What determines the similarity of braille letters? A matrix of perceived letter similarity in braille by blind individuals

Ana Baciero[1,2], Pablo Gomez[3], Jon Andoni Duñabeitia[1,4], and & Manuel Perea[1,5]

[1] Universidad Antonio de Nebrija

[2] DePaul University

[3] California State University San Bernardino

Palm Desert Campus

[4] The Arctic University of Norway

[5] Universitat de València

Author Note

Add complete departmental affiliations for each author here. Each new line herein must be indented, like this line.

Enter author note here.

The authors made the following contributions. Ana Baciero: e.g.,, Conceptualization, Design, Data preparation and analyses, Writing - Original Draft Preparation, Writing - Review & Editing); Pablo Gomez: XXXX; Jon Andoni Duñabeitia: XXXX; Manuel Perea: XXXX.

Correspondence concerning this article should be addressed to Ana Baciero, Santa Cruz de Marcenado, 27. 28015, Madrid,Spain. E-mail: abaciero@nebrija.es

Abstract

One or two sentences providing a **basic introduction** to the field, comprehensible to a scientist in any discipline.

Two to three sentences of **more detailed background**, comprehensible to scientists in related disciplines.

One sentence clearly stating the **general problem** being addressed by this particular study.

One sentence summarizing the main result (with the words "**here we show**" or their equivalent).

Two or three sentences explaining what the **main result** reveals in direct comparison to what was thought to be the case previously, or how the main result adds to previous knowledge.

One or two sentences to put the results into a more **general context**.

Two or three sentences to provide a **broader perspective**, readily comprehensible to a scientist in any discipline.

Keywords: keywords

Word count: X

What determines the similarity of braille letters? A matrix of perceived letter

similarity in braille by blind individuals

Introduction

TEXT INTRO

26 basic letters of the Latin alphabet

Experiment 1: DePaul

Method

Only passive

Participants

86 undergraduate students at DePaul University who did not know how to read braille were recruited through the subject pool system. All of them gave informed consent before their participation and earned one course-credit for taking part in the study. With this sample size, we wanted to ensure each pair of different letters was observed a minimum of 15 times (considering pairs containing the same two different letters in the opposite order as being different pairs [e.g., ⠳ ⠊ different from ⠊ ⠳], and taking into account that some trials may be lost in data cleaning).

Materials

The study used all possible 2-letter combinations: 676 pairs. Out of those pairs, 26 were the same two letters (e.g., ⠊ ⠊), and 650 two different letters (e.g., ⠊ ⠳). Thus, five different lists of pairs were created in which 130 were same pairs (i.e., formed by the same two letters), and 130 were different pairs (i.e., formed by two different letters). Each participant perceived 266 trials, where 6 were practice and 260 were target trials; the order of presentation was randomized for each participant.

61   **3 PARTICIPANTS (87-89) ONLY 210!**

62 *Procedure*

63   The experiment took place individually in a quiet room. Participants used the

64 moving version of TouchScope. Hence, participants did not move their fingers to perceive the

65 stimuli. They were instructed to place their index fingertip on the start position to let the

66 braille display slide against it. The braille display moved for 5 cm at 38.9 mm/s (35.9

67 mm/rev x 65 rpm / 60). This speed was chosen considering previous studies on passive

68 touch (see Vega-Bermudez et al., 1991), as well as our own experience testing it. After

69 moving said distance, the display stopped until participants responded and reset its position

70 during the one-second ITI. This experiment also took around 30 minutes to complete.

71 *Data analysis*

72 **Results**

73 `## [1] 14`

74 `## Bayes factor analysis`

75 `## --------------`

76 `## [1] Alt., r=0.707 : 2955488 ±0%`

77 `##`

78 `## Against denominator:`

79 `##    Null, mu = 0`

80 `## ---`

81 `## Bayes factor type: BFoneSample, JZS`

82 `## Bayes factor analysis`

83 `## --------------`

84 `## [1] Alt., r=0.707 : 0.1300824 ±0%`

```
## 

## Against denominator:

##   Null, mu = 0

## ---

## Bayes factor type: BFoneSample, JZS
```

	a	b	c	d	e	f	g	h	i	j	k	l
a	NA	0.979	0.948	0.992	0.992	0.930	0.944	0.906	0.915	0.954	1.008	0.946
b	0.979	NA	0.993	1.026	0.988	0.990	0.990	0.969	1.047	1.074	0.942	0.982
c	0.948	0.993	NA	0.980	1.060	0.955	1.011	1.074	1.020	1.119	0.991	0.938
d	0.992	1.026	0.980	NA	1.077	1.038	1.014	1.063	1.092	0.980	1.052	1.184
e	0.992	0.988	1.060	1.077	NA	1.004	0.974	1.028	1.010	1.160	0.923	1.052
f	0.930	0.990	0.955	1.038	1.004	NA	1.014	1.045	1.145	1.107	1.051	0.995
g	0.944	0.990	1.011	1.014	0.974	1.014	NA	1.139	0.950	1.020	0.887	1.004
h	0.906	0.969	1.074	1.063	1.028	1.045	1.139	NA	1.070	1.070	0.994	1.010
i	0.915	1.047	1.020	1.092	1.010	1.145	0.950	1.070	NA	1.002	0.946	0.970
j	0.954	1.074	1.119	0.980	1.160	1.107	1.020	1.070	1.002	NA	1.142	1.054
k	1.008	0.942	0.991	1.052	0.923	1.051	0.887	0.994	0.946	1.142	NA	1.080
l	0.946	0.982	0.938	1.184	1.052	0.995	1.004	1.010	0.970	1.054	1.080	NA
m	0.940	0.881	0.909	1.082	0.942	0.935	1.022	1.010	1.011	0.949	1.204	0.985
n	0.935	0.908	1.010	0.968	1.040	1.027	0.935	0.978	0.943	1.054	0.991	0.925
o	0.924	0.919	0.900	0.986	1.020	0.997	0.990	1.031	1.041	1.086	0.914	1.036
p	0.863	0.970	0.977	0.920	0.934	0.965	1.059	0.931	0.973	1.015	0.934	1.003
q	0.967	0.915	1.006	0.978	0.915	1.083	1.123	1.072	0.954	1.018	0.980	0.991
r	0.922	0.953	0.931	0.883	0.943	1.079	0.994	1.054	0.963	1.067	0.938	0.977
s	0.988	0.893	0.896	1.013	1.053	0.972	1.152	1.038	1.096	0.974	0.984	1.036
t	0.936	0.978	0.931	1.065	0.954	0.961	1.059	0.995	0.958	1.068	0.917	0.939
u	0.928	1.025	0.972	1.022	0.973	1.033	0.944	0.966	1.025	1.085	1.443	1.008
v	0.921	0.981	0.936	0.974	0.966	1.010	1.214	1.136	0.944	0.983	1.044	1.220
w	1.020	0.918	0.964	1.159	0.994	1.381	0.928	1.014	1.028	0.928	0.996	0.977
x	0.980	0.911	0.903	0.966	0.961	0.993	1.006	0.951	0.962	1.041	0.926	1.067
y	0.941	0.896	0.879	1.032	0.992	0.953	0.999	0.949	0.929	1.045	0.919	1.012
z	0.903	0.907	0.918	0.859	0.945	0.918	0.952	1.042	0.999	1.008	0.953	0.968

