The Efficacy of Euler Diagrams and Linear Diagrams for Visualizing Set Cardinality

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This document is supplementary material for the associated paper submitted to InfoVis. In contains the following information:

- Appendix A contains information on how the questions were generated for the tasks in the study.
- Appendix B presents the examples used for training participants.
- Appendix C presents the questions and associated diagrams used in the studies.
- Appendix D describes in more detail than the associated paper the method used to collect data.
- Appendix E provides information on the statistical methods used to analyse the data.
- Appendices F- H present all of the statistical output generated from the methods employed for the three studies.

All of the diagrams included in this document are scaled to 50% of the actual size used in the study in order to fit within the page width.

Appendix A
Question Generation

For the S-type questions, a random permutation of the list of labels (set names) was generated using the website `www.random.org`. The first label in this permuted list then became the label which would appear in the question, and the next four labels in the permuted list were the labels which would appear as check-boxes, alongside the "None of the above" option. Where there were only five sets in the diagram, the second step was redundant.

For the I-type questions, a random permutation of the list containing those intersections containing at most three labels, was generated using the website `www.random.org`. The first intersection in this permuted list became the intersection which would appear in the question, and the next four intersections in the permuted list were the intersections which would appear as check-boxes, alongside the "None of the above" option.

A check was performed on the number of set-based check-boxes (by that we mean excluding 'None of the above') that appeared in the correct answer which ranged from 0 (when 'None of the above' was the correct answer) to 4. These numbers were:

- 0/"None of the above": 7 questions
- 1 set-based check-box to be checked: 6 questions

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- 2 set-based check-boxes to be checked: 7 questions
- 3 set-based check-boxes to be checked: 7 questions
- 4 set-based check-boxes to be checked: 5 questions.

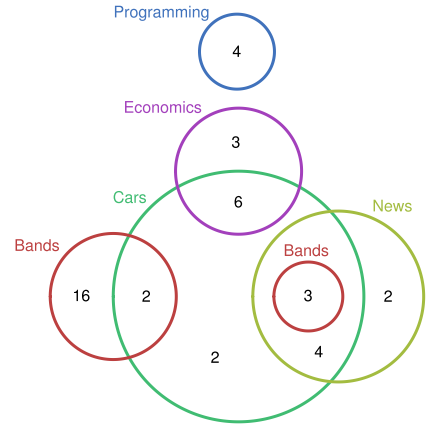
Thus, there was no systematic bias towards any number of check-boxes appearing in the correct answer.

Appendix B
Training for Studies A, B & C

This section contains the data presented to participants for the purposes of training. After attempting each question, participants were given the correct answer, an explanation of the correct answer (with reference to the diagram) and (for questions 1 and 2) a modified diagram with the regions of interest highlighted. These modified diagrams are presented alongside each question.

Question 1

- **Question:** Tick the check boxes where **more people** have exactly that combination of interests than **Cars and Economics only**.
- **Check boxes to be ticked:** Bands
- **Task Type:** Intersection comparison - More than.
- **SNAP Data Set Used:** 44130462
- ED-N



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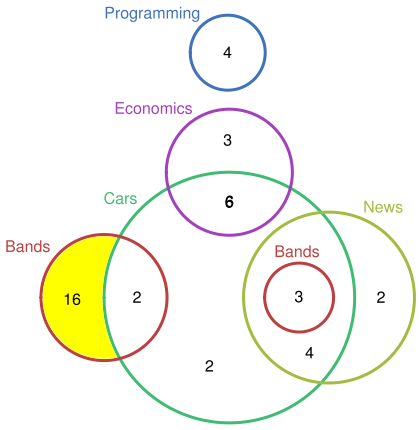

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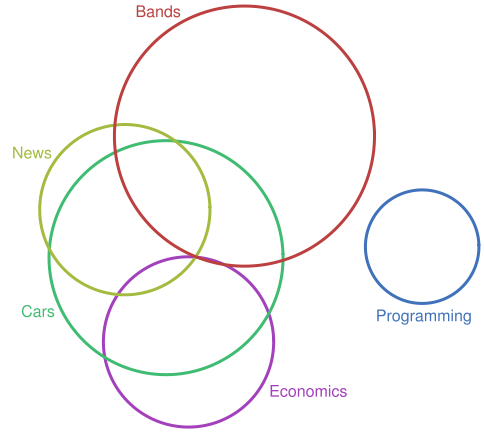
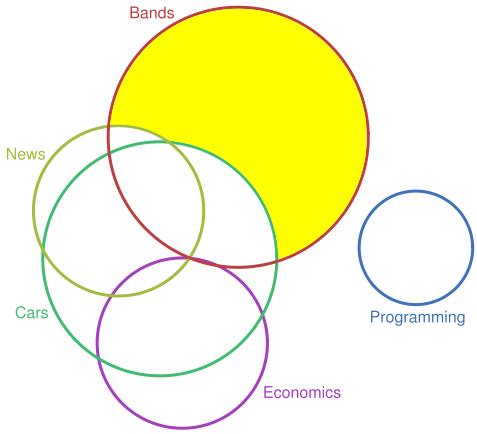


- ED-P:Explanation



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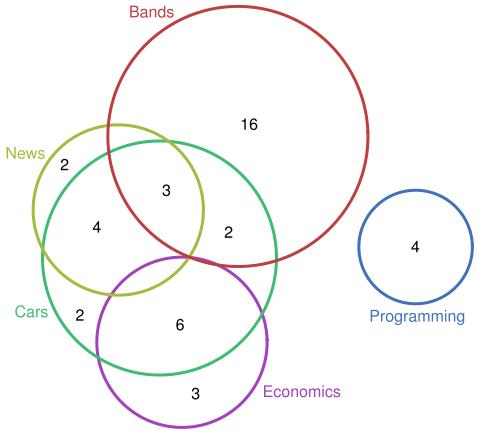

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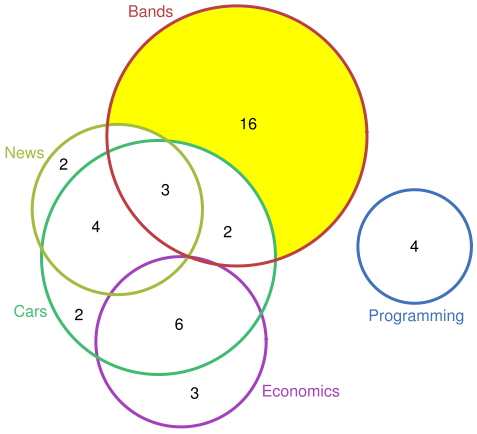
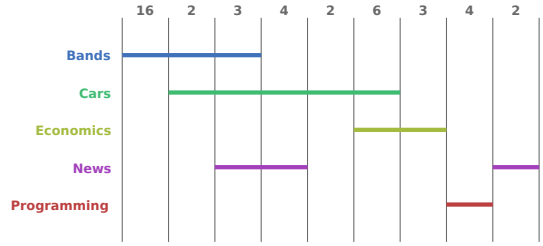
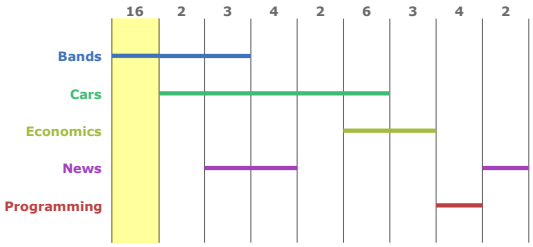


- LD-N



- LD-N:Explanation



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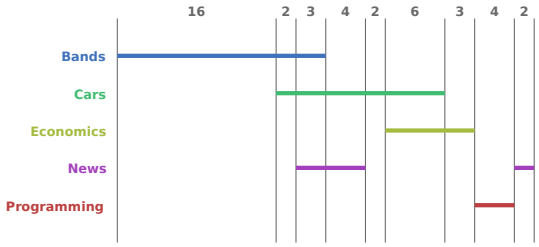

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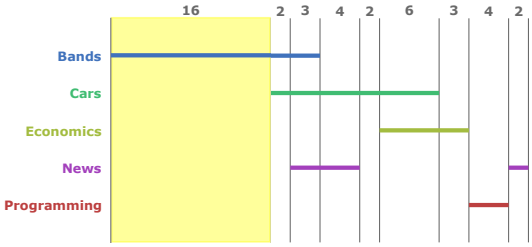

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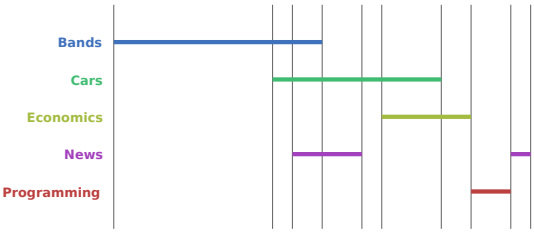

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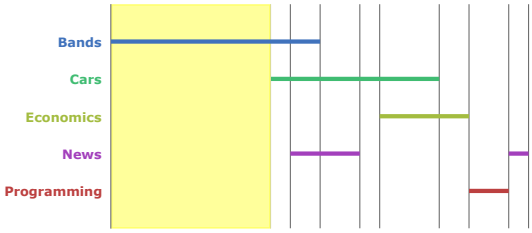
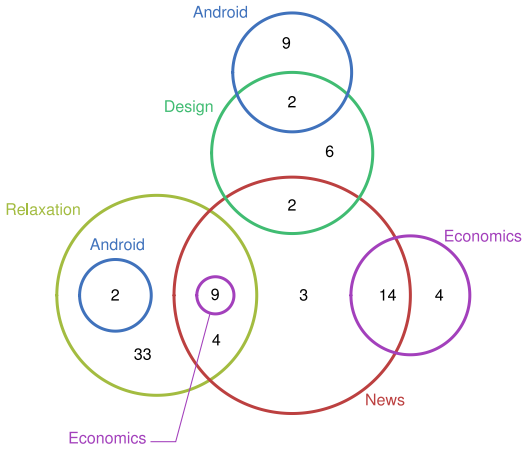


Question 2

- **Question:** Tick the check boxes where the total number of people interested in that topic is **less than** the total number of people interested in **Economics**.
- **Check boxes to be ticked:** Android, Design
- **Task Type:** Set comparison - Less than.
- **SNAP Data Set Used:** 16652550

