
##	[156,]	0 2 0	0.4807692
##	[157,]	0 2 0	0.4777070
##	[158,]	0 2 0	0.4746835
##	[159,]	0 2 1	0.4779874
##	[160,]	0 2 0	0.4750000
##	[161,]	0 2 0	0.4720497
##	[162,]	0 2 1	0.4753086
##	[163,]	0 2 0	0.4723926
##	[164,]	0 2 0	0.4695122
##	[165,]	0 2 0	0.4666667
##	[166,]	0 2 0	0.4638554
##	[167,]	0 2 0	0.4610778
##	[168,]	0 2 0	0.4583333
##	[169,]	0 2 0	0.4556213
##	[170,]	0 2 1	0.4588235
##	[171,]	0 2 0	0.4561404
##	[172,]	0 2 0	0.4534884
##	[173,]	0 2 0	0.4508671
##	[174,]	0 2 0	0.4482759
##	[175,]	0 2 0	0.4457143
##	[176,]	0 2 0	0.4431818
##	[177,]	0 2 0	0.4406780
##	[178,]	0 2 1	0.4438202
##	[179,]	0 2 0	0.4413408
##	[180,]	0 2 1	0.4444444
##	[181,]	0 2 1	0.4475138
##	[182,]	0 2 0	0.4450549
##	[183,]	0 2 1	0.4480874
##	[184,]	0 2 1	0.4510870
##	[185,]	0 2 0	0.4486486

##	[186,]	0 2 0	0.4462366
##	[187,]	0 2 0	0.4438503
##	[188,]	0 2 0	0.4414894
##	[189,]	0 2 1	0.4444444
##	[190,]	0 2 1	0.4473684
##	[191,]	0 2 0	0.4450262
##	[192,]	0 2 0	0.4427083
##	[193,]	0 2 0	0.4404145
##	[194,]	0 2 1	0.4432990
##	[195,]	0 2 0	0.4410256
##	[196,]	0 2 0	0.4387755
##	[197,]	0 2 1	0.4416244
##	[198,]	0 2 0	0.4393939
##	[199,]	0 2 0	0.4371859
##	[200,]	0 2 1	0.4400000
##	[201,]	0 2 0	0.4378109
##	[202,]	0 2 1	0.4405941
##	[203,]	0 2 0	0.4384236
##	[204,]	0 2 0	0.4362745
##	[205,]	0 2 0	0.4341463
##	[206,]	0 2 0	0.4320388
##	[207,]	0 2 1	0.4347826
##	[208,]	0 2 1	0.4375000
##	[209,]	0 2 0	0.4354067
##	[210,]	0 2 1	0.4380952
##	[211,]	0 2 0	0.4360190
##	[212,]	0 2 0	0.4339623
##	[213,]	0 2 1	0.4366197
##	[214,]	0 2 1	0.4392523
##	[215,]	0 2 0	0.4372093
##	[216,]	0 2 1	0.4398148
##	[217,]	0 2 1	0.4423963
##	[218,]	0 2 0	0.4403670
##	[219,]	0 2 0	0.4383562
##	[220,]	0 2 1	0.4409091
##	[221,]	0 2 1	0.4434389
##	[222,]	0 2 1	0.4459459
##	[223,]	0 2 0	0.4439462
##	[224,]	0 2 0	0.4419643
##	[225,]	0 2 0	0.4400000
##	[226,]	0 2 1	0.4424779
##	[227,]	0 2 1	0.4449339
##	[228,]	0 2 1	0.4473684
##	[229,]	0 2 0	0.4454148
##	[230,]	0 2 0	0.4434783
##	[231,]	0 2 0	0.4415584
##	[232,]	0 2 0	0.4396552
##	[233,]	0 2 0	0.4377682
##	[234,]	0 2 1	0.4401709
##	[235,]	0 2 0	0.4382979
##	[236,]	0 2 1	0.4406780
##	