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

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Enter author note here.

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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

pga *Pablo's comments look like this*

abl *Ana's comments look like this*

mpl *Manolo's comments look like this*

jad *Jon Andoni's comments look like this*

pga *I propose the following organization for the paper: 1. Why is it important to know the features of characters in alphabetic systems" 2. Explain what Braille is 3. Say briefly what was done expirically and statistically*

We dont need the numberging below, It is moslty to keep track

pga *Why*

For most sighted people, the small raised dot patterns that configure braille characters feels like little more than an undifferentiated textured surface. Similarly, when we see graphemes of an alphabet or that we are unfamiliar with, it is hard to distinguish among the different symbols that, for the untrained eye, look "alike". However, expert readers (of braille, or any other writing system) automatically extract the critical features in letters, and are, for the most part, unbothered by their accidental features. Indeed, there is a long tradition in the visual word recognition literature that has reliably demonstrated that the extraction of the relevant letter features to form abstract orthographic representations is quite robust to many manipulations (see Carreiras et al., 2012; Dehaene et al., 2005; Grainger et al., 2008; Pelli et al., 2006). On this general basis, many studies have been devoted to the examination of the similarity/confusability of letters in various alphabets

(e.g., Roman: Simpson et al., 2013; see also Mueller & Weidemann, 2012 for a review; Arabic: Boudelaa et al., 2020; Wiley et al., 2016), which has allowed researchers to carry out further investigations in reading and word recognition while controlling for letter similarity (abl *CITE: e.g., XXXX Marcet...*), and move towards a comprehensive understanding of letter identification and reading. abl *Say something about expertise effects -> WILEY*.

pga *The first sentence below is really odd beacause you never said in the paragrpah above that there is a consensus, or that the studies were about letter features.*

Of course, this consensus on the idea that letter perception follows a hierarchical mechanism that starts with the extraction of basic letter features is based on visual reading findings.

pga *What about this?: In visualreading research, a caonsensus has emerged regarding the extraction of features from the retinal image; in other words, we do not simply use the pattern of pixels, but instead use lines, angles, and curves as the building blocks for letter recognition.*

Braille letter perception has been far less studied and, therefore, its theoretical accounts have been discussed and examined in a smaller extent. Here we aim to understand what the features of braille letters are, and whether such features change depending on braille literacy.

pga *Explain what Braille is* abl *& what its known regarding letter perception*

Braille is unique among writing systems for many reasons. Of course, the most obvious one is that it was developed to be used by blind people though the sense of touch. Hence, it was devised taking into account the specific characteristics of the sensory modality at play, reflecting a compromise between amount of information and the skin's acuity.

Importantly, the braille system is also significatly different from other contemporary writing systems because it is a modern (1824) pga *en algun sitio he visto 1829, asi que ya no se yo*

cual es la fecha invention that has remained essentailly unchanged since Louis Braille engineered it. In contrast, visual writing systems currently in used have evolved thorugh cultural contact and ergonomic constraints over thousands of years.

Braille is a system of embossed dots whose basic unit is *the cell*, an array of 2x3 dots in which the different variations of raised dots form the elements of the written language (e.g., z = ⠵, ! = ⠮). Hence, an important characteristic of the braille writing system is its simplicity (see Figure 1). Indeed, as Millar (2003) said, "Braille characters are bound to be similar to each other since they all derive from the same (2×3) matrix" (p. 32). In addition, braille is highly standardized in the shape and size of the matrix with minor variations in the standards set by different regulatory bodies; hence, there are not *glyphs* in braille.

An explanation of how Luis Braille deviced the system is in order. The first 10 characters in the alphabet (a-j) are written using the top two rows of dots ⠁ ⠃ ⠉ ⠙ ⠑ ⠋ ⠛ ⠓ ⠊ ⠚, the next ten letters (k-t) repeat the patterns of the previous ten, but add a dot in the 3rd position ⠅ ⠇ ⠍ ⠝ ⠕ ⠏ ⠟ ⠗ ⠎ ⠞, the next group of letters (u - z)also repeat the pattern but add a dot in the 4th position ⠥ ⠧ ⠺ ⠭ ⠽ ⠵. The w, not being part of the French alphabet was later assigned the character ⠾. Later developments include letter combiations such as "th" ⠹ and ch ⠡.

One of the initial hypotheses on braille letter perception suggested that braille letters were perceived holistically, by their "global shape" (e.g., abl *CITE: Nolan & Kederis, 1969*). Nonetheless, in a series of experiments, abl *CITE: Millar 1977 a, b, 1985, see also 2003...* showed that was not the case, since . . . abl *explain results: high accuracy in same/different but not able to recall/drawing...*. Indeed, Millar suggested that braille lacks prominent features and that letter perception in braille initially depends on dot density ("texture"), and that once learning has taken place, then shape coding occurs (i.e., the dots within a character can be located by reference to each other -> spatial organization)

. . . abl *link to what we're doing – even though "braille letters are bound to be similar to each other"...are all of them equally similar?*

. . . pga *Also, are there primitives in braille such as "vertical line"*

It is unclear from the literature the extent to which braille letters are similar to each other. Here. . .