- ED-N



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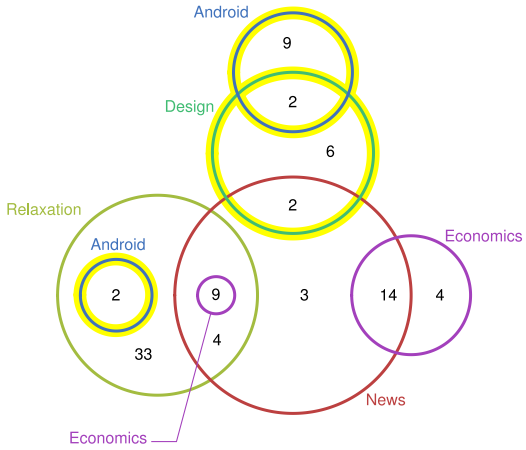

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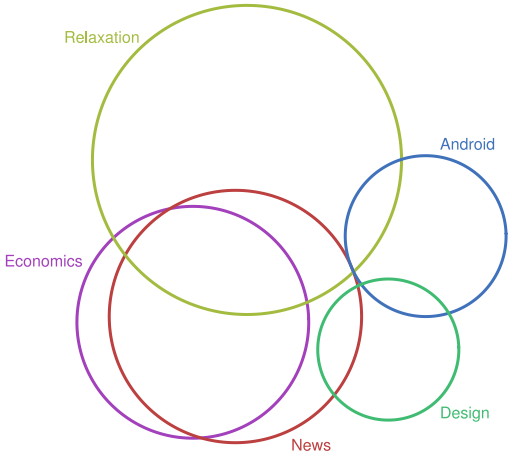

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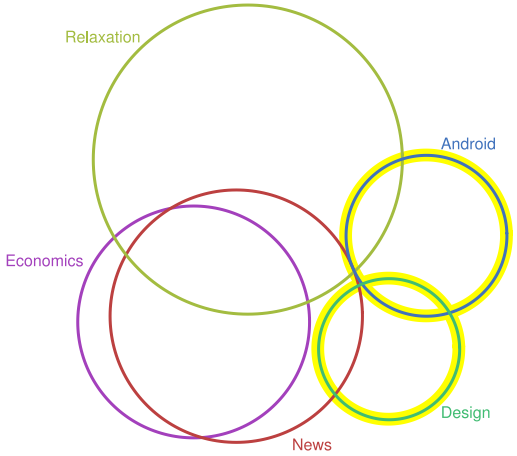

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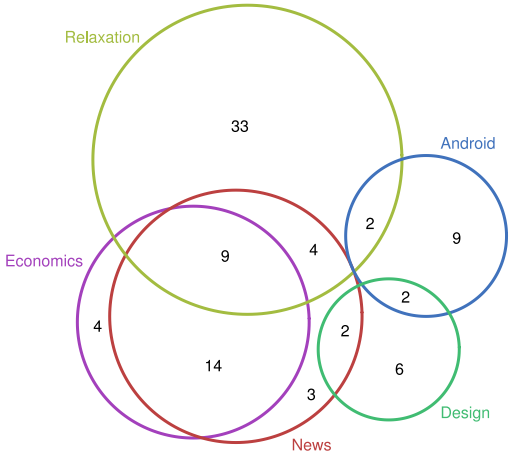

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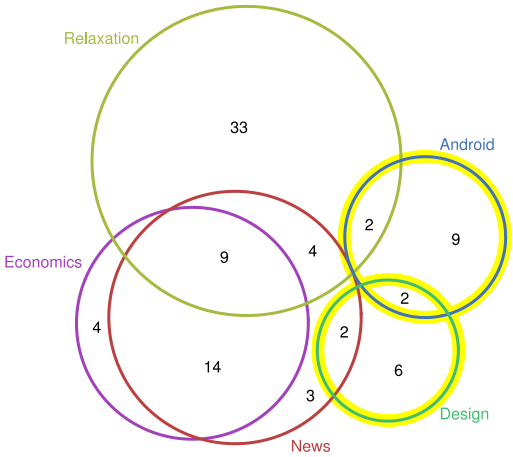

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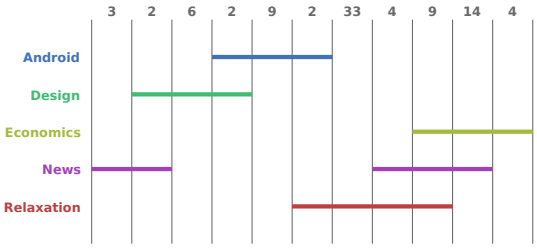

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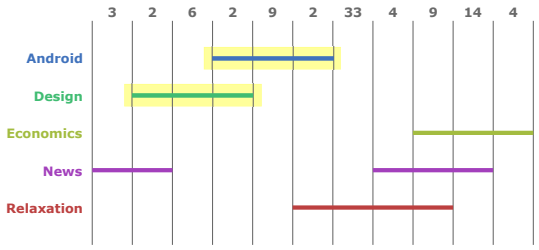

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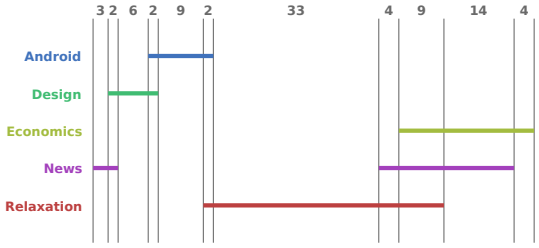

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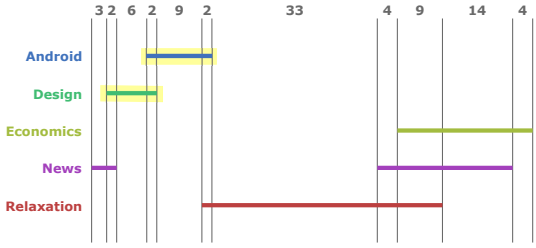
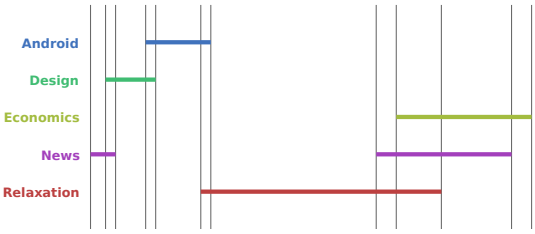


- LD-P&N



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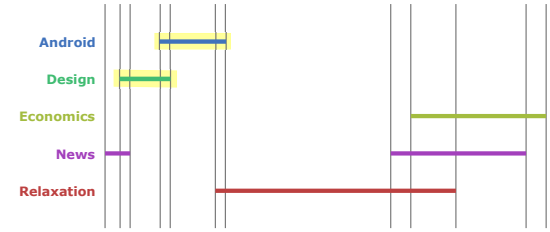
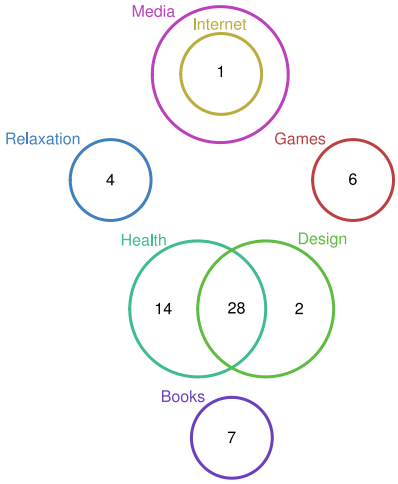


Question 3

- **Question:** Tick the check boxes where **more people** have exactly that combination of interests than **Games only**.
- **Check boxes to be ticked:** Books, Design and Health
- **Task Type:** Intersection comparison - More than.
- **SNAP Data Set Used:** 19492215
- ED-N



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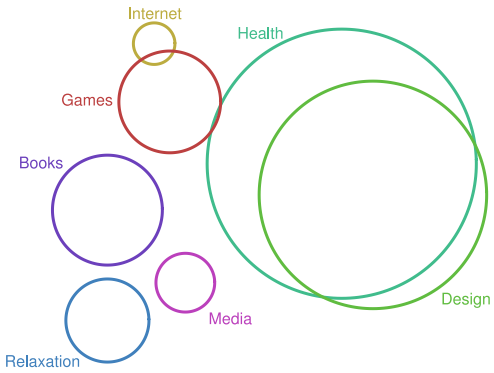
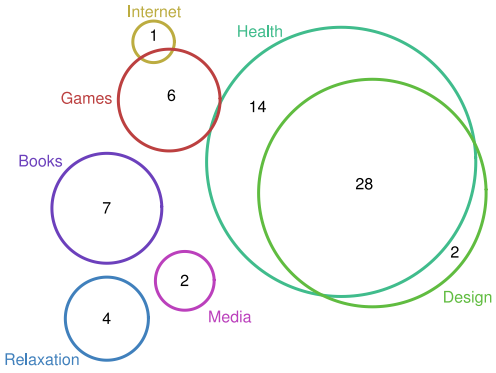
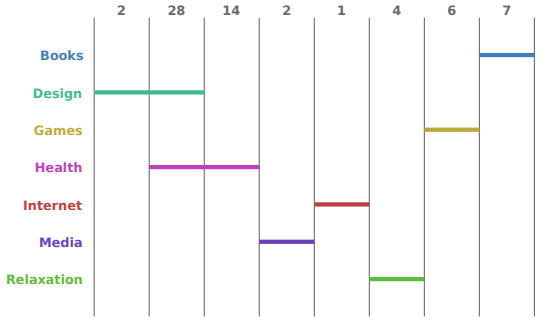


- ED-P&N



- LD-N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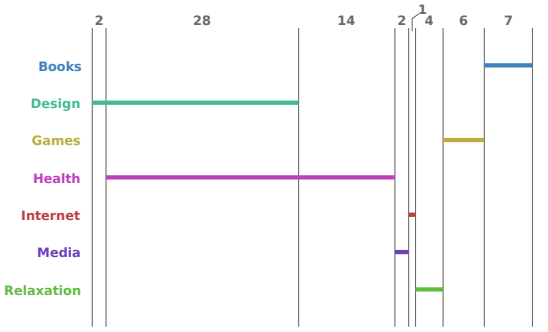
Books
Design
Games
Health
Internet
Media
Relaxation

- LD-P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Books
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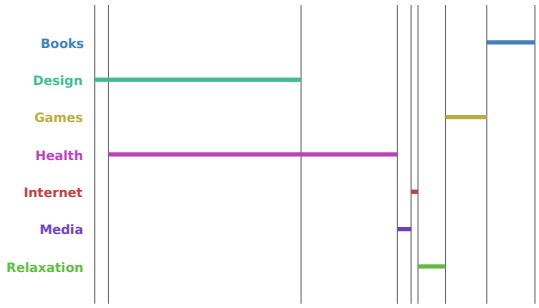
Relaxation