90

	a	b	c	d	e	f	g	h	i	j	k	l	
a	NA	1.021	1.054	1.008	1.008	1.075	1.059	1.104	1.092	1.048	0.992	1.057	1.
b	1.021	NA	1.007	0.975	1.013	1.010	1.010	1.032	0.955	0.931	1.062	1.018	1.
c	1.054	1.007	NA	1.020	0.943	1.048	0.989	0.932	0.980	0.893	1.009	1.067	1.
d	1.008	0.975	1.020	NA	0.929	0.964	0.986	0.941	0.915	1.020	0.950	0.845	0.
e	1.008	1.013	0.943	0.929	NA	0.996	1.027	0.972	0.990	0.862	1.083	0.951	1.
f	1.075	1.010	1.048	0.964	0.996	NA	0.986	0.957	0.873	0.903	0.951	1.005	1.
g	1.059	1.010	0.989	0.986	1.027	0.986	NA	0.878	1.053	0.981	1.127	0.996	0.
h	1.104	1.032	0.932	0.941	0.972	0.957	0.878	NA	0.934	0.934	1.007	0.990	0.
i	1.092	0.955	0.980	0.915	0.990	0.873	1.053	0.934	NA	0.998	1.057	1.030	0.
j	1.048	0.931	0.893	1.020	0.862	0.903	0.981	0.934	0.998	NA	0.876	0.949	1.
k	0.992	1.062	1.009	0.950	1.083	0.951	1.127	1.007	1.057	0.876	NA	0.925	0.
l	1.057	1.018	1.067	0.845	0.951	1.005	0.996	0.990	1.030	0.949	0.925	NA	1.
m	1.063	1.135	1.100	0.925	1.062	1.070	0.979	0.991	0.989	1.054	0.830	1.015	
n	1.069	1.101	0.990	1.033	0.961	0.974	1.070	1.022	1.060	0.949	1.009	1.081	1.
o	1.082	1.088	1.111	1.014	0.980	1.004	1.010	0.970	0.961	0.920	1.094	0.965	0.
p	1.158	1.030	1.024	1.087	1.071	1.036	0.944	1.074	1.028	0.985	1.070	0.997	0.
q	1.035	1.092	0.995	1.022	1.092	0.923	0.890	0.933	1.049	0.982	1.021	1.009	1.
r	1.084	1.049	1.074	1.132	1.060	0.926	1.007	0.949	1.039	0.937	1.067	1.023	0.
s	1.012	1.120	1.115	0.987	0.950	1.029	0.868	0.964	0.912	1.027	1.016	0.965	0.
t	1.068	1.022	1.074	0.939	1.048	1.041	0.944	1.005	1.044	0.936	1.090	1.066	0.
u	1.078	0.976	1.028	0.979	1.028	0.968	1.060	1.036	0.976	0.922	0.693	0.992	1.
v	1.086	1.019	1.068	1.026	1.036	0.991	0.823	0.881	1.060	1.017	0.957	0.819	1.
w	0.980	1.089	1.037	0.863	1.006	0.724	1.078	0.987	0.973	1.078	1.004	1.024	0.
x	1.020	1.097	1.107	1.035	1.041	1.007	0.994	1.052	1.040	0.961	1.080	0.937	0.
y	1.063	1.116	1.138	0.969	1.008	1.050	1.002	1.054	1.076	0.957	1.088	0.988	1.
z	1.108	1.102	1.089	1.163	1.058	1.089	1.050	0.960	1.001	0.992	1.050	1.033	1.