pga *Brief intro on what we are doing*

- choice of task (common in visual modality) -> speeded same-different judgments for letter pairs (this task allows for normal perception conditions, while limiting the influence of task irrelevant knowledge, such as vocabulary knowledge) -> speeded = apparatus
- confussion matrices to examine what determines letter similarity in braille -> as research in visual modality
- Expertise effects in letter perception
- Dots/position weights -> is any position more important? Given that we know how it was created. . . (dot 3, 6. . .)

abl *importance*

Theoretical and practical reasons . . .

abl *limitations on interpretation*

The comparison between groups of course is not perfect: braille readers have greater tactile sensitivity in addition to knowledge about braille letters, and sighted individuals might use strategies, such as to mentally visualize the pattern, that are influenced by their vision experience. . . nonetheless, it is still possible to gain knowledge on tactile letter

processing in general as well as the way literacy affects it, which, in turn, will assist on the improvement of teaching (practical) and models of word recognition and reading (theoretical)...

Experiment 1: Similarity judgements by naïve braille readers

Apparatus

Two braille displays were used to present the braille letters (i.e., a Focus 40 blue, an

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.

3 PARTICIPANTS (87-89) ONLY 210!

Procedure

The experiment took place individually in a quiet room. Participants used the moving version of TouchScope. Hence, participants did not move their fingers to perceive the stimuli. They were instructed to place their index fingertip on the start position to let the braille display slide against it. The braille display moved for 5 cm at 38.9 mm/s (35.9 mm/rev x 65 rpm / 60). This speed was chosen considering previous studies on passive touch (see Vega-Bermudez et al., 1991), as well as our own experience testing it. After moving said distance, the display stopped until participants responded and reset its position during the one-second ITI. This experiment also took around 30 minutes to complete.

Data analysis

Results

```
## [1] 14
```

```
## Bayes factor analysis
## --------------
## [1] Alt., r=0.707 : 2955488 ±0%
##
## Against denominator:
##   Null, mu = 0
## ---
## Bayes factor type: BFoneSample, JZS
```

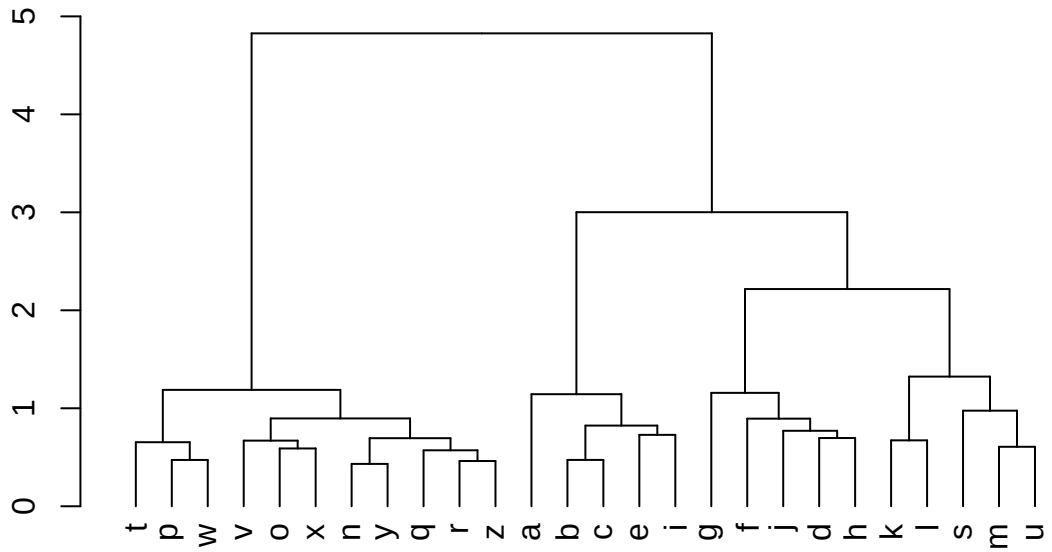
```
## Bayes factor analysis
## --------------
## [1] Alt., r=0.707 : 0.1300824 ±0%
```

```
##
## 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	0.
b	0.979	NA	0.993	1.026	0.988	0.990	0.990	0.969	1.047	1.074	0.942	0.982	0.
c	0.948	0.993	NA	0.980	1.060	0.955	1.011	1.074	1.020	1.119	0.991	0.938	0.
d	0.992	1.026	0.980	NA	1.077	1.038	1.014	1.063	1.092	0.980	1.052	1.184	1.
e	0.992	0.988	1.060	1.077	NA	1.004	0.974	1.028	1.010	1.160	0.923	1.052	0.
f	0.930	0.990	0.955	1.038	1.004	NA	1.014	1.045	1.145	1.107	1.051	0.995	0.
g	0.944	0.990	1.011	1.014	0.974	1.014	NA	1.139	0.950	1.020	0.887	1.004	1.
h	0.906	0.969	1.074	1.063	1.028	1.045	1.139	NA	1.070	1.070	0.994	1.010	1.
i	0.915	1.047	1.020	1.092	1.010	1.145	0.950	1.070	NA	1.002	0.946	0.970	1.
j	0.954	1.074	1.119	0.980	1.160	1.107	1.020	1.070	1.002	NA	1.142	1.054	0.
k	1.008	0.942	0.991	1.052	0.923	1.051	0.887	0.994	0.946	1.142	NA	1.080	1.
l	0.946	0.982	0.938	1.184	1.052	0.995	1.004	1.010	0.970	1.054	1.080	NA	0.
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	0.
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	1.
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	1.
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	0.
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	1.
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	1.
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	1.
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	0.
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	0.
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	1.
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	1.
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	0.
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	0.

	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.