[237,]	0 2 1	0.4430380
##	[238,]	0 2 0	0.4411765
##	[239,]	0 2 0	0.4393305

##	[240,]	0 2 0	0.4375000
##	[241,]	0 2 0	0.4356846
##	[242,]	0 2 1	0.4380165
##	[243,]	0 2 1	0.4403292
##	[244,]	0 2 0	0.4385246
##	[245,]	0 2 0	0.4367347
##	[246,]	0 2 0	0.4349593
##	[247,]	0 2 1	0.4372470
##	[248,]	0 2 1	0.4395161
##	[249,]	0 2 1	0.4417671
##	[250,]	0 2 1	0.4440000
##	[251,]	0 2 0	0.4422311
##	[252,]	0 2 0	0.4404762
##	[253,]	0 2 0	0.4387352
##	[254,]	0 2 0	0.4370079
##	[255,]	0 2 0	0.4352941
##	[256,]	0 2 1	0.4375000
##	[257,]	0 2 0	0.4357977
##	[258,]	0 2 0	0.4341085
##	[259,]	0 2 1	0.4362934
##	[260,]	0 2 0	0.4346154
##	[261,]	0 2 0	0.4329502
##	[262,]	0 2 0	0.4312977
##	[263,]	0 2 0	0.4296578
##	[264,]	0 2 1	0.4318182
##	[265,]	0 2 0	0.4301887
##	[266,]	0 2 0	0.4285714
##	[267,]	0 2 1	0.4307116
##	[268,]	0 2 0	0.4291045
##	[269,]	0 2 0	0.4275093
##	[270,]	0 2 0	0.4259259
##	[271,]	0 2 0	0.4243542
##	[272,]	0 2 1	0.4264706
##	[273,]	0 2 1	0.4285714
##	[274,]	0 2 1	0.4306569
##	[275,]	0 2 0	0.4290909
##	[276,]	0 2 1	0.4311594
##	[277,]	0 2 0	0.4296029
##	[278,]	0 2 0	0.4280576
##	[279,]	0 2 0	0.4265233
##	[280,]	0 2 0	0.4250000
##	[281,]	0 2 0	0.4234875
##	[282,]	0 2 1	0.4255319
##	[283,]	0 2 1	0.4275618
##	[284,]	0 2 0	0.4260563
##	[285,]	0 2 0	0.4245614
##	[286,]	0 2 1	0.4265734
##	[287,]	0 2 0	0.4250871
##	[288,]	0 2 0	0.4236111
##	[289,]	0 2 1	0.4256055
##	[290,]	0 2 0	0.4241379
##	[291,]	0 2 0	0.4226804
##	[292,]	0 2 0	0.4212329
##	[293,]	0 2 0	0.4197952

##	[294,]	0 2 1	0.4217687
##	[295,]	0 2 0	0.4203390
##	[296,]	0 2 1	0.4222973
##	[297,]	0 2 1	0.4242424
##	[298,]	0 2 0	0.4228188
##	[299,]	0 2 0	0.4214047
##	[300,]	0 2 1	0.4233333
##	[301,]	0 2 0	0.4219269
##	[302,]	0 2 0	0.4205298
##	[303,]	0 2 0	0.4191419
##	[304,]	0 2 0	0.4177632
##	[305,]	0 2 1	0.4196721
##	[306,]	0 2 0	0.4183007
##	[307,]	0 2 0	0.4169381
##	[308,]	0 2 0	0.4155844
##	[309,]	0 2 1	0.4174757
##	[310,]	0 2 0	0.4161290
##	[311,]	0 2 0	0.4147910
##	[312,]	0 2 0	0.4134615
##	[313,]	0 2 1	0.4153355
##	[314,]	0 2 0	0.4140127
##	[315,]	0 2 1	0.4158730
##	[316,]	0 2 0	0.4145570
##	[317,]	0 2 0	0.4132492
##	[318,]	