91

```
## 	 average 	 single 	 complete 	 ward
## 0.6270286 0.3390563 0.7372065 0.8636821
```
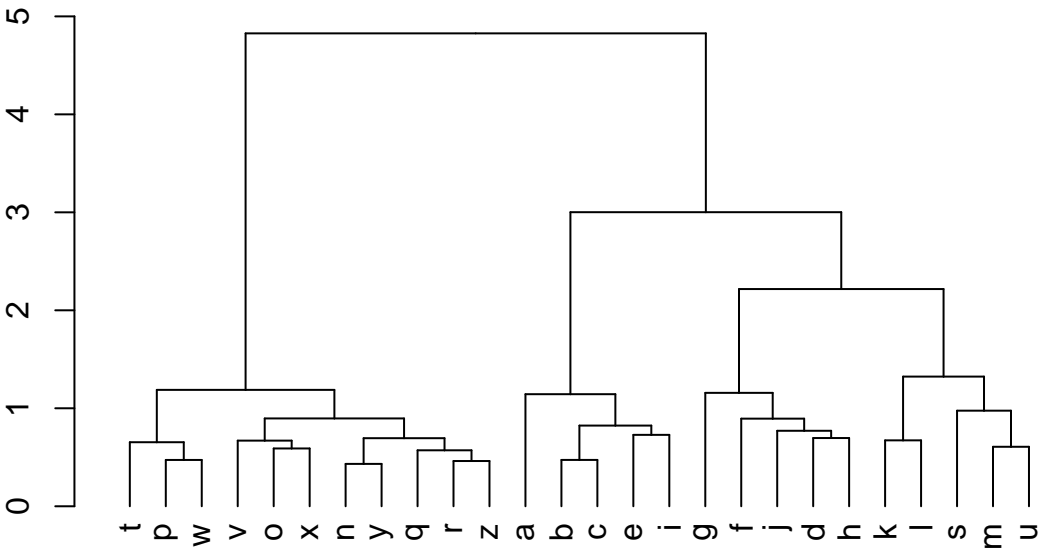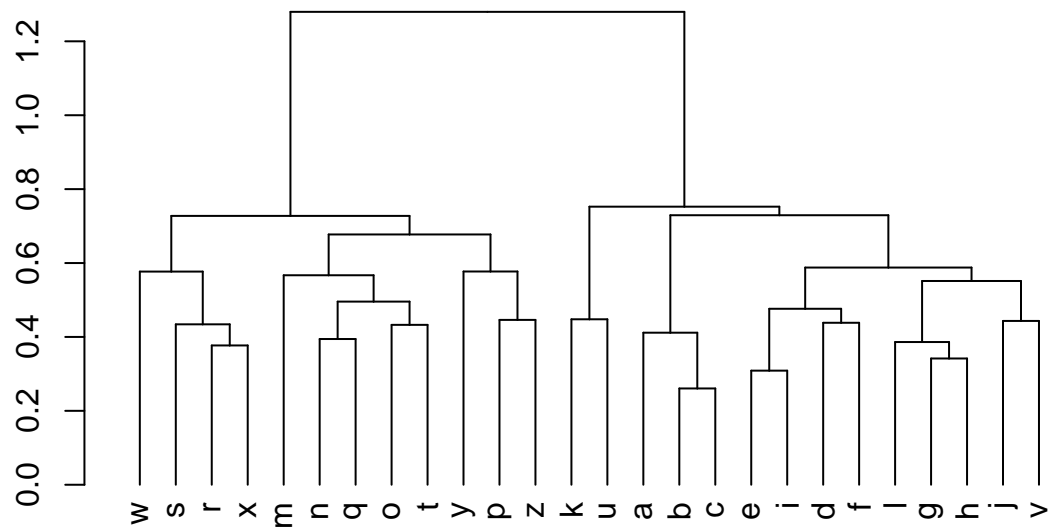


```
## 	 [1] 20 16 23 22 15 24 14 25 17 18 26  1  