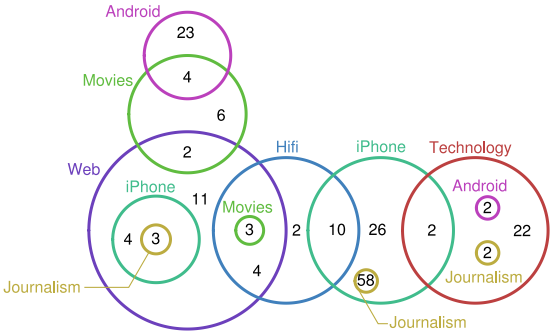
- LD-P&N


Books
Design
Games
Health
Internet
Media
Relaxation

Question 4

- **Question:** Tick the check boxes where the total number of people interested in that topic is **greater than** the total number of people interested in **iPhone**.
- **Check boxes to be ticked:** None of the above
- **Task Type:** Set comparison - More than.
- **SNAP Data Set Used:** 105918870

- ED-N



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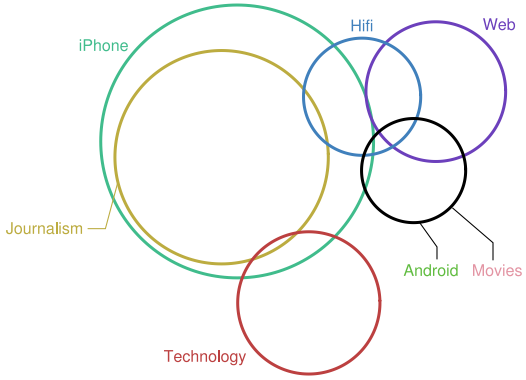
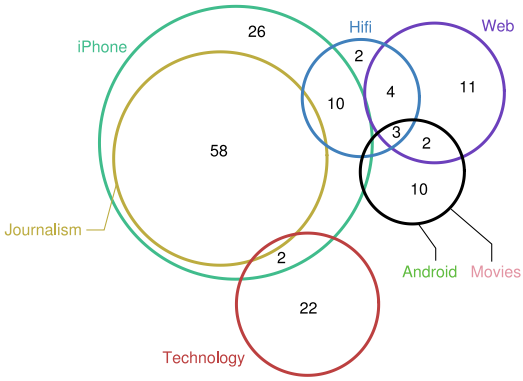
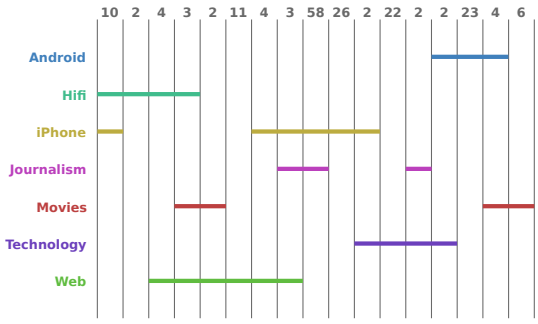


- ED-P&N



- LD-N



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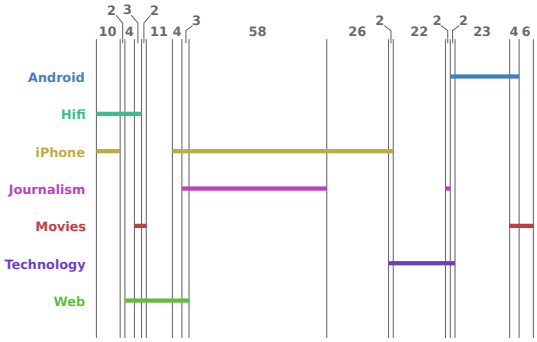
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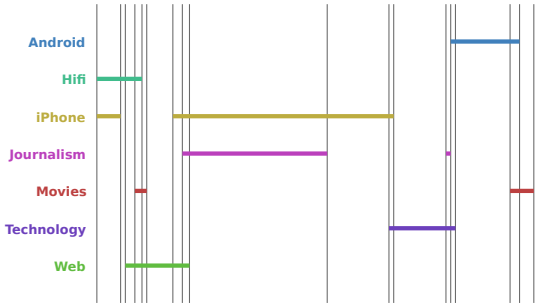
Android
Hifi
iPhone
Journalism
Movies
Technology
Web

- LD-P&N

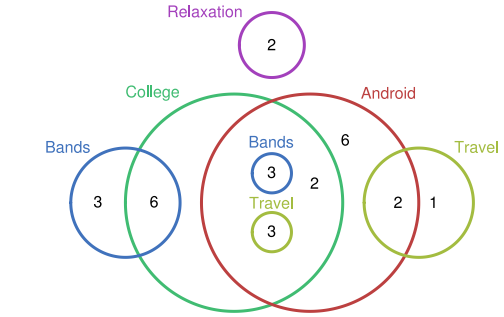

Android
Hifi
iPhone
Journalism
Movies
Technology
Web

Appendix C
Studies A, B & C

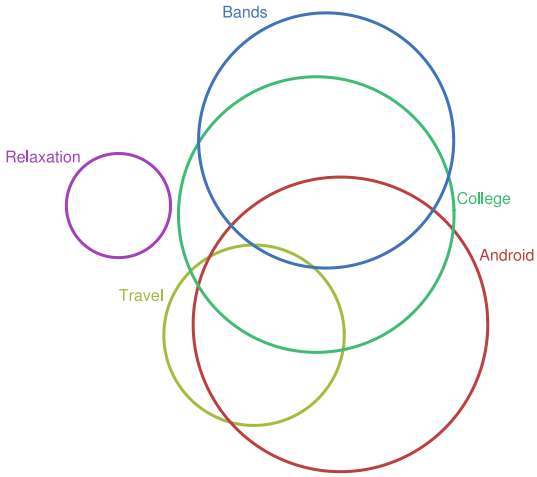
Question 1

- **Question:** Tick the check boxes where the total number of people interested in that topic is **greater than** the total number of people interested in **Relaxation**.
- **Check boxes to be ticked:** Android, Bands, College, Travel
- **Task Type:** Set comparison - More than.
- **SNAP Data Set Used:** 73024519

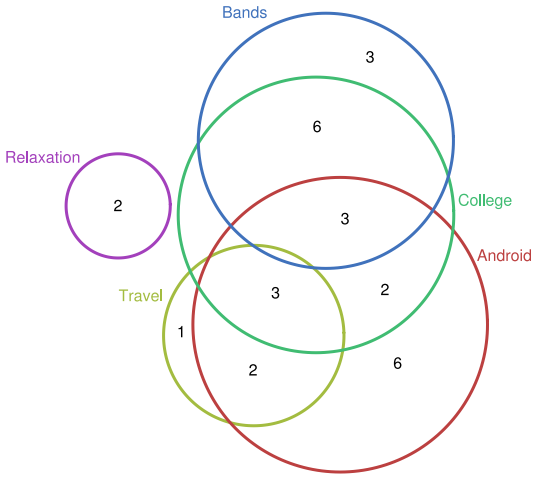
- ED-N



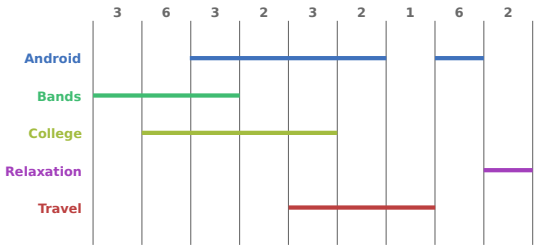
- ED-P



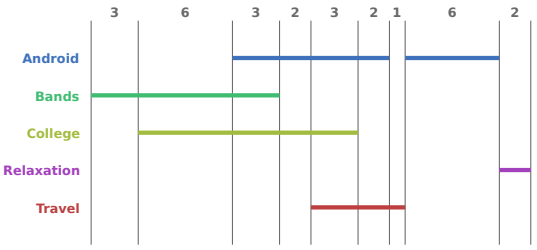
- ED-P&N



- LD-N


3 6 3 2 3 2 1 6 2
Android
Bands
College
Relaxation
Travel

- LD-P


3 6 3 2 3 2 1 6 2
Android
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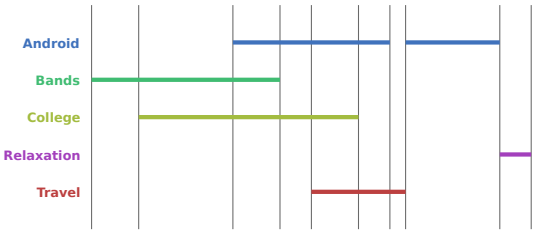
College
Relaxation
Travel

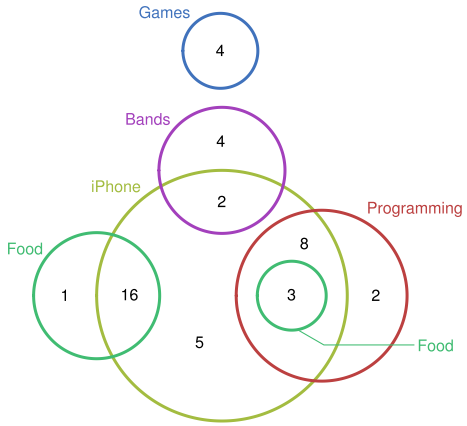
- LD-P&N


Android
Bands
College
Relaxation
Travel

Question 2

- **Question:** Tick the check boxes where the total number of people interested in that topic is **less than** the total number of people interested in **Programming**.
- **Check boxes to be ticked:** Bands, Games
- **Task Type:** Set comparison - Less than.
- **SNAP Data Set Used:** 73738774

- ED-N



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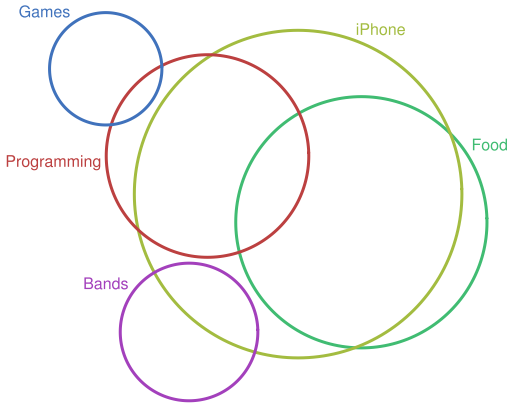
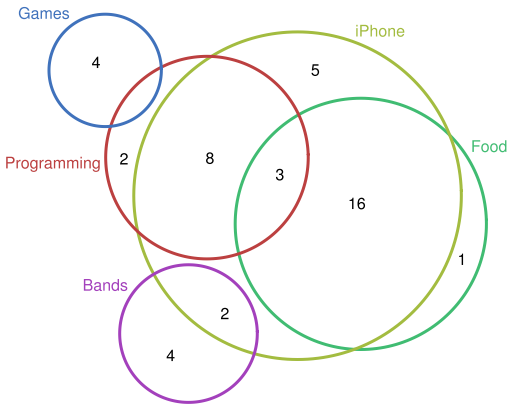
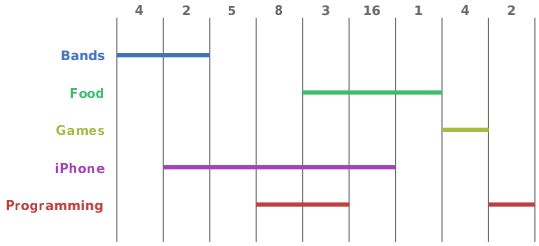