```
##   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
```

```
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## 0.3185801 0.1944902 0.4879093 0.6774162
```
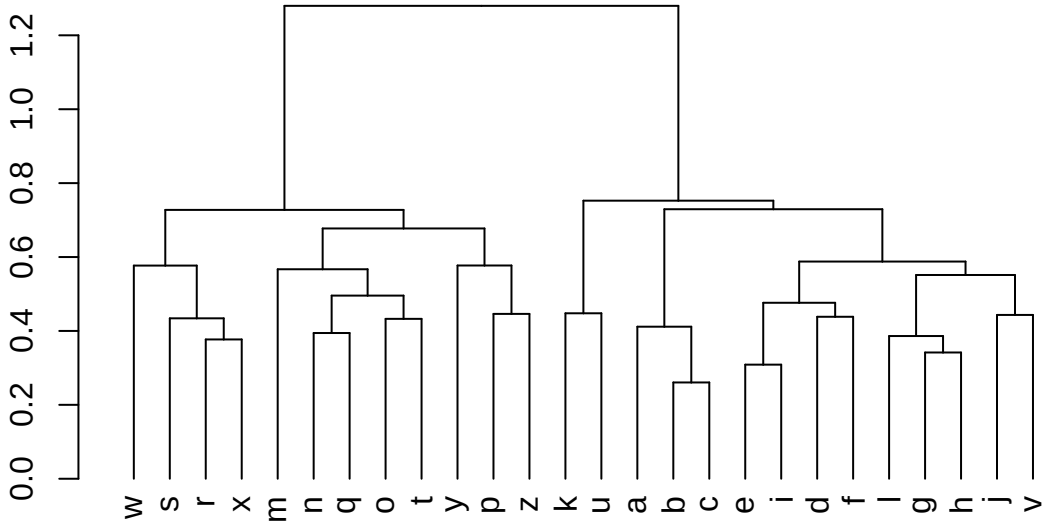
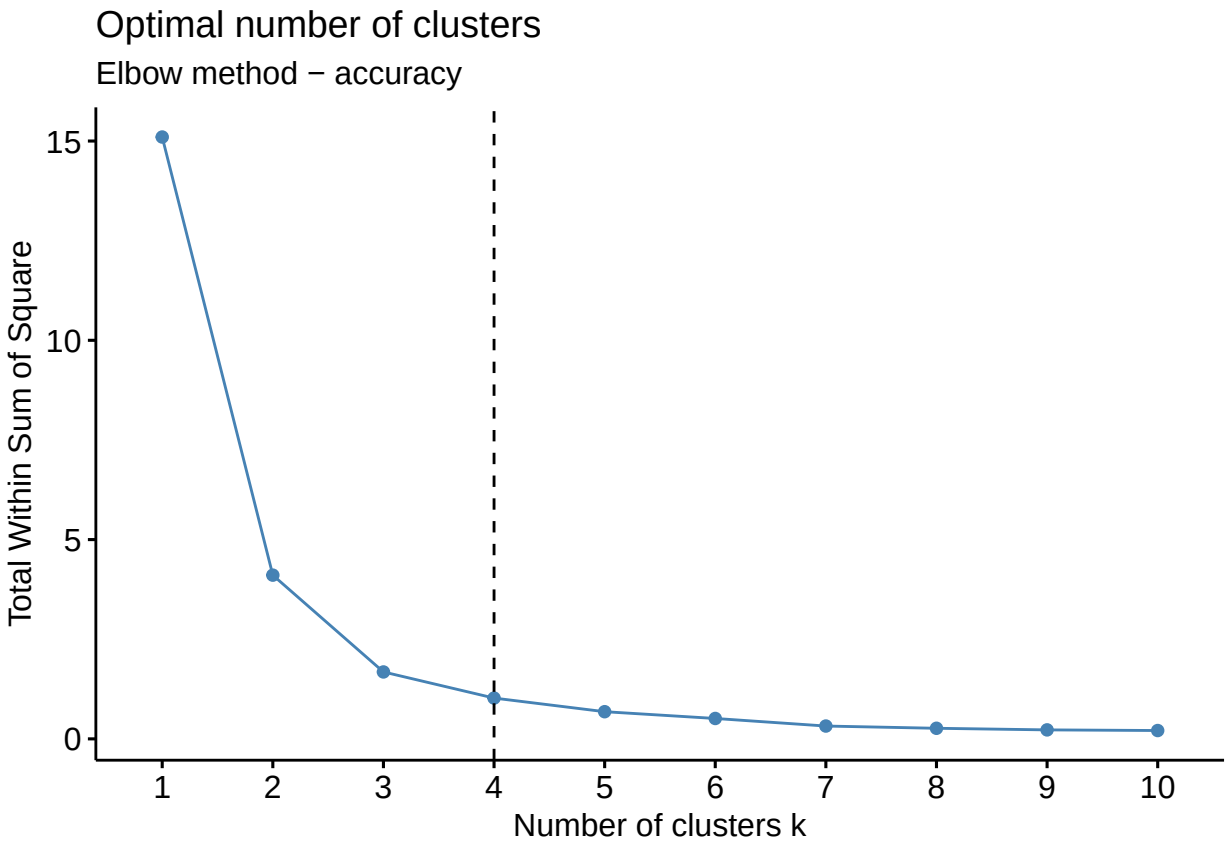



189


Optimal number of clusters