2  3  5  9  7  6 10  4  8 11 12 19 13
## [26] 21
```
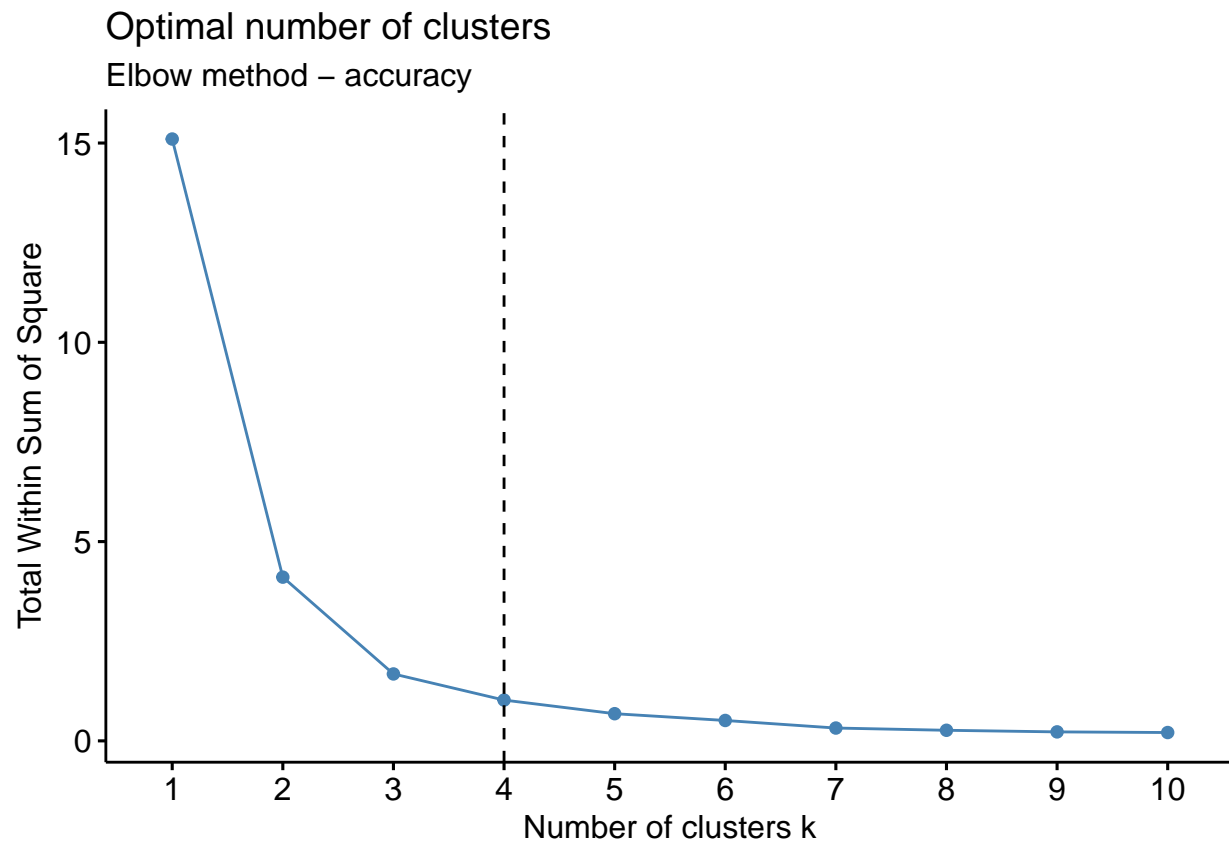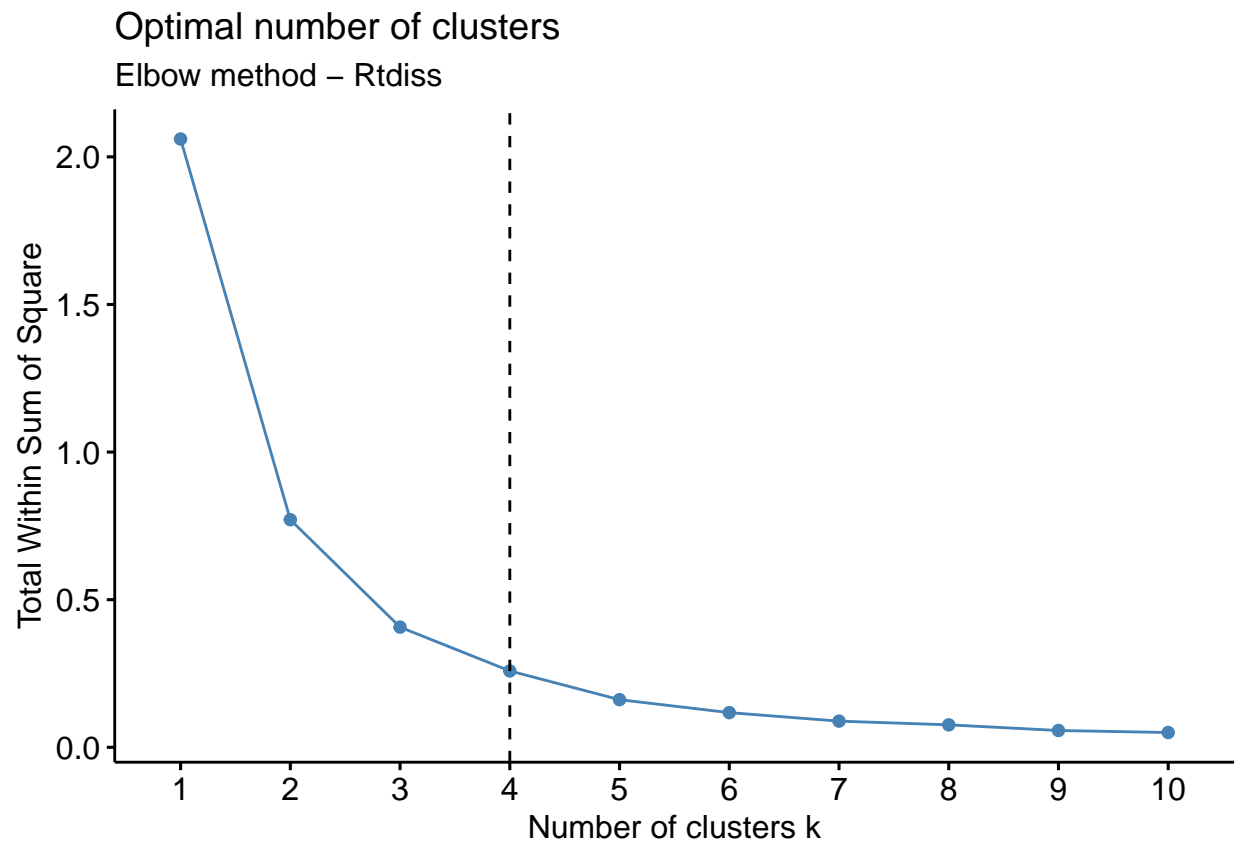
```
## 	 average 	 single 	 complete 	 ward
## 0.3185801 0.1944902 0.4879093 0.6774162
```