0 2 1	0.4150943
##	[319,]	0 2 0	0.4137931
##	[320,]	0 2 0	0.4125000
##	[321,]	0 2 1	0.4143302
##	[322,]	0 2 0	0.4130435
##	[323,]	0 2 0	0.4117647
##	[324,]	0 2 0	0.4104938
##	[325,]	0 2 0	0.4092308
##	[326,]	0 2 1	0.4110429
##	[327,]	0 2 1	0.4128440
##	[328,]	0 2 1	0.4146341
##	[329,]	0 2 0	0.4133739
##	[330,]	0 2 0	0.4121212
##	[331,]	0 2 0	0.4108761
##	[332,]	0 2 0	0.4096386
##	[333,]	0 2 0	0.4084084
##	[334,]	0 2 1	0.4101796
##	[335,]	0 2 0	0.4089552
##	[336,]	0 2 1	0.4107143
##	[337,]	0 2 1	0.4124629
##	[338,]	0 2 0	0.4112426
##	[339,]	0 2 0	0.4100295
##	[340,]	0 2 0	0.4088235
##	[341,]	0 2 1	0.4105572
##	[342,]	0 2 0	0.4093567
##	[343,]	0 2 1	0.4110787
##	[344,]	0 2 0	0.4098837
##	[345,]	0 2 1	0.4115942
##	[346,]	0 2 1	0.4132948
##	[347,]	0 2 0	0.4121037

##	[348,]	0 2 0	0.4109195
##	[349,]	0 2 0	0.4097421
##	[350,]	0 2 1	0.4114286
##	[351,]	0 2 0	0.4102564
##	[352,]	0 2 0	0.4090909
##	[353,]	0 2 1	0.4107649
##	[354,]	0 2 1	0.4124294
##	[355,]	0 2 1	0.4140845
##	[356,]	0 2 0	0.4129213
##	[357,]	0 2 1	0.4145658
##	[358,]	0 2 1	0.4162011
##	[359,]	0 2 0	0.4150418
##	[360,]	0 2 0	0.4138889
##	[361,]	0 2 0	0.4127424
##	[362,]	0 2 1	0.4143646
##	[363,]	0 2 1	0.4159780
##	[364,]	0 2 1	0.4175824
##	[365,]	0 2 0	0.4164384
##	[366,]	0 2 0	0.4153005
##	[367,]	0 2 1	0.4168937
##	[368,]	0 2 0	0.4157609
##	[369,]	0 2 0	0.4146341
##	[370,]	0 2 1	0.4162162
##	[371,]	0 2 0	0.4150943
##	[372,]	0 2 1	0.4166667
##	[373,]	0 2 1	0.4182306
##	[374,]	0 2 1	0.4197861
##	[375,]	0 2 1	0.4213333
##	[376,]	0 2 1	0.4228723
##	[377,]	0 2 1	0.4244032
##	[378,]	0 2 1	0.4259259
##	[379,]	0 2 1	0.4274406
##	[380,]	0 2 0	0.4263158
##	[381,]	0 2 0	0.4251969
##	[382,]	0 2 1	0.4267016
##	[383,]	0 2 1	0.4281984
##	[384,]	0 2 0	0.4270833
##	[385,]	0 2 0	0.4259740
##	[386,]	0 2 0	0.4248705
##	[387,]	0 2 0	0.4237726
##	[388,]	0 2 1	0.4252577
##	[389,]	0 2 1	0.4267352
##	[390,]	0 2 0	0.4256410
##	[391,]	0 2 1	0.4271100
##	[392,]	0 2 0	0.4260204
##	[393,]	0 2 0	0.4249364
##	[394,]	0 2 1	0.4263959
##	[395,]	0 2 0	0.4253165
##	[396,]	0 2 0	0.4242424
##	[397,]	0 2 0	0.4231738
##	[398,]	0 2 1	0.4246231
##	[399,]	0 2 0	0.4235589
##	[400,]	0 2 0	0.4225000
##	[401,]	0 2 0	0.4214464

##	[402,]	0 2 1	0.4228856
##	[403,]	0 2 0	0.4218362
##	[404,]	0 2 1	0.4232673
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##	[409,]	0 2 0	0.4254279