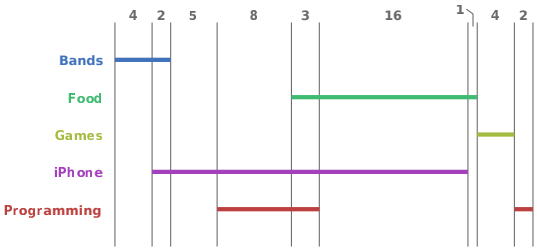
- ED-P&N



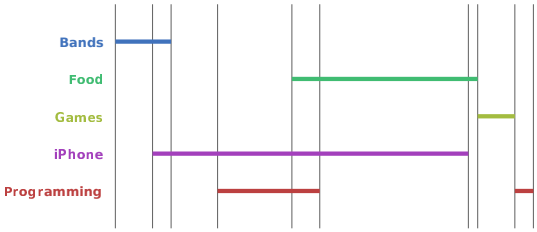
- LD-N


4 2 5 8 3 16 1 4 2
Bands
Food
Games
iPhone
Programming

- LD-P


4 2 5 8 3 16 1 4 2
Bands
Food
Games
iPhone
Programming

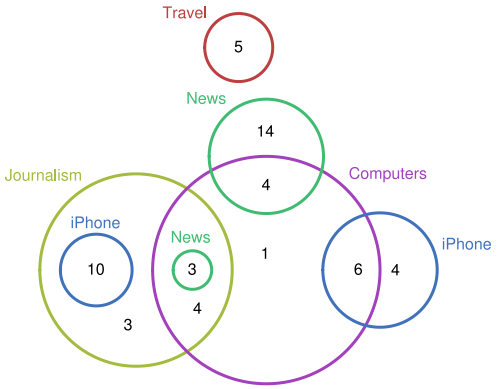
- LD-P&N


Bands
Food
Games
iPhone
Programming

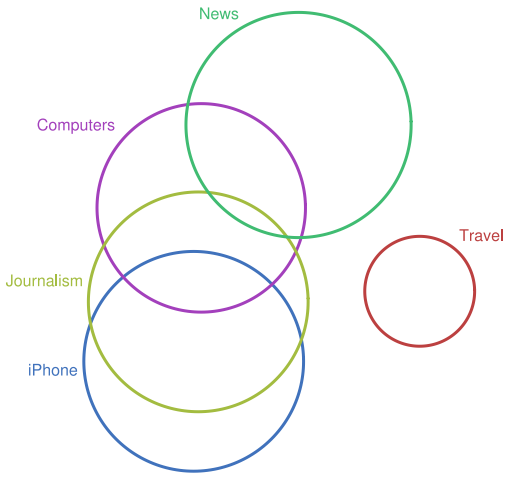
Question 3

- **Question:** Tick the check boxes where **more people** have exactly that combination of interests than **News only**.
- **Check boxes to be ticked:** None of the above
- **Task Type:** Intersection comparison - More than.
- **SNAP Data Set Used:** 14957252

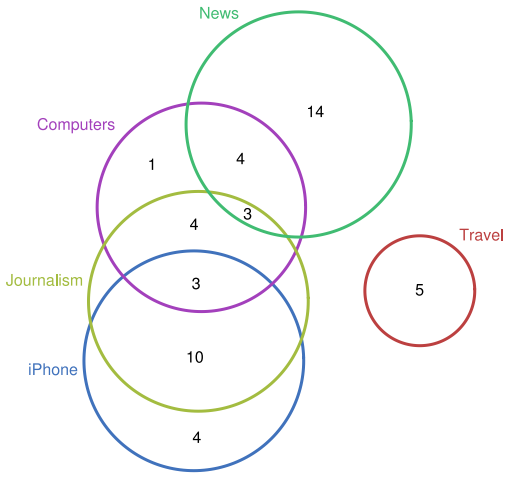
- ED-N



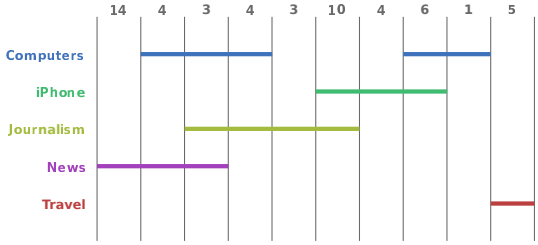
- ED-P



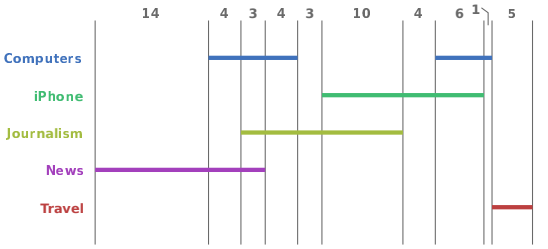
- ED-P&N



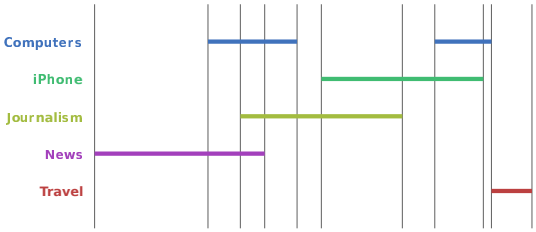
- LD-N


14 4 3 4 3 10 4 6 1 5
Computers
iPhone
Journalism
News
Travel

- LD-P


14 4 3 4 3 10 4 6 1 5
Computers
iPhone
Journalism
News
Travel

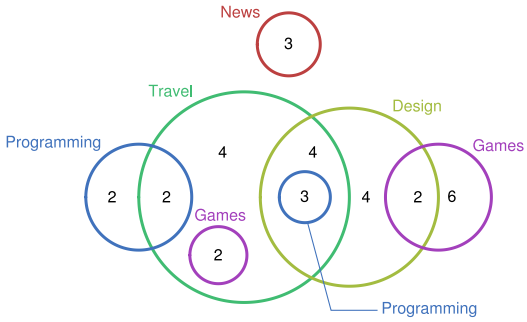
- LD-P&N


Computers
iPhone
Journalism
News
Travel

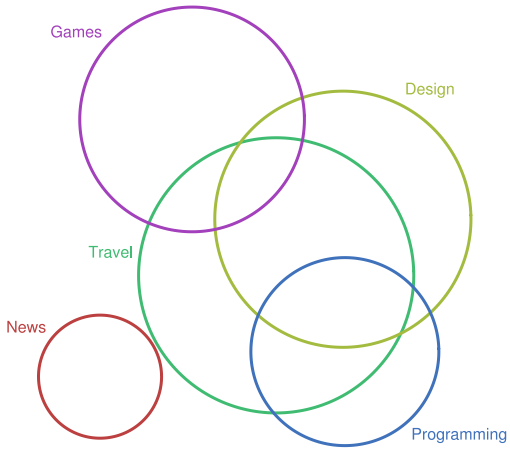
Question 4

- **Question:** Tick the check boxes where **more people** have exactly that combination of interests than **Design and Games only**.
- **Check boxes to be ticked:** None of the above
- **Task Type:** Intersection comparison - Less than.
- **SNAP Data Set Used:** 18687625

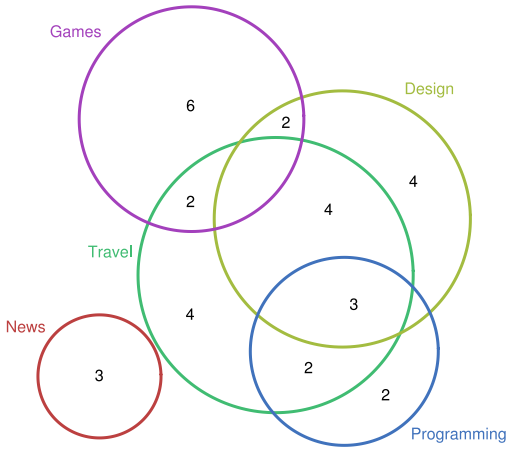
- ED-N



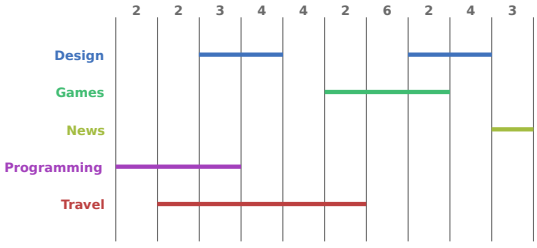
- ED-P



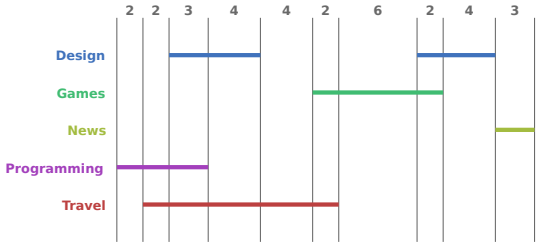
- ED-P&N



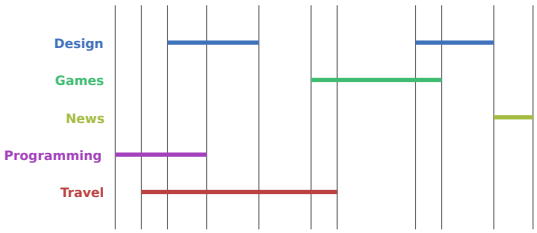
- LD-N



- LD-P


2 2 3 4 4 2 6 2 4 3
Design
Games
News
Programming
Travel

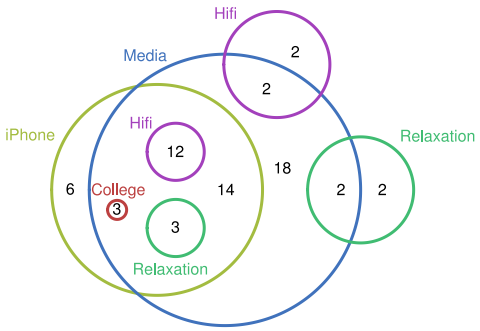
- LD-P&N


Design
Games
News
Programming
Travel

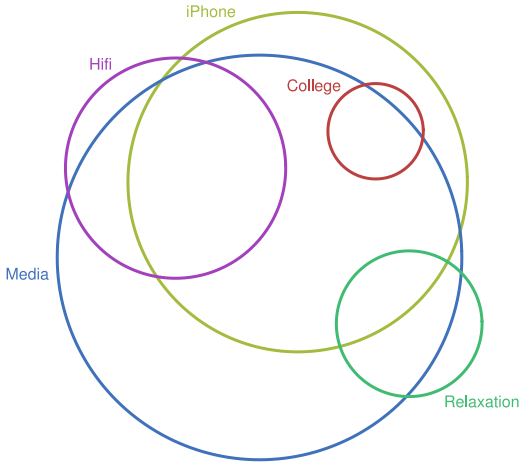
Question 5

- **Question:** Tick the check boxes where the total number of people interested in that topic is **greater than** the total number of people interested in **Relaxation**.
- **Check boxes to be ticked:** Hifi, iPhone, Media
- **Task Type:** Set comparison - More than.
- **SNAP Data Set Used:** 234169190