Elbow method − accuracy
Total Within Sum of Square
Number of clusters k
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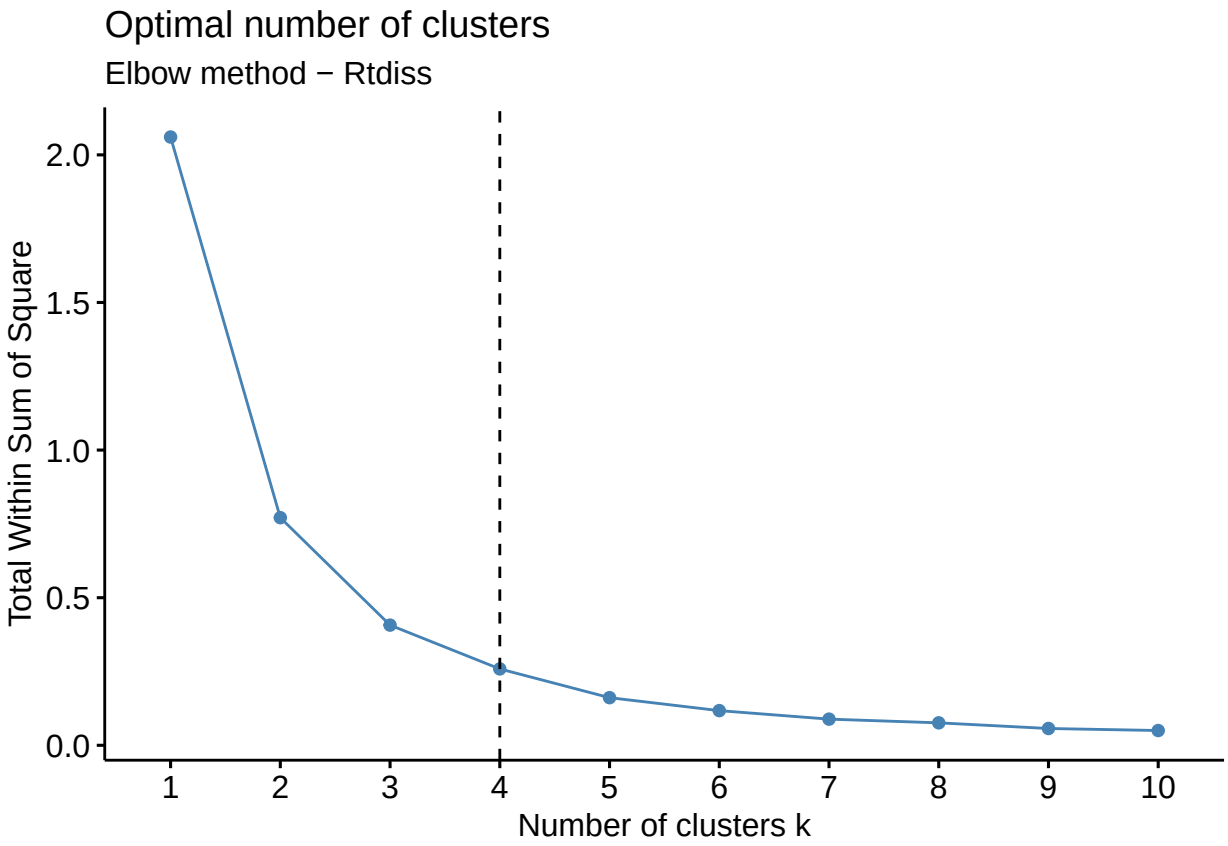
10
15
1
2
3
4
5
6
7
8
9
10

190


Optimal number of clusters
Elbow method − Rtdiss
Total Within Sum of Square