Optimal number of clusters
Elbow method – accuracy

100

Optimal number of clusters

Elbow method – Rtdiss

Accuracy

RT
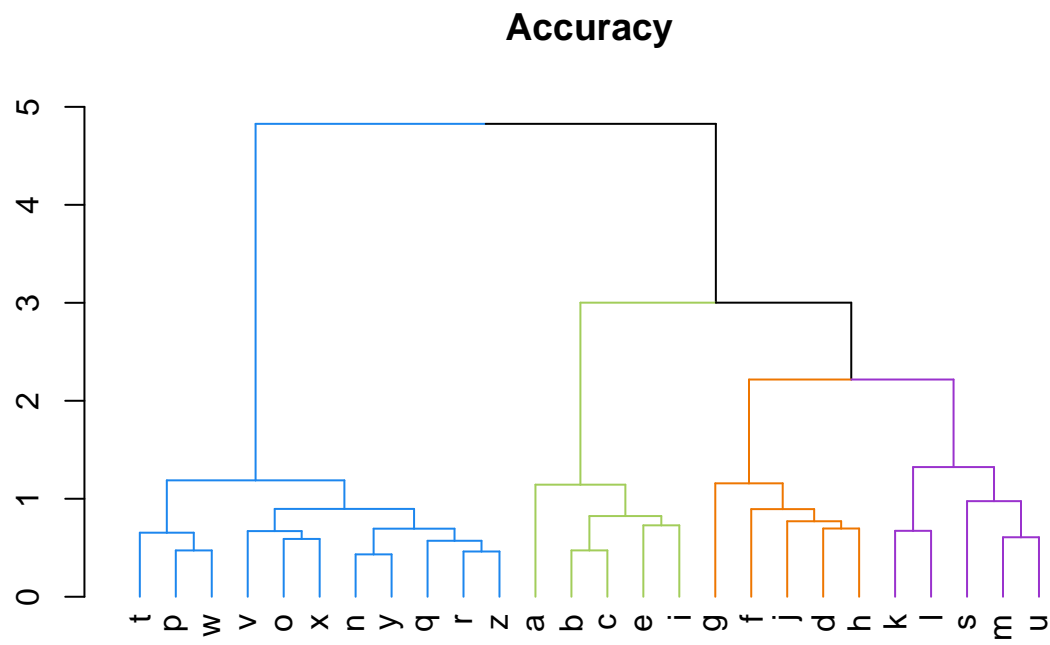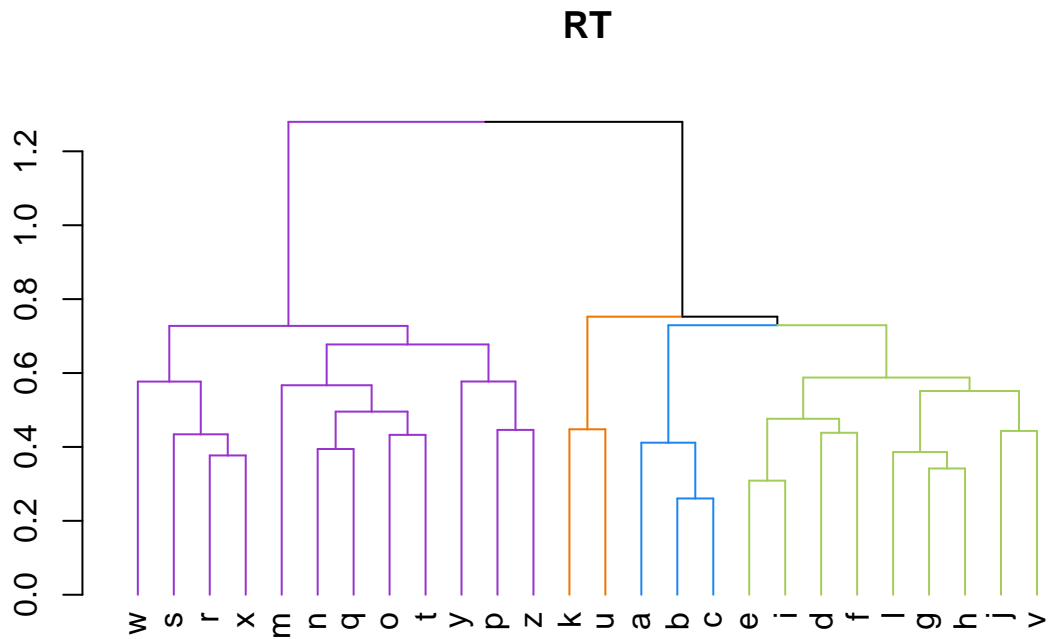
Discussion

Experiment 2: Ciegos

Motor Control

- file = "motor_control_BF-ino"

- speed = 7000rpm (left to right); 260 rpm (right to left –> because of Miguel)

- distance = 250 steps (~4.5cm)

  REMEMBER. To calculate speed:

1. steps/mm = $200 1/2 20 = 5$

2. mm/rev = 200/5 = 40 (IN VALENCIA - CHI different because different pulley)

3. mm/sec = 40*rpm/60

Method

Participants

24 blind adult individuals...

Material

All combinations. 5 lists (some 4... PANDEMIC)

Procedure

Data analysis

Results

```
##
##   Paired t-test
##
## data:  Acc.orders$MAcc1 and Acc.orders$MAcc2
## t = 0.67851, df = 324, p-value = 0.4979
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  -0.003492687  0.007170277
## sample estimates:
## mean of the differences
##               0.001838795


##
##   Paired t-test
##
## data:  RT.orders.blind$MNRT1 and RT.orders.blind$MNRT2
## t = -1.6644, df = 324, p-value = 0.09701
```

138 ## alternative hypothesis: true difference in means is not equal to 0

139 ## 95 percent confidence interval:

140 ## -0.01314649 0.00109665

141 ## sample estimates:

142 ## mean of the differences

143 ##   -0.006024921

	a	b	c	d	e	f	g	h	i	j	k	l	
a	NA	0.948	1.099	0.970	0.954	1.045	0.996	0.962	1.037	0.956	1.000	1.016	0.
b	0.948	NA	1.022	1.006	0.992	1.022	1.005	1.020	1.002	1.004	0.950	1.045	0.
c	1.099	1.022	NA	1.028	0.946	0.960	0.957	0.965	0.966	0.986	0.977	0.960	0.
d	0.970	1.006	1.028	NA	1.129	1.100	0.990	1.018	0.986	1.047	1.035	1.003	0.
e	0.954	0.992	0.946	1.129	NA	0.988	1.139	1.011	1.056	0.994	0.963	0.944	0.
f	1.045	1.022	0.960	1.100	0.988	NA	1.085	1.064	0.995	1.086	1.006	1.008	0.
g	0.996	1.005	0.957	0.990	1.139	1.085	NA	1.061	0.974	1.011	0.926	1.012	0.
h	0.962	1.020	0.965	1.018	1.011	1.064	1.061	NA	0.999	1.130	0.946	0.992	0.
i	1.037	1.002	0.966	0.986	1.056	0.995	0.974	0.999	NA	1.107	1.008	0.946	0.
j	0.956	1.004	0.986	1.047	0.994	1.086	1.011	1.130	1.107	NA	0.936	0.976	0.
k	1.000	0.950	0.977	1.035	0.963	1.006	0.926	0.946	1.008	0.936	NA	0.980	1.
l	1.016	1.045	0.960	1.003	0.944	1.008	1.012	0.992	0.946	0.976	0.980	NA	1.
m	0.993	0.923	0.942	0.972	0.966	0.951	0.974	0.941	0.992	0.906	1.060	1.006	
n	0.964	1.001	0.959	0.967	0.948	0.997	0.966	0.999	0.954	1.010	1.039	0.950	0.
o	0.966	0.980	0.945	0.957	1.027	0.955	0.992	0.988	0.974	0.983	1.030	0.966	0.
p	0.946	0.996	0.954	0.958	0.931	0.943	1.044	0.990	1.006	0.918	1.002	1.056	0.
q	1.000	0.970	1.022	0.945	0.980	1.085	1.089	0.960	0.951	0.972	0.955	0.980	0.
r	0.943	1.000	0.985	0.985	0.996	1.007	1.030	1.010	0.984	0.993	1.010	1.064	0.
s	0.984	1.001	0.931	0.967	0.970	1.072	0.976	1.009	1.034	0.992	0.990	0.976	0.
t	1.010	0.988	0.967	0.998	0.962	0.969	0.994	0.982	0.980	0.978	0.960	0.996	0.
u	0.992	0.931	0.977	0.924	0.942	0.979	0.978	0.959	0.951	0.977	1.229	1.030	1.
v	0.952	0.955	0.975	0.972	0.933	0.954	0.962	0.997	0.944	0.983	0.978	1.015	0.
w	0.968	0.970	0.978	1.000	1.027	0.994	0.968	1.041	0.960	1.007	1.038	0.998	0.
x	0.945	0.970	0.945	0.994	0.968	0.967	0.973	0.990	0.972	0.958	1.000	0.996	1.
y	1.070	0.970	0.914	0.986	0.909	0.980	1.084	0.963	0.967	0.973	0.994	0.993	1.
z	0.948	0.976	0.962	0.964	0.979	0.980	0.990	1.004	0.999	0.968	0.990	0.980	0.