##	[410,]	0 2 0	0.4243902
##	[411,]	0 2 0	0.4233577
##	[412,]	0 2 0	0.4223301
##	[413,]	0 2 1	0.4237288
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##	[415,]	0 2 0	0.4216867
##	[416,]	0 2 1	0.4230769
##	[417,]	0 2 0	0.4220624
##	[418,]	0 2 0	0.4210526
##	[419,]	0 2 0	0.4200477
##	[420,]	0 2 0	0.4190476
##	[421,]	0 2 0	0.4180523
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##	[423,]	0 2 0	0.4184397
##	[424,]	0 2 1	0.4198113
##	[425,]	0 2 0	0.4188235
##	[426,]	0 2 1	0.4201878
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##	[432,]	0 2 1	0.4189815
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##	[435,]	0 2 1	0.4206897
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##	[438,]	0 2 0	0.4178082
##	[439,]	0 2 1	0.4191344
##	[440,]	0 2 0	0.4181818
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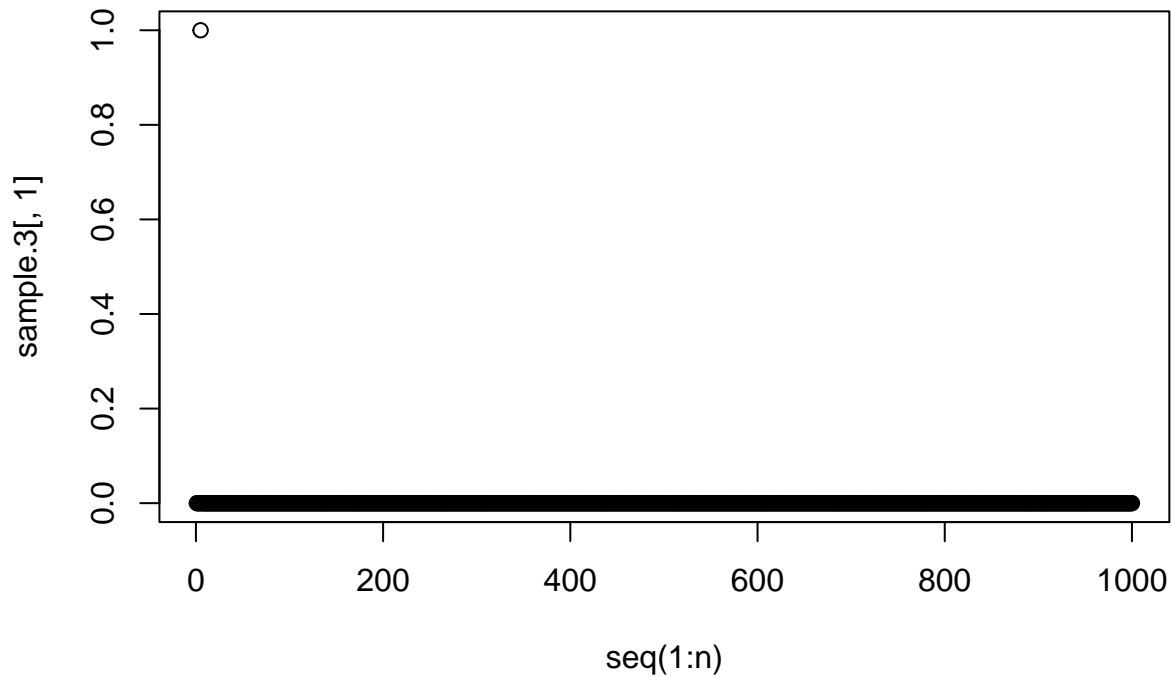
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##	[847,]	0 2 1	0.4085006
##	[848,]	0 2 0	0.4080189
##	[849,]	0 2 1	0.4087161
##	[850,]	0 2 0	0.4082353
##	[851,]	0 2 1	0.4089307
##	[852,]	0 2 1	0.4096244
##	[853,]	0 2 0	0.4091442
##	[854,]	0 2 0	0.4086651
##	[855,]	0 2 0	0.4081871
##	[856,]	0 2 1	0.4088785
##	[857,]	0 2 0	0.4084014
##	[858,]	0 2 1	0.4090909
##	[859,]	0 2 0	0.4086147
##	[860,]	0 2 0	0.4081395
##	[861,]	0 2 1	0.4088269
##	[862,]	0 2 1	0.4095128
##	[863,]	0 2 1	0.4101970
##	[864,]	0 2 1	0.4108796
##	[865,]	0 2 0	0.4104046
##	[866,]	0 2 0	0.4099307
##	[867,]	0 2 0	0.4094579
##	[868,]	0 2 0	0.4089862
##	[869,]	0 2 1	0.4096663
##	[870,]	0 2 0	0.4091954
##	[871,]	0 2 1	0.4098737
##	[872,]	0 2 0	0.4094037
##	[873,]	0 2 0	0.4089347
##	[874,]	0 2 1	0.4096110
##	[875,]	0 2 0	0.4091429
##	[876,]	0 2 1	0.4098174
##	[877,]	0 2 0	0.4093501
##	[878,]	0 2 1	0.4100228
##	[879,]	0 2 0	0.4095563
##	[880,]	0 2 0	0.4090909
##	[881,]	0 2 1	0.4097616
##	[882,]	0 2 0	0.4092971
##	[883,]	0 2 0	