2.0
1.5
1.0
0.5
0.0
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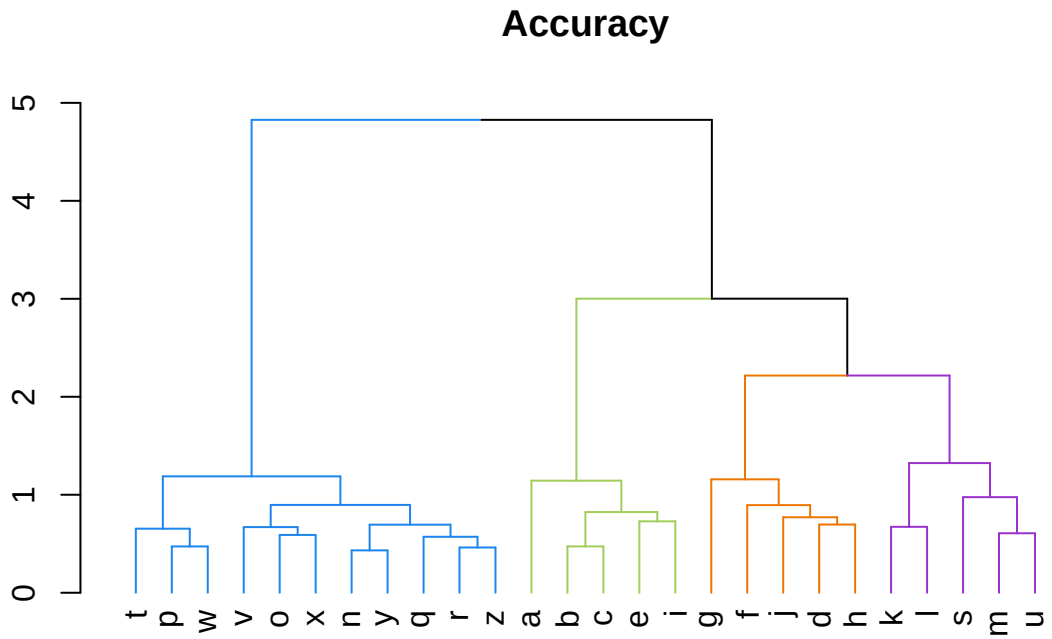
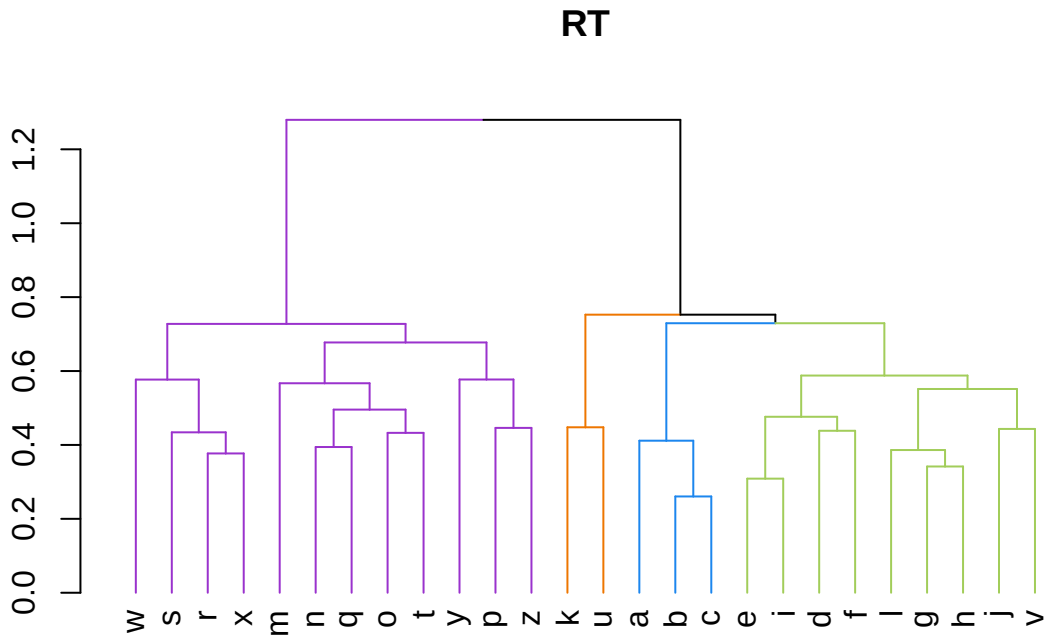
2
3
4
5
6
7
8
9
10
Number of clusters k

191



192



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
```