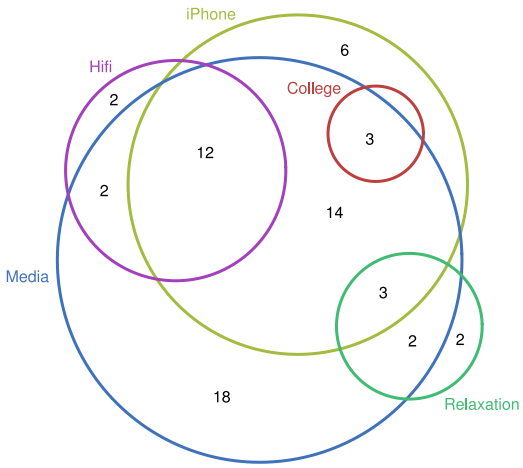
- ED-N



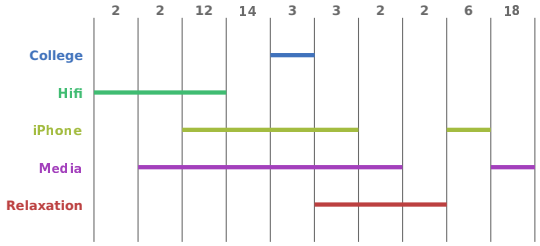
- ED-P



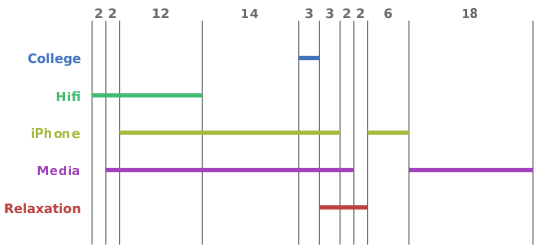
- ED-P&N



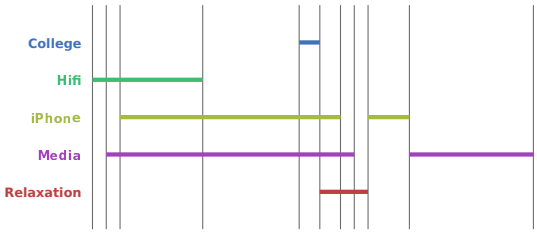
- LD-N


2 2 12 14 3 3 2 2 6 18
College
Hifi
iPhone
Media
Relaxation

- LD-P


2 2 12 14 3 3 2 2 6 18
College
Hifi
iPhone
Media
Relaxation

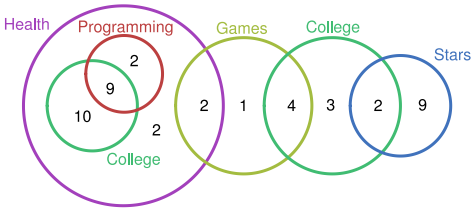
- LD-P&N


College
Hifi
iPhone
Media
Relaxation

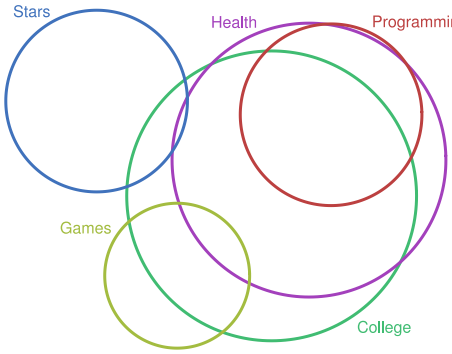
Question 6

- **Question:** Tick the check boxes where the total number of people interested in that topic is **less than** the total number of people interested in **Stars**.
- **Check boxes to be ticked:** Games
- **Task Type:** Set comparison - Less than.
- **SNAP Data Set Used:** 46160500

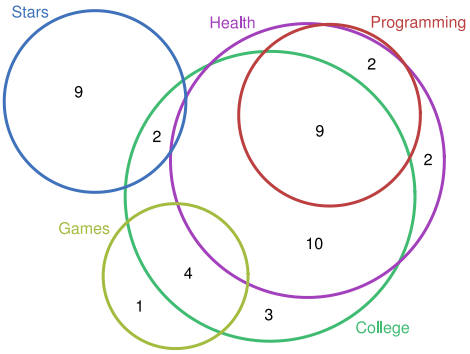
- ED-N



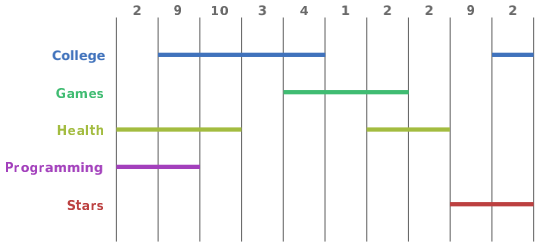
- ED-P



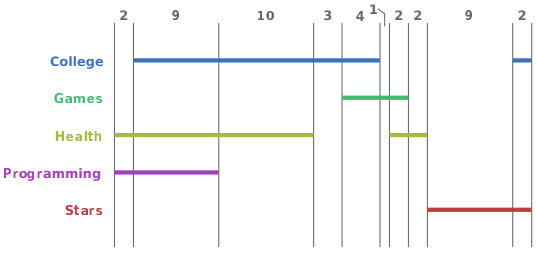
- ED-P&N



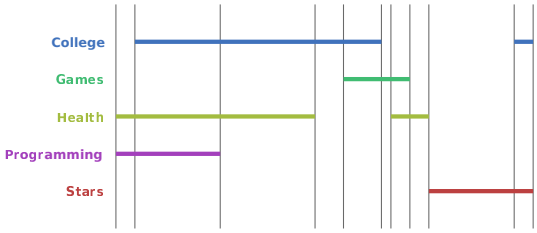
- LD-N



- LD-P

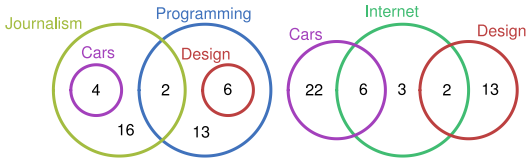


- LD-P&N

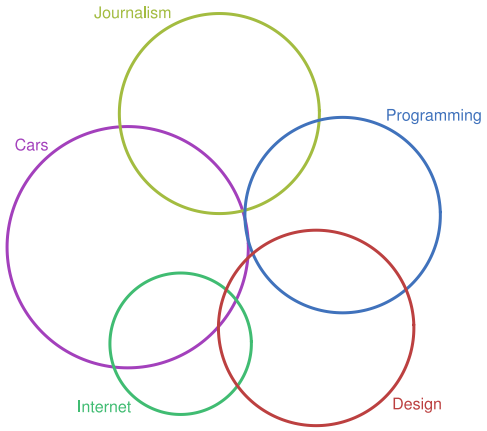


Question 7

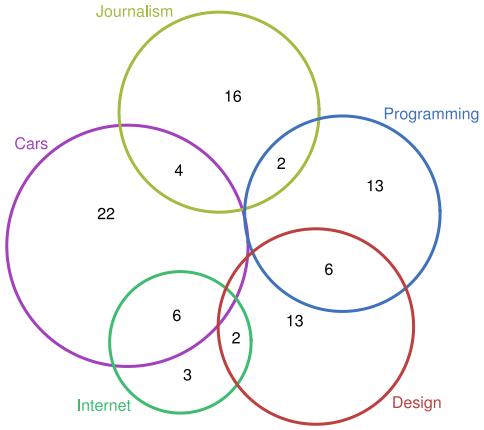
- **Question:** Tick the check boxes where **more people** have exactly that combination of interests than **Internet only**.
- **Check boxes to be ticked:** Cars, Cars and Internet, Design and Programming, Programming
- **Task Type:** Intersection comparison - More than.
- **SNAP Data Set Used:** 87004822
- ED-N



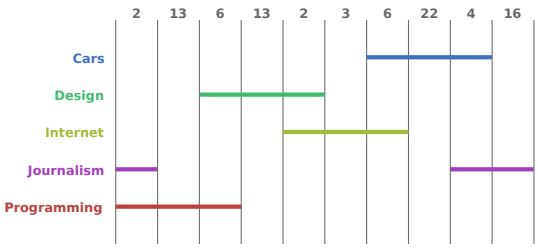
- ED-P



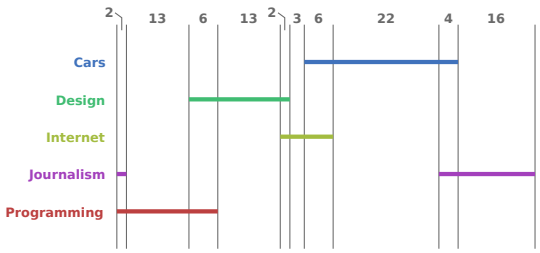
- ED-P&N



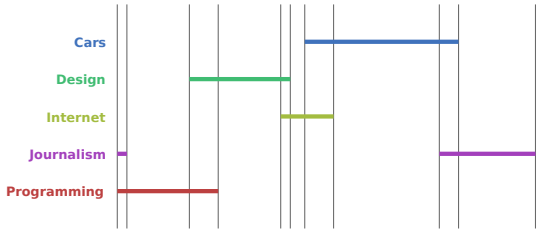
- LD-N



- LD-P


2
13
6
13
2
3
6
22
4
16
Cars
Design
Internet
Journalism
Programming

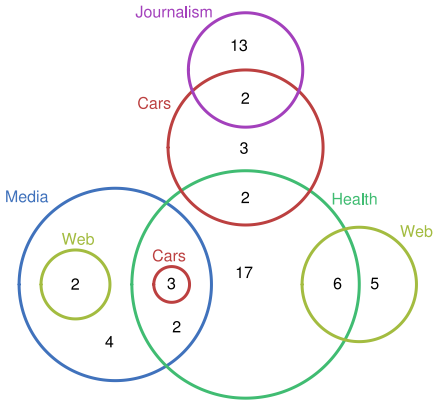
- LD-P&N


Cars
Design
Internet
Journalism
Programming

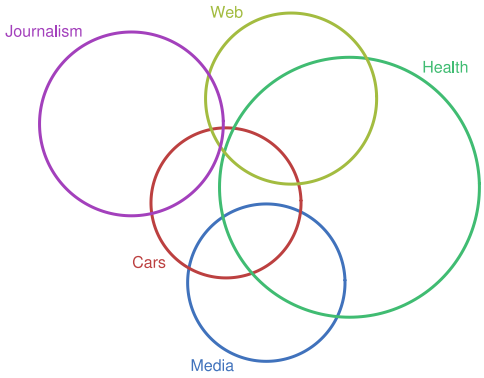
Question 8

- **Question:** Tick the check boxes where **more people** have exactly that combination of interests than **Web only**.
- **Check boxes to be ticked:** Cars, Health and Media, Media
- **Task Type:** Intersection comparison - Less than.
- **SNAP Data Set Used:** 14528221