0.4088335
##	[884,]	0 2 0	0.4083710
##	[885,]	0 2 1	0.4090395
##	[886,]	0 2 1	0.4097065
##	[887,]	0 2 0	0.4092446

##	[888,]	0 2 1	0.4099099
##	[889,]	0 2 1	0.4105737
##	[890,]	0 2 1	0.4112360
##	[891,]	0 2 0	0.4107744
##	[892,]	0 2 0	0.4103139
##	[893,]	0 2 0	0.4098544
##	[894,]	0 2 1	0.4105145
##	[895,]	0 2 1	0.4111732
##	[896,]	0 2 1	0.4118304
##	[897,]	0 2 0	0.4113712
##	[898,]	0 2 1	0.4120267
##	[899,]	0 2 1	0.4126808
##	[900,]	0 2 0	0.4122222
##	[901,]	0 2 0	0.4117647
##	[902,]	0 2 0	0.4113082
##	[903,]	0 2 0	0.4108527
##	[904,]	0 2 1	0.4115044
##	[905,]	0 2 0	0.4110497
##	[906,]	0 2 0	0.4105960
##	[907,]	0 2 0	0.4101433
##	[908,]	0 2 0	0.4096916
##	[909,]	0 2 0	0.4092409
##	[910,]	0 2 1	0.4098901
##	[911,]	0 2 1	0.4105379
##	[912,]	0 2 1	0.4111842
##	[913,]	0 2 0	0.4107338
##	[914,]	0 2 1	0.4113786
##	[915,]	0 2 1	0.4120219
##	[916,]	0 2 0	0.4115721
##	[917,]	0 2 0	0.4111232
##	[918,]	0 2 1	0.4117647
##	[919,]	0 2 0	0.4113166
##	[920,]	0 2 1	0.4119565
##	[921,]	0 2 0	0.4115092
##	[922,]	0 2 1	0.4121475
##	[923,]	0 2 0	0.4117010
##	[924,]	0 2 0	0.4112554
##	[925,]	0 2 0	0.4108108
##	[926,]	0 2 0	0.4103672
##	[927,]	0 2 1	0.4110032
##	[928,]	0 2 0	0.4105603
##	[929,]	0 2 1	0.4111948
##	[930,]	0 2 0	0.4107527
##	[931,]	0 2 1	0.4113856
##	[932,]	0 2 1	0.4120172
##	[933,]	0 2 0	0.4115756
##	[934,]	0 2 0	0.4111349
##	[935,]	0 2 1	0.4117647
##	[936,]	0 2 0	0.4113248
##	[937,]	0 2 1	0.4119530
##	[938,]	0 2 0	0.4115139
##	[939,]	0 2 1	0.4121406
##	[940,]	0 2 0	0.4117021
##	[941,]	0 2 0	0.4112646

##	[942,]	0 2 0	0.4108280
##	[943,]	0 2 0	0.4103924
##	[944,]	0 2 0	0.4099576
##	[945,]	0 2 1	0.4105820
##	[946,]	0 2 1	0.4112051
##	[947,]	0 2 0	0.4107709
##	[948,]	0 2 0	0.4103376
##	[949,]	0 2 1	0.4109589
##	[950,]	0 2 1	0.4115789
##	[951,]	0 2 1	0.4121977
##	[952,]	0 2 0	0.4117647
##	[953,]	0 2 1	0.4123820
##	[954,]	0 2 0	0.4119497
##	[955,]	0 2 1	0.4125654
##	[956,]	0 2 0	0.4121339
##	[957,]	0 2 1	0.4127482
##	[958,]	0 2 1	0.4133612
##	[959,]	0 2 0	0.4129301
##	[960,]	0 2 1	0.4135417
##	[961,]	0 2 1	0.4141519
##	[962,]	0 2 0	0.4137214
##	[963,]	0 2 1	0.4143302
##	[964,]	0 2 1	0.4149378