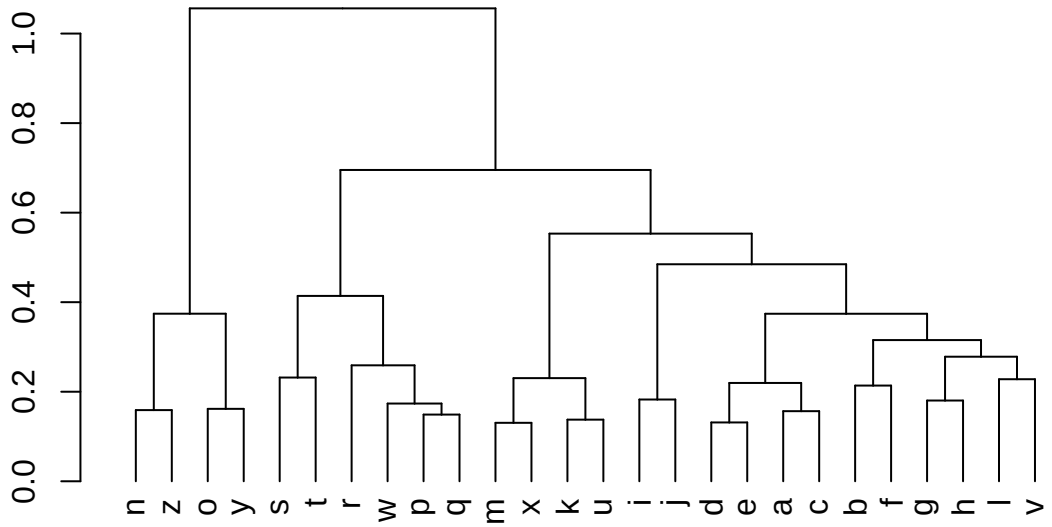
```
##
##  Paired t-test
##
## data:  RT.orders.blind$MNRT1 and RT.orders.blind$MNRT2
## t = -1.6644, df = 324, p-value = 0.09701
```

```
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  -0.01314649  0.00109665
## sample estimates:
## mean of the differences
##             -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.

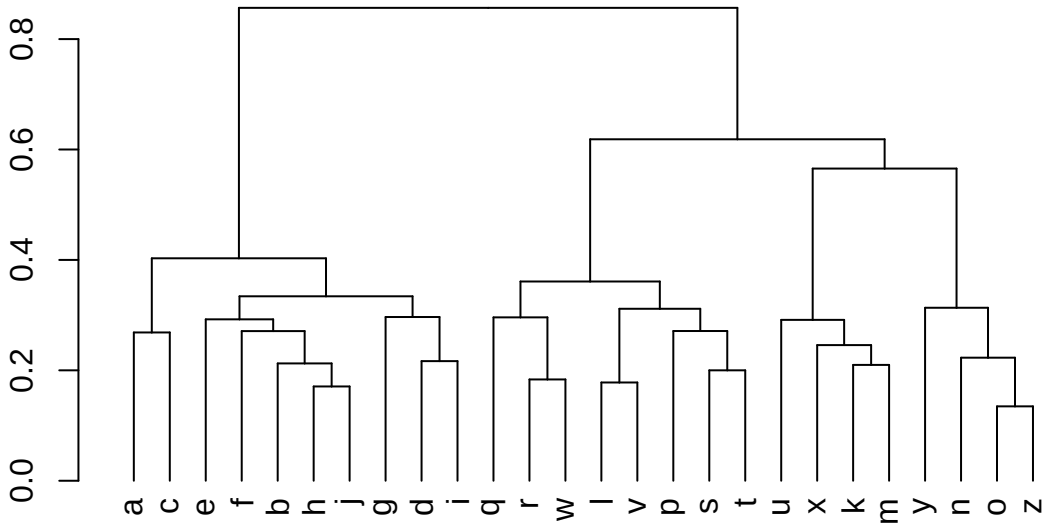
	a	b	c	d	e	f	g	h	i	j	k	l	
a	NA	1.055	0.910	1.031	1.049	0.957	1.004	1.040	0.964	1.047	1.000	0.984	1.
b	1.055	NA	0.978	0.994	1.008	0.979	0.995	0.980	0.998	0.997	1.053	0.957	1.
c	0.910	0.978	NA	0.972	1.057	1.041	1.045	1.036	1.035	1.015	1.024	1.042	1.
d	1.031	0.994	0.972	NA	0.886	0.909	1.010	0.982	1.015	0.955	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.