144

	a	b	c	d	e	f	g	h	i	j	k	l	
a	NA	1.055	0.910	1.031	1.049	0.957	1.004	1.040	0.964	1.047	1.000	0.984	1.
b	1.055	NA	0.978	0.994	1.008	0.979	0.995	0.980	0.998	0.997	1.053	0.957	1.
c	0.910	0.978	NA	0.972	1.057	1.041	1.045	1.036	1.035	1.015	1.024	1.042	1.
d	1.031	0.994	0.972	NA	0.886	0.909	1.010	0.982	1.015	0.955	0.966	0.997	1.
e	1.049	1.008	1.057	0.886	NA	1.012	0.878	0.989	0.947	1.006	1.038	1.059	1.
f	0.957	0.979	1.041	0.909	1.012	NA	0.922	0.939	1.005	0.921	0.994	0.992	1.
g	1.004	0.995	1.045	1.010	0.878	0.922	NA	0.943	1.027	0.989	1.080	0.988	1.
h	1.040	0.980	1.036	0.982	0.989	0.939	0.943	NA	1.001	0.885	1.058	1.008	1.
i	0.964	0.998	1.035	1.015	0.947	1.005	1.027	1.001	NA	0.903	0.992	1.058	1.
j	1.047	0.997	1.015	0.955	1.006	0.921	0.989	0.885	0.903	NA	1.068	1.025	1.
k	1.000	1.053	1.024	0.966	1.038	0.994	1.080	1.058	0.992	1.068	NA	1.020	0.
l	0.984	0.957	1.042	0.997	1.059	0.992	0.988	1.008	1.058	1.025	1.020	NA	0.
m	1.007	1.083	1.062	1.029	1.035	1.052	1.026	1.063	1.008	1.104	0.943	0.994	
n	1.038	1.000	1.043	1.034	1.055	1.003	1.035	1.001	1.049	0.991	0.962	1.053	1.
o	1.035	1.020	1.058	1.045	0.973	1.047	1.008	1.012	1.027	1.017	0.971	1.035	1.
p	1.057	1.004	1.049	1.044	1.074	1.061	0.958	1.011	0.994	1.089	0.999	0.947	1.
q	1.000	1.030	0.978	1.059	1.020	0.921	0.918	1.042	1.052	1.028	1.047	1.020	1.
r	1.061	1.000	1.015	1.015	1.004	0.993	0.971	0.991	1.016	1.007	0.990	0.940	1.
s	1.017	0.999	1.075	1.034	1.031	0.932	1.025	0.991	0.967	1.008	1.011	1.025	1.
t	0.991	1.012	1.034	1.002	1.040	1.032	1.006	1.018	1.020	1.023	1.042	1.004	1.
u	1.008	1.074	1.024	1.082	1.062	1.021	1.022	1.043	1.052	1.024	0.813	0.970	0.
v	1.050	1.047	1.026	1.029	1.072	1.048	1.039	1.003	1.059	1.017	1.022	0.985	1.
w	1.033	1.031	1.022	1.000	0.973	1.006	1.033	0.961	1.042	0.993	0.963	1.002	1.
x	1.058	1.031	1.059	1.006	1.033	1.034	1.028	1.011	1.029	1.044	1.000	1.004	0.
y	0.934	1.031	1.094	1.014	1.100	1.020	0.922	1.038	1.034	1.027	1.006	1.007	0.
z	1.055	1.025	1.040	1.037	1.021	1.020	1.010	0.997	1.001	1.033	1.011	1.020	1.

145

146 ##   average   single complete   ward
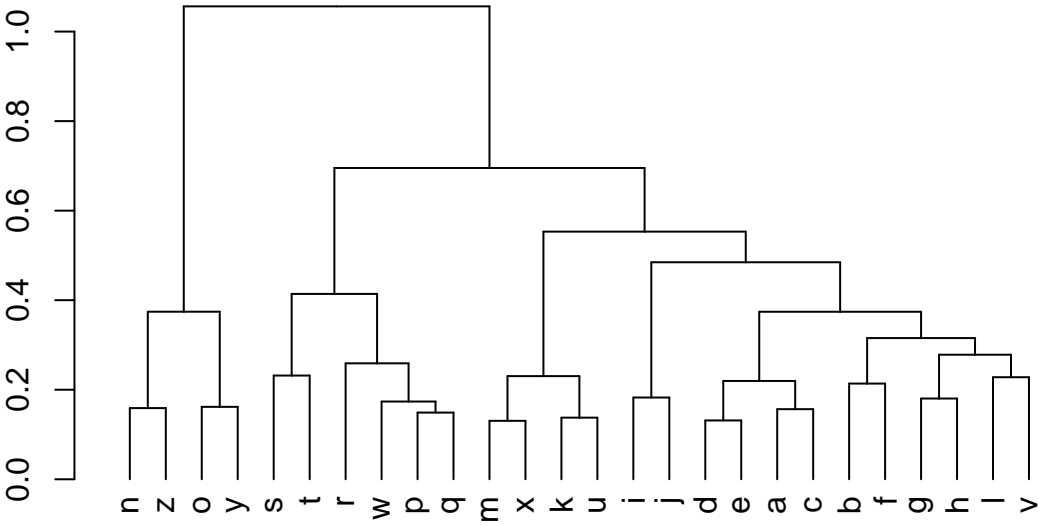
147 ## 0.6361242 0.5132008 0.7165643 0.8340732