##	[965,]	0 2 0	0.4145078
##	[966,]	0 2 1	0.4151139
##	[967,]	0 2 1	0.4157187
##	[968,]	0 2 0	0.4152893
##	[969,]	0 2 1	0.4158927
##	[970,]	0 2 1	0.4164948
##	[971,]	0 2 1	0.4170958
##	[972,]	0 2 1	0.4176955
##	[973,]	0 2 0	0.4172662
##	[974,]	0 2 0	0.4168378
##	[975,]	0 2 1	0.4174359
##	[976,]	0 2 1	0.4180328
##	[977,]	0 2 1	0.4186285
##	[978,]	0 2 1	0.4192229
##	[979,]	0 2 0	0.4187947
##	[980,]	0 2 0	0.4183673
##	[981,]	0 2 0	0.4179409
##	[982,]	0 2 0	0.4175153
##	[983,]	0 2 0	0.4170905
##	[984,]	0 2 0	0.4166667
##	[985,]	0 2 0	0.4162437
##	[986,]	0 2 0	0.4158215
##	[987,]	0 2 0	0.4154002
##	[988,]	0 2 0	0.4149798
##	[989,]	0 2 0	0.4145602
##	[990,]	0 2 0	0.4141414
##	[991,]	0 2 1	0.4147326
##	[992,]	0 2 0	0.4143145
##	[993,]	0 2 0	0.4138973
##	[994,]	0 2 0	0.4134809
##	[995,]	0 2 1	0.4140704

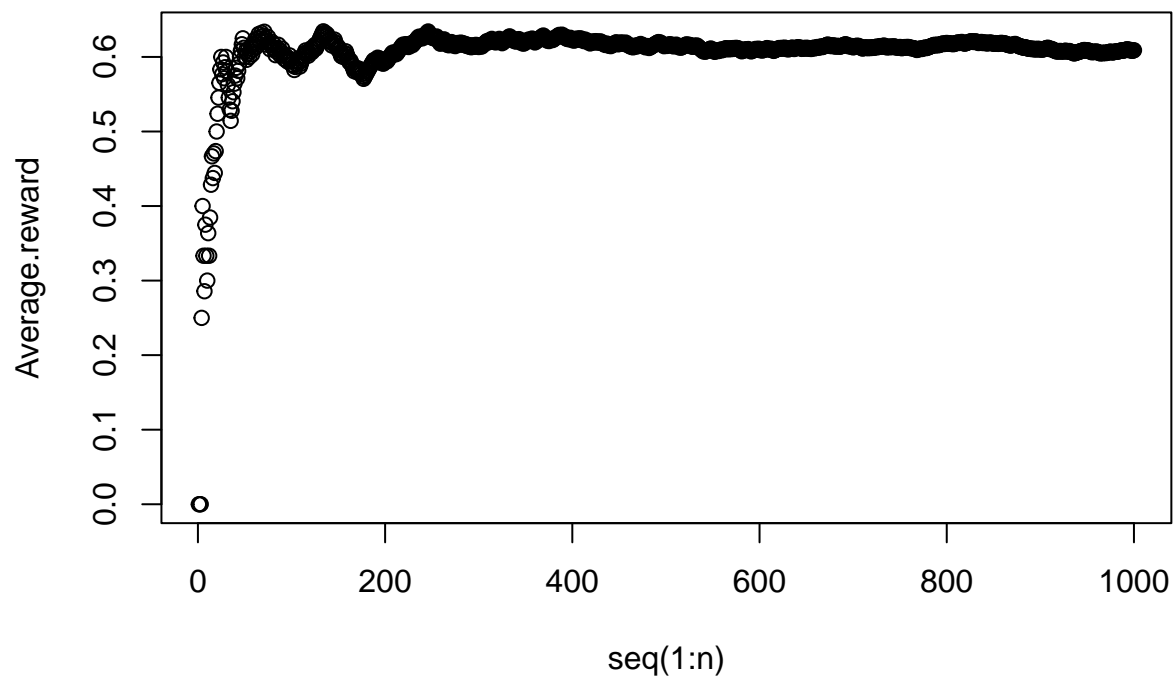
```
## [996,]      0 2 0      0.4136546
## [997,]      0 2 1      0.4142427
## [998,]      0 2 0      0.4138277
## [999,]      0 2 0      0.4134134
## [1000,]     0 2 0      0.4130000
```

```
plot(seq(1:n),sample.3[,1])
```



2(d) At every time step we play an arm based on what we have seen so far for Thompson sampling, however for epsilon-decreasing we play a random arm with probability epsilon i at time i . Thompson uses a Bayesian approach to update our beliefs about the success probabilities of each arm, whereas epsilon-decreasing uses a frequentist approach to do this. Thompson requires an original prior distribution for the success probabilities of each arm, but epsilon-decreasing does not. Thompson method works almost surely from the theorem in the notes but epsilon decreasing does not guarantee this for all choices of epsilon - only works if epsilon is decreasing slowly enough. As can be seen from the graphs for average reward over time, Thompson (red) converged slower in this example than epsilon decreasing (blue for part b and green for part c).

```
plot(x=seq(1:1000),y=thompson(1000, 0.6, 0.4, 10, 10)[,3],col="red")
```



```
points(x=seq(1:1000),y=sample.1[,4],col="blue")  
points(x=seq(1:1000),y=sample.2[,4],col="green")
```