```
##   average    single  complete      ward
## 0.6361242 0.5132008 0.7165643 0.8340732
```




```
##  [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
## [26] 22
```

```
##   average    single  complete      ward
## 0.4173949 0.2259740 0.5526253 0.7378997
```



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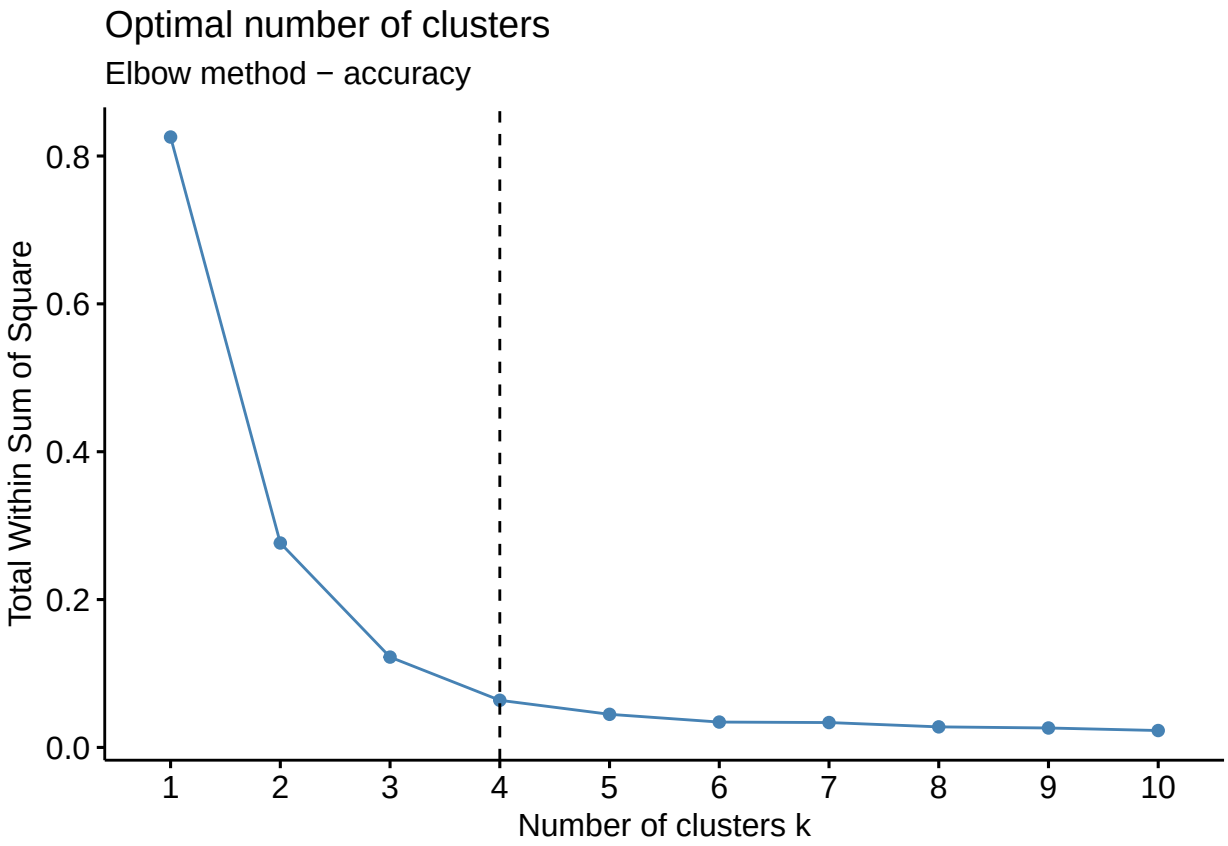
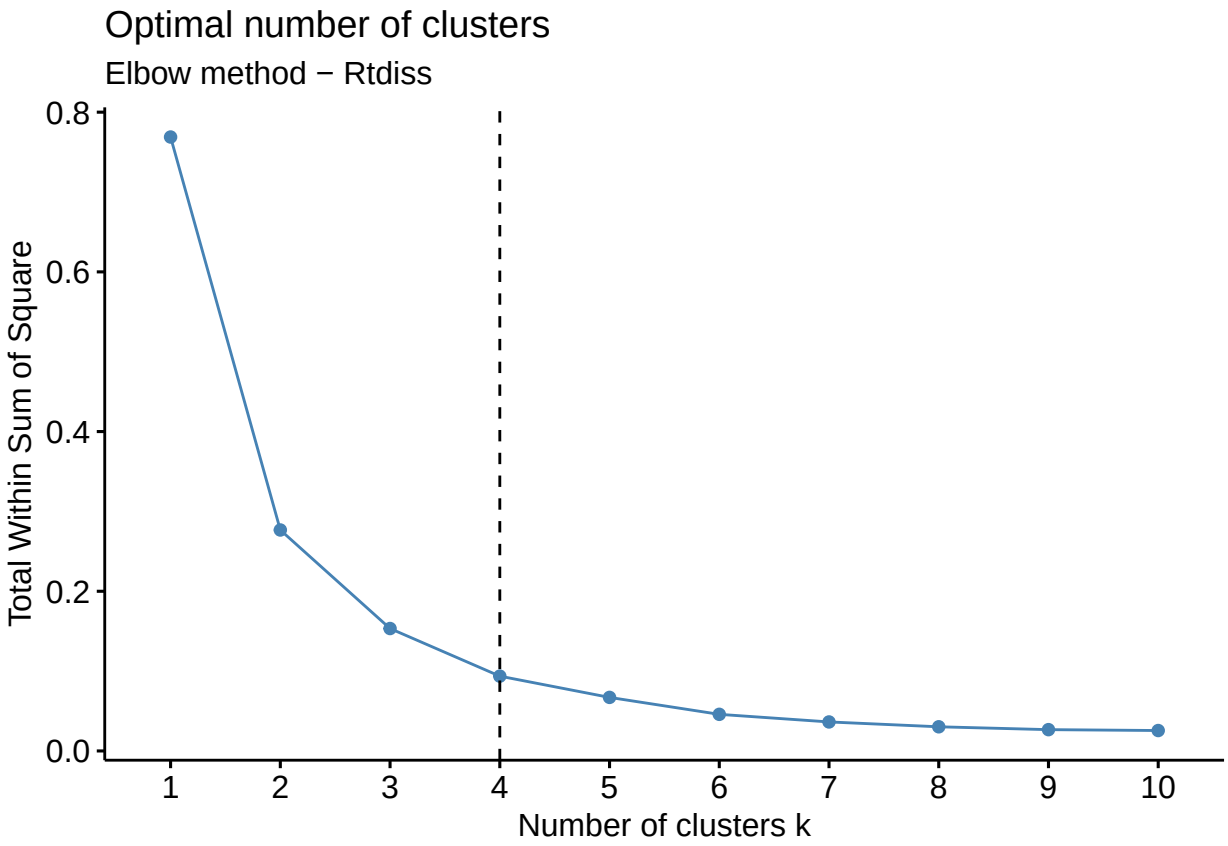
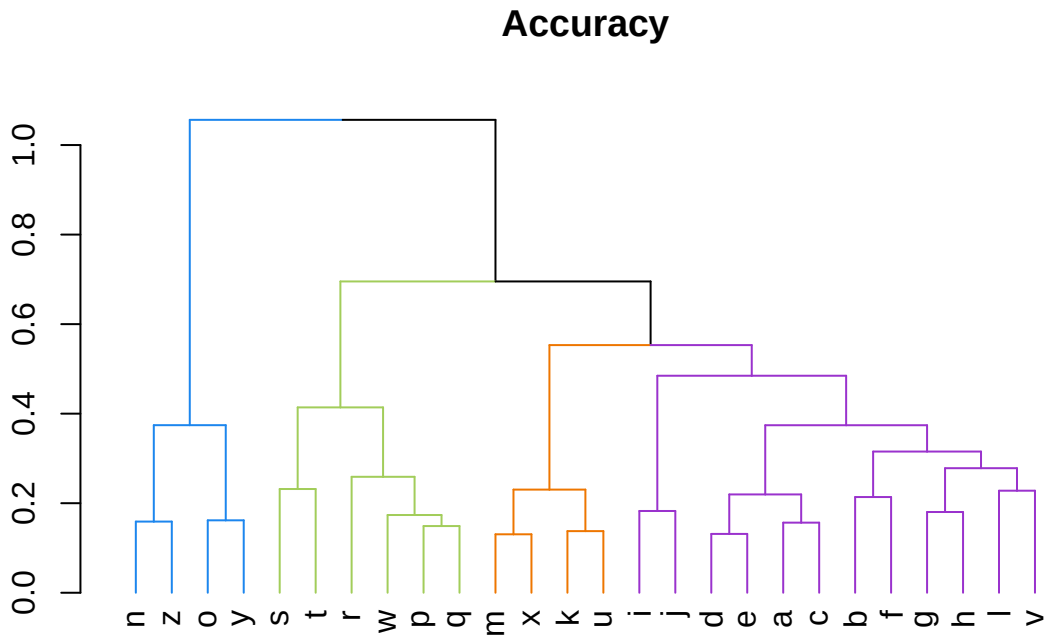

Optimal number of clusters
Elbow method − accuracy
Total Within Sum of Square