148

149 ##   [1] 14 26 15 25 19 20 18 23 16 17 13 24 11 21 9 10 4 5 1 3 2 6 7 8 12
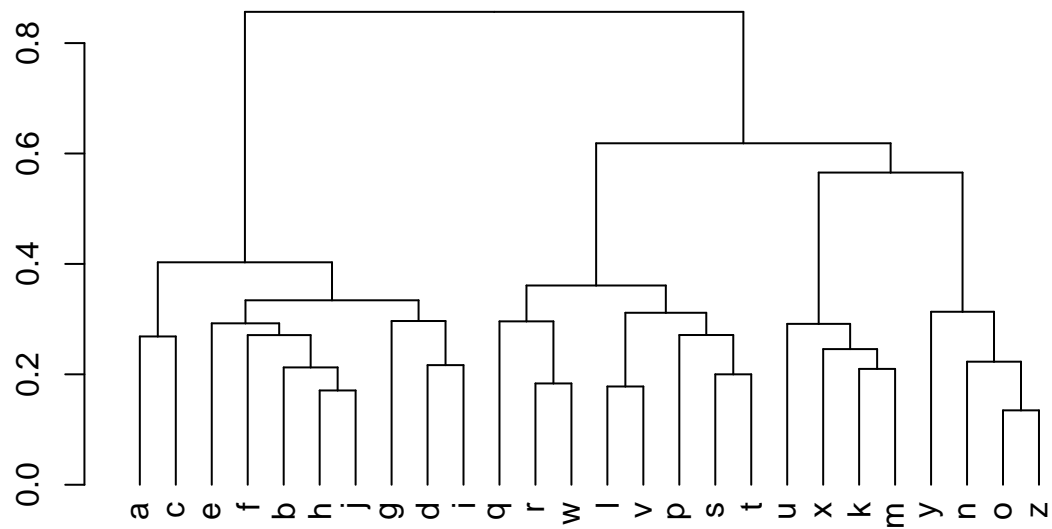
150 ## [26] 22