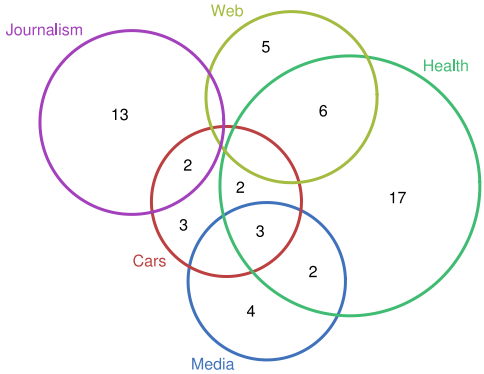
- ED-N



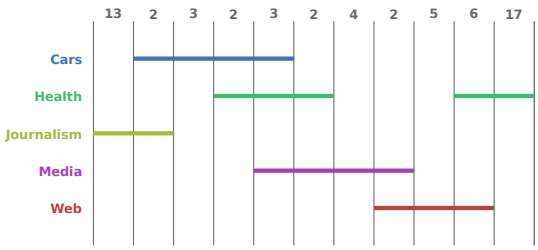
- ED-P



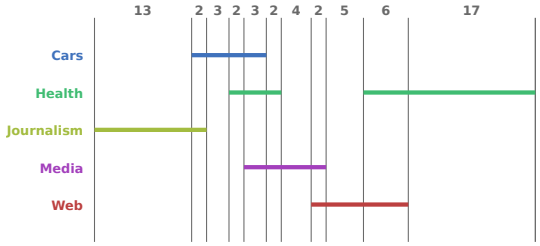
- ED-P&N



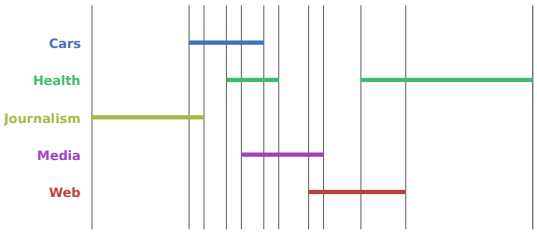
- LD-N



- LD-P

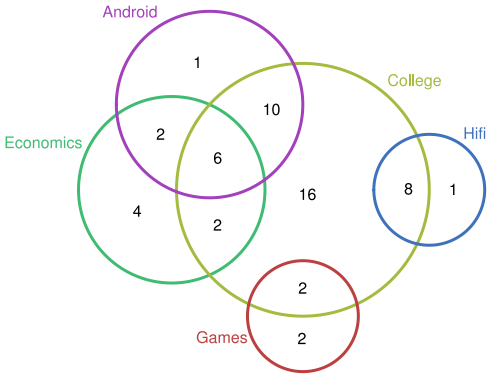

13
2 3 2 3 2 4 2 5 6 17
Cars
Health
Journalism
Media
Web

- LD-P&N

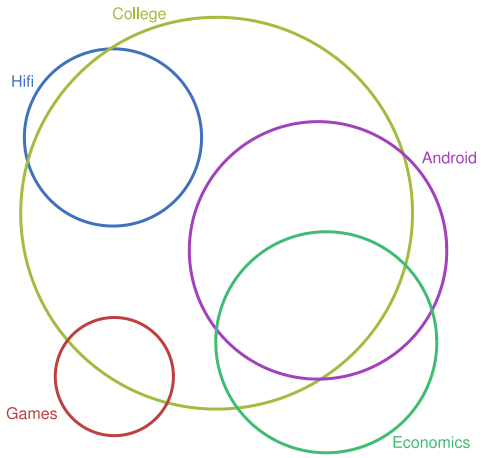

Cars
Health
Journalism
Media
Web

Question 9

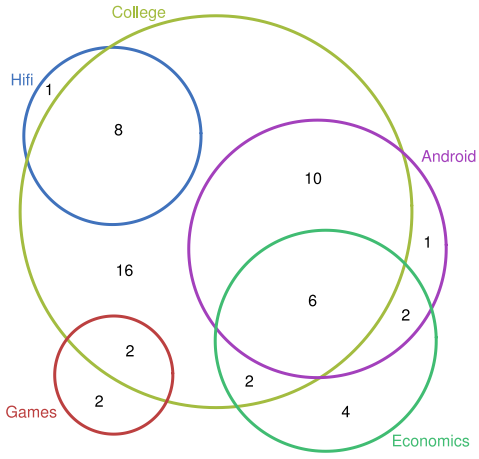
- **Question:** Tick the check boxes where the total number of people interested in that topic is **greater than** the total number of people interested in **Games**.
- **Check boxes to be ticked:** Android, College, Economics, Hifi
- **Task Type:** Set comparison - More than.
- **SNAP Data Set Used:** 17561785
- ED-N



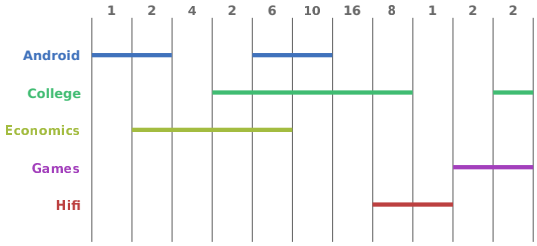
- ED-P



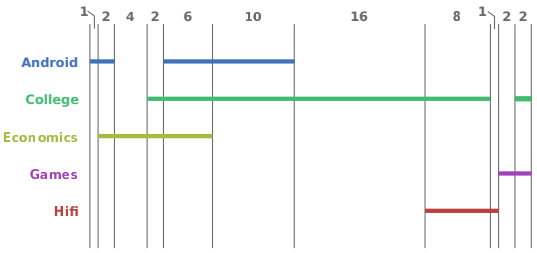
- ED-P&N



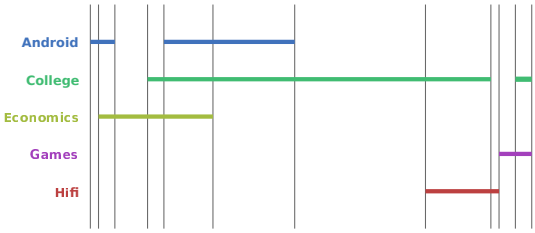
- LD-N


1 2 4 2 6 10 16 8 1 2 2
Android
College
Economics
Games
Hifi

- LD-P


1 2 4 2 6 10 16 8 1 2 2
Android
College
Economics
Games
Hifi

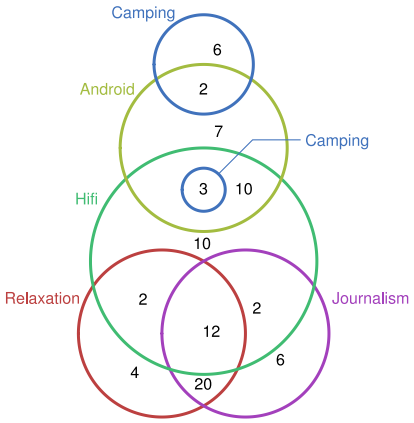
- LD-P&N


Android
College
Economics
Games
Hifi

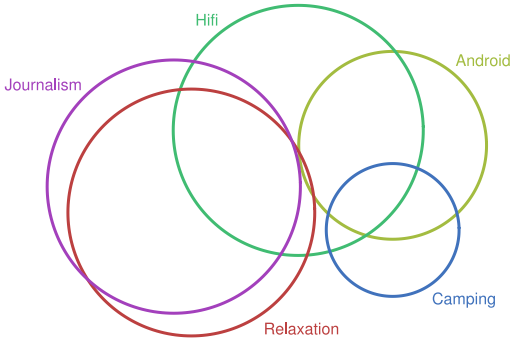
Question 10

- **Question:** Tick the check boxes where the total number of people interested in that topic is **less than** the total number of people interested in **Camping**.
- **Check boxes to be ticked:** None of the above
- **Task Type:** Set comparison - Less than.
- **SNAP Data Set Used:** 105150583