0.0
0.2
0.4
0.6
0.8
1
2
3
4
5
6
7
8
9
10
Number of clusters k


Optimal number of clusters
Elbow method − Rtdiss
Total Within Sum of Square
0.0
0.2
0.4
0.6
0.8
1
2
3
4
5
6
7
8
9
10
Number of clusters k



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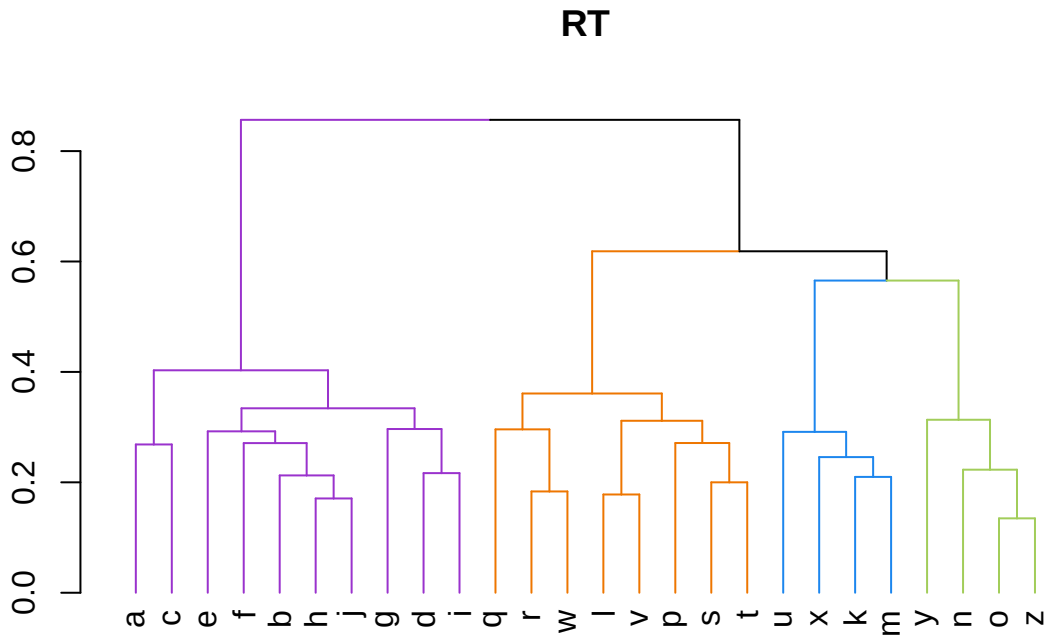

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248 ## Discussion

249 ### General Discussion

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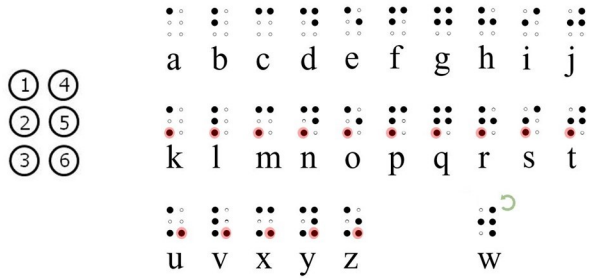

Figure 1