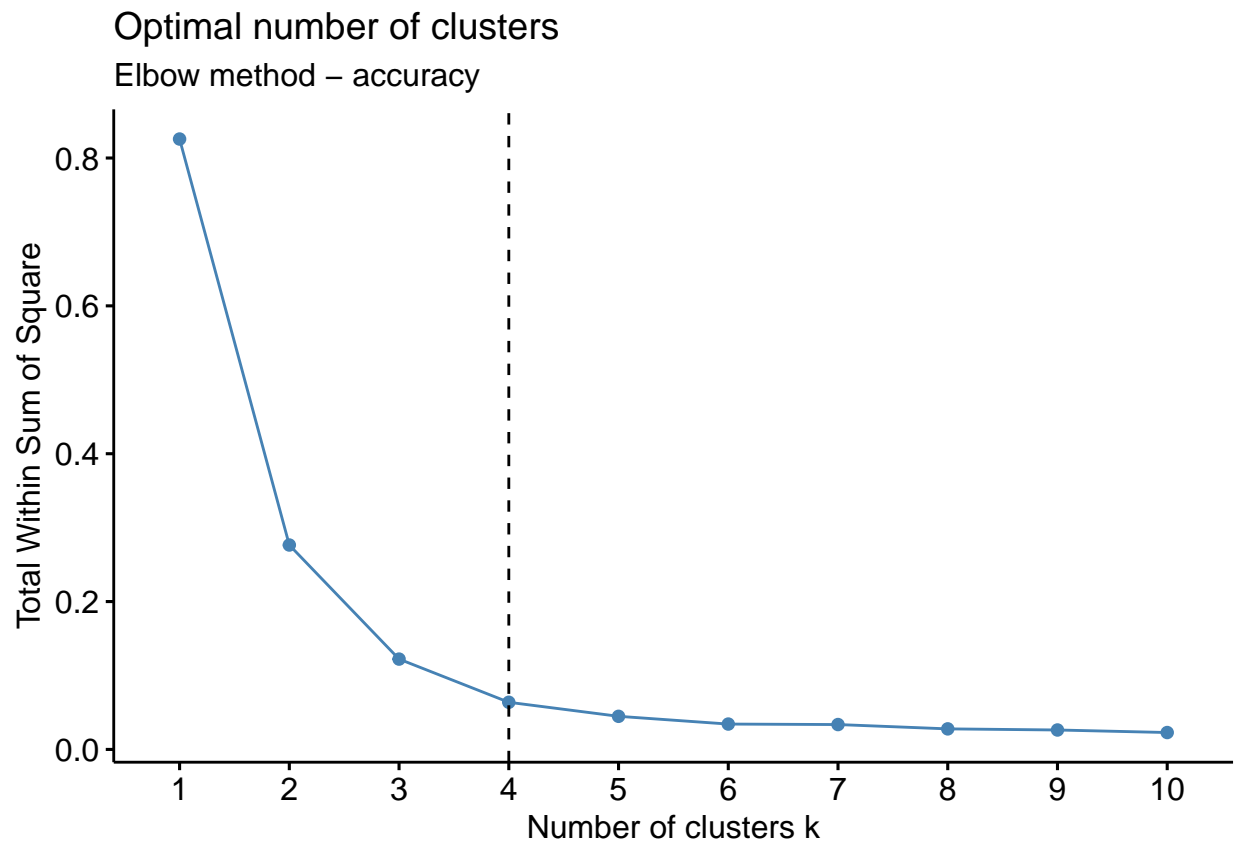151 ##   average   single complete   ward
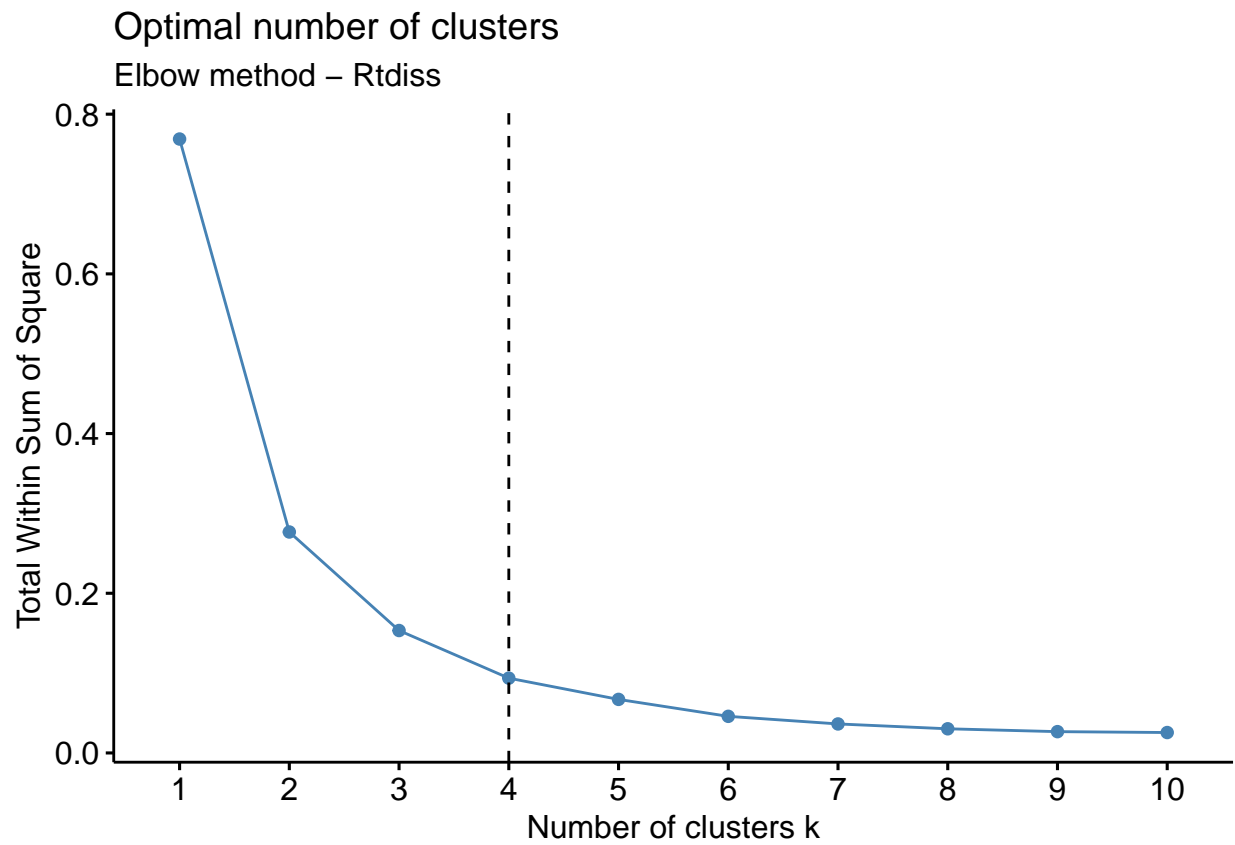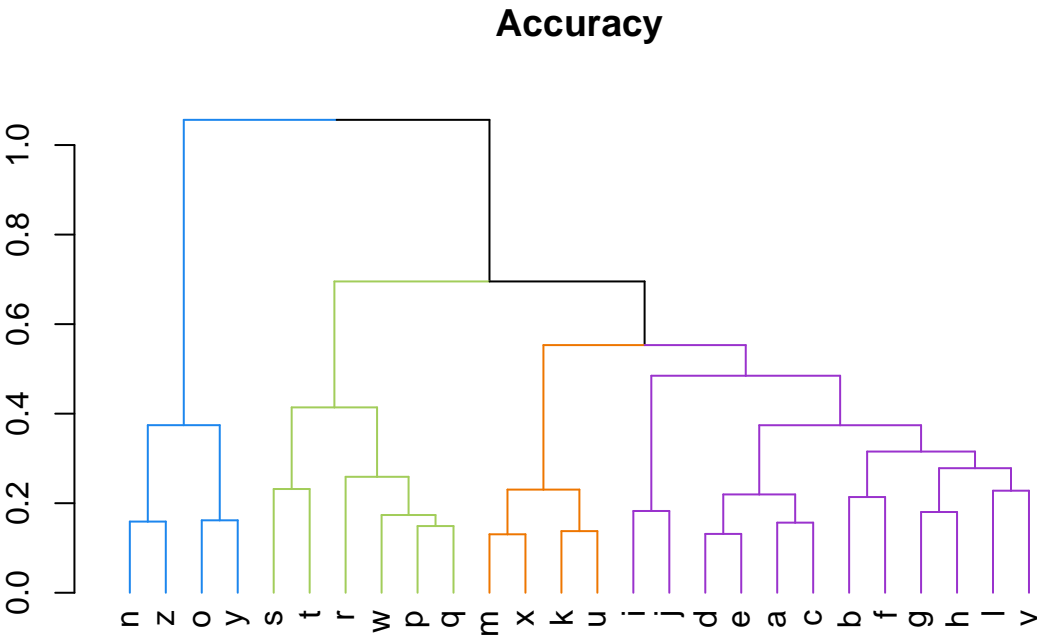
152 ## 0.4173949 0.2259740 0.5526253 0.7378997

Optimal number of clusters

Elbow method – accuracy

Optimal number of clusters
Elbow method – Rtdiss

Accuracy

RT

157

Discussion

General Discussion

160

References