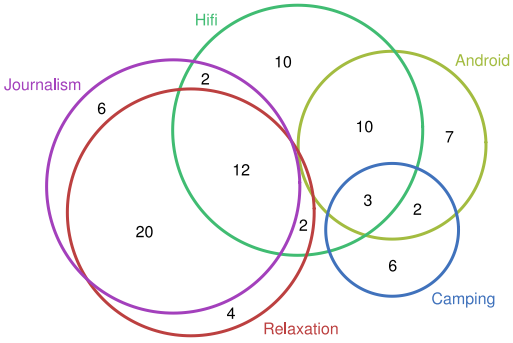
- ED-N



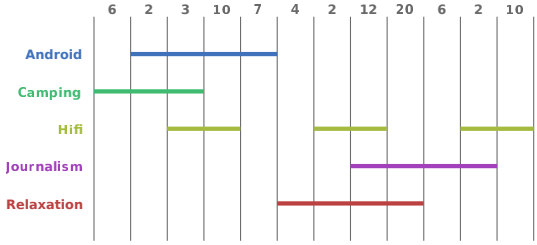
- ED-P



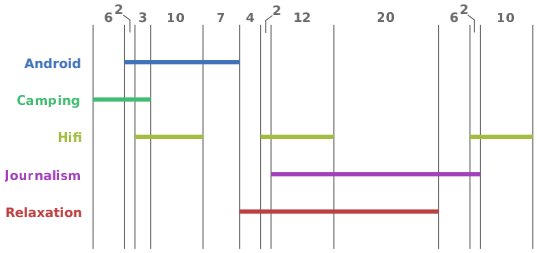
- ED-P&N



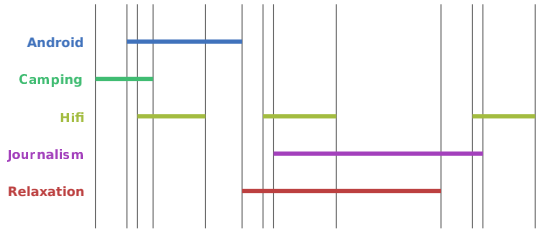
- LD-N



- LD-P


6
2
3
10
7
4
2
12
20
6
2
10
Android
Camping
Hifi
Journalism
Relaxation

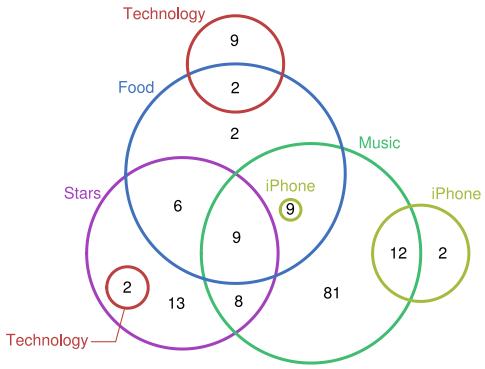
- LD-P&N


Android
Camping
Hifi
Journalism
Relaxation

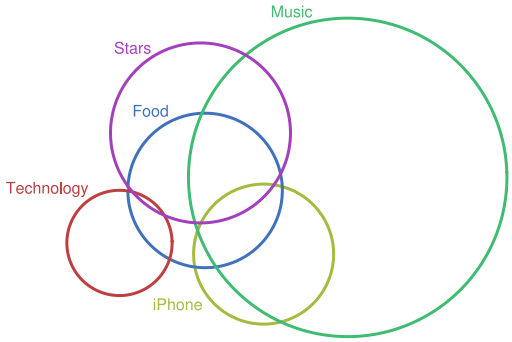
Question 11

- **Question:** Tick the check boxes where **more people** have exactly that combination of interests than **Technology only**.
- **Check boxes to be ticked:** None of the above
- **Task Type:** Intersection comparison - More than.
- **SNAP Data Set Used:** 18534908

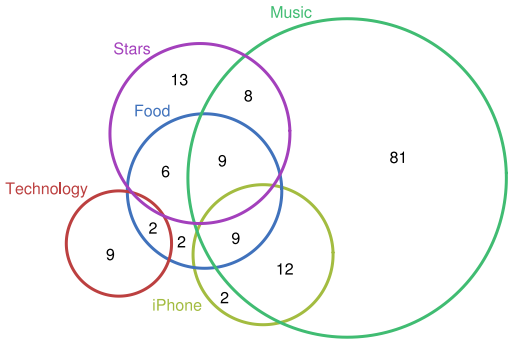
- ED-N



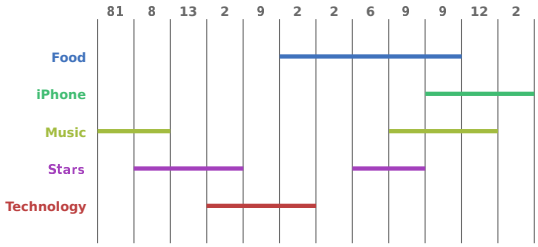
- ED-P



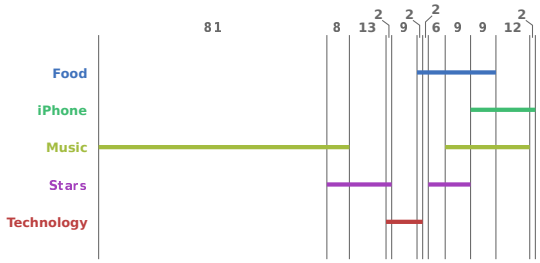
- ED-P&N



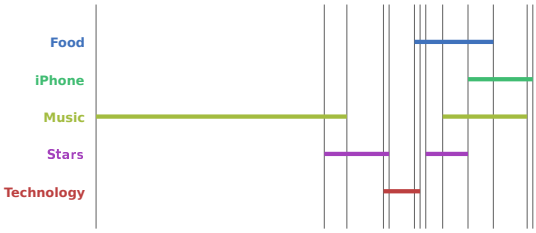
- LD-N



- LD-P


81
8
13
2
9
2
2
6
9
9
12
2
Food
iPhone
Music
Stars
Technology

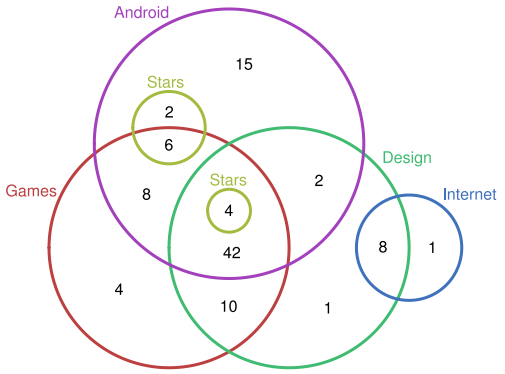
- LD-P&N


Food
iPhone
Music
Stars
Technology

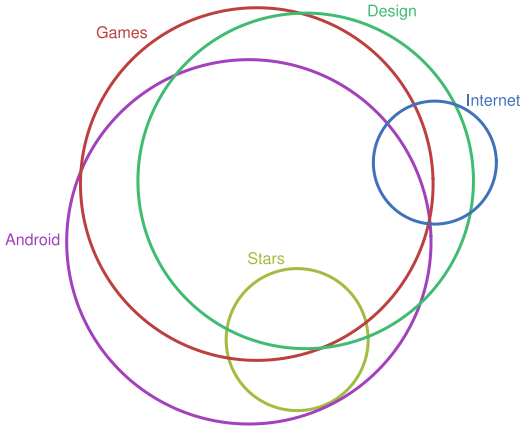
Question 12

- **Question:** Tick the check boxes where **more people** have exactly that combination of interests than **Android and Games only**.
- **Check boxes to be ticked:** Android and Design, Android and Stars
- **Task Type:** Intersection comparison - Less than.
- **SNAP Data Set Used:** 59588845

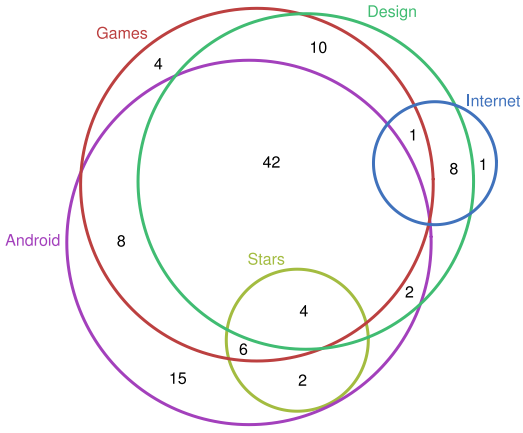
- ED-N



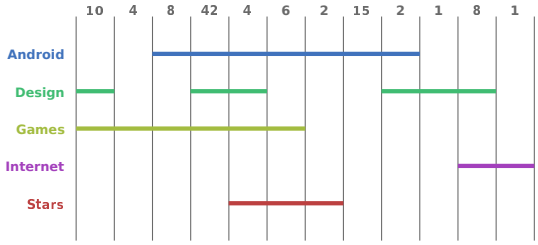
- ED-P



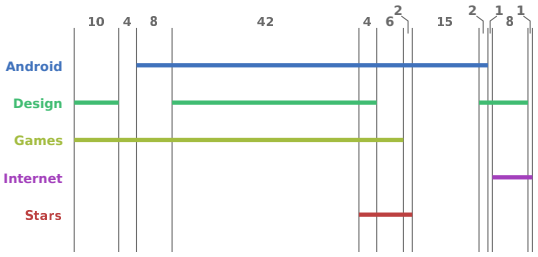
- ED-P&N



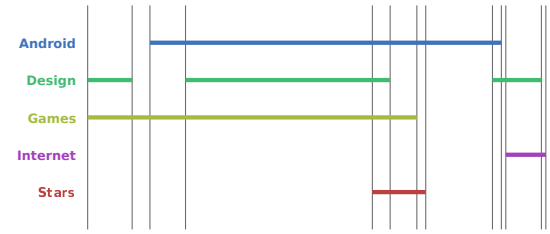
- LD-N


10 4 8 42 4 6 2 15 2 1 8 1
Android
Design
Games
Internet
Stars

- LD-P


10 4 8 42 4 6 2 15 2 1 8 1
Android
Design
Games
Internet
Stars

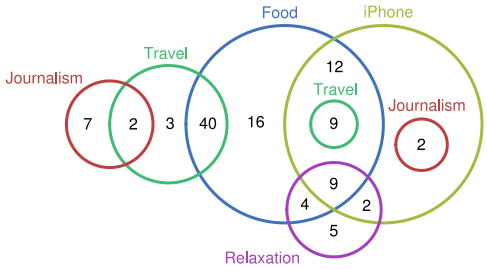
- LD-P&N


Android
Design
Games
Internet
Stars

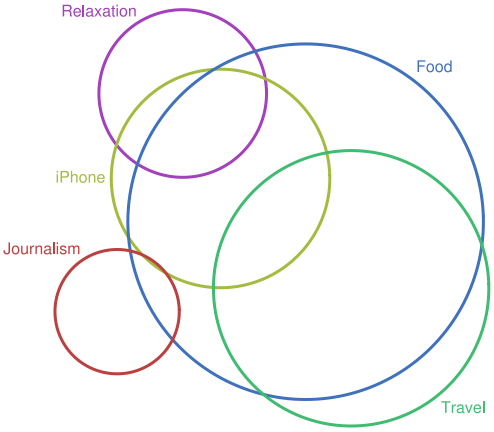
Question 13

- **Question:** Tick the check boxes where the total number of people interested in that topic is **greater than** the total number of people interested in **Relaxation**.
- **Check boxes to be ticked:** Food, iPhone, Travel
- **Task Type:** Set comparison - More than.
- **SNAP Data Set Used:** 64441390

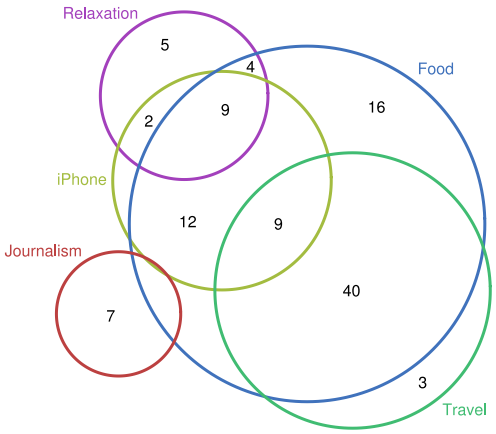
- ED-N



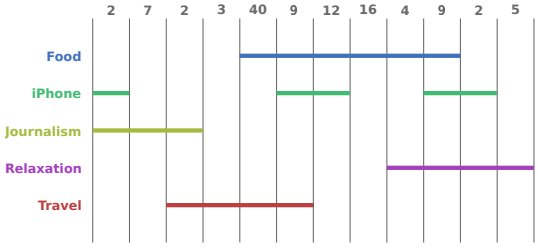
- ED-P



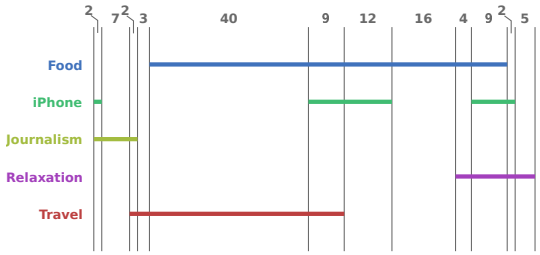
- ED-P&N



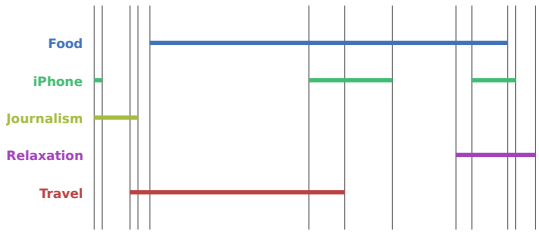
- LD-N



- LD-P


2
2
7
3
40
9
12
16
4
9
2
5
Food
iPhone
Journalism
Relaxation
Travel

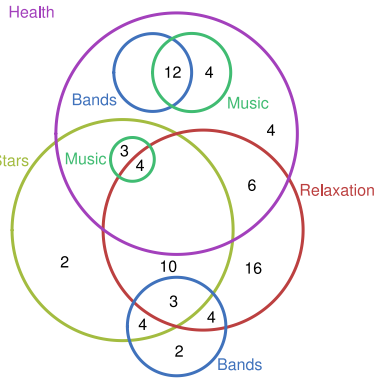
- LD-P&N


Food
iPhone
Journalism
Relaxation
Travel

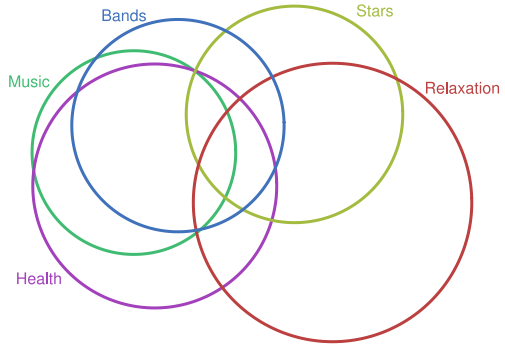
Question 14

- **Question:** Tick the check boxes where the total number of people interested in that topic is **less than** the total number of people interested in **Stars**.
- **Check boxes to be ticked:** Music
- **Task Type:** Set comparison - Less than.
- **SNAP Data Set Used:** 190696559

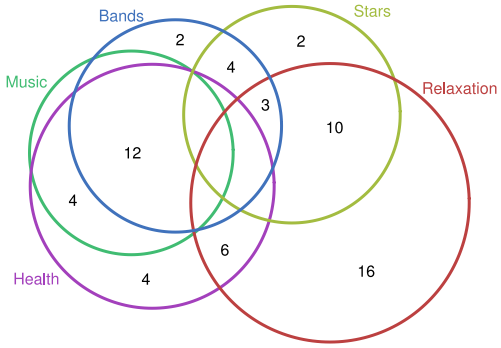
- ED-N



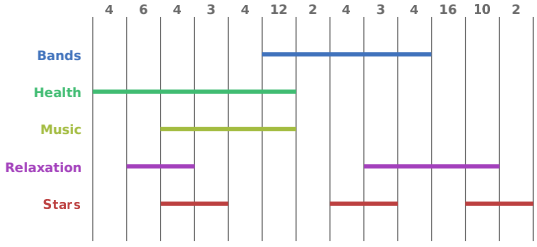
- ED-P



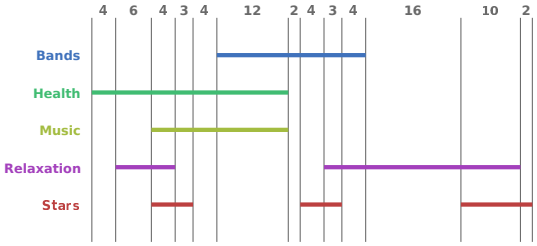
- ED-P&N



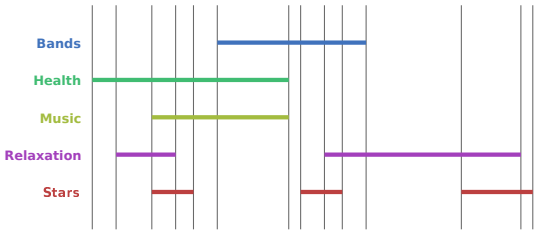
- LD-N



- LD-P


4 6 4 3 4 12 2 4 3 4 16 10 2
Bands
Health
Music
Relaxation
Stars

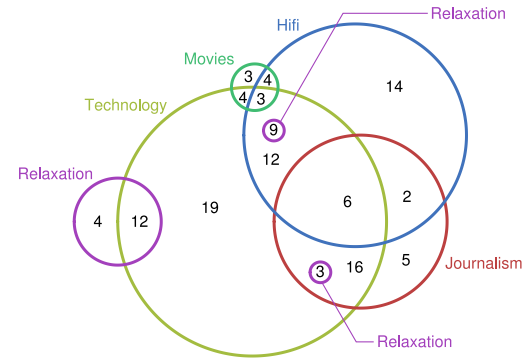
- LD-P&N


Bands
Health
Music
Relaxation
Stars

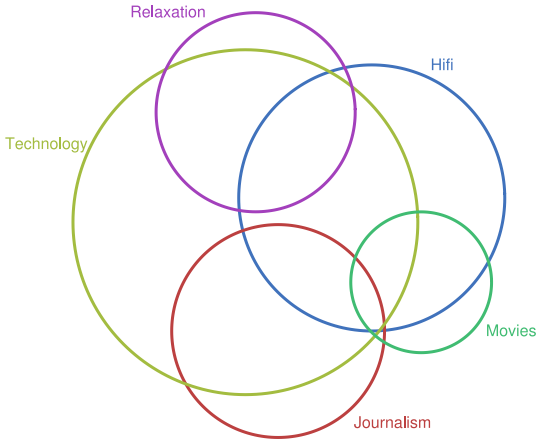
Question 15

- **Question:** Tick the check boxes where **more people** have exactly that combination of interests than **Hifi, Movies and Technology only**.
- **Check boxes to be ticked:** Hifi, Journalism and Technology, Hifi and Journalism and Technology, Hifi and Relaxation and Technology
- **Task Type:** Intersection comparison - More than.
- **SNAP Data Set Used:** 22863638

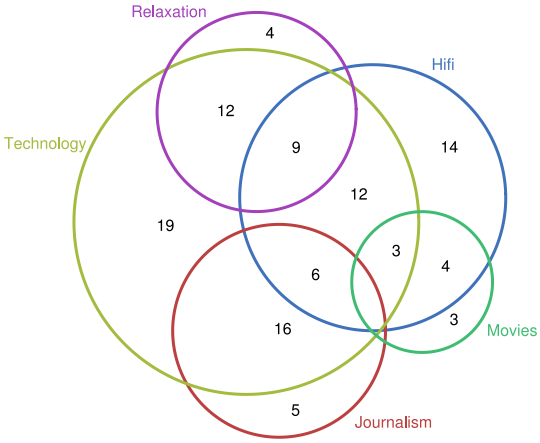
- ED-N



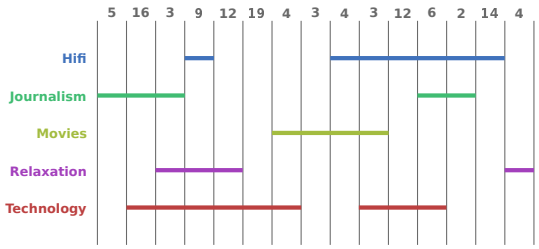
- ED-P



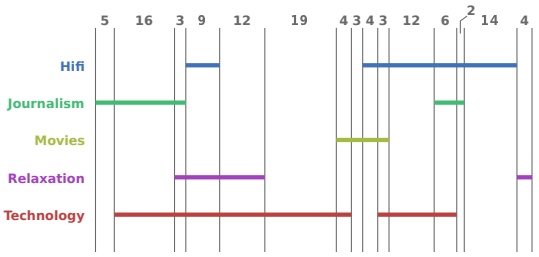
- ED-P&N



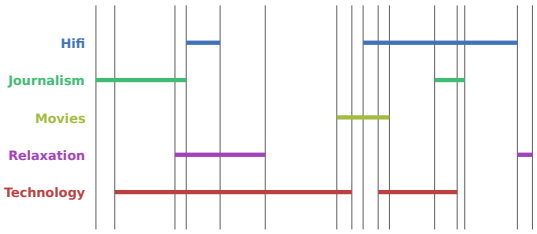
- LD-N


5 16 3 9 12 19 4 3 4 3 12 6 2 14 4
Hifi
Journalism
Movies
Relaxation
Technology

- LD-P


5 16 3 9 12 19 4 3 4 3 12 6 2 14 4
Hifi
Journalism
Movies
Relaxation
Technology

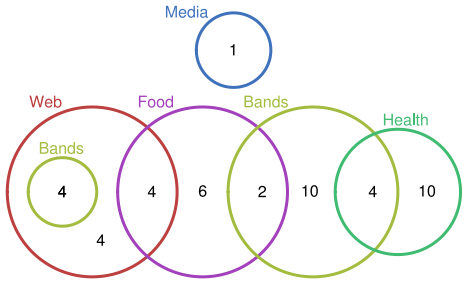
- LD-P&N


Hifi
Journalism
Movies
Relaxation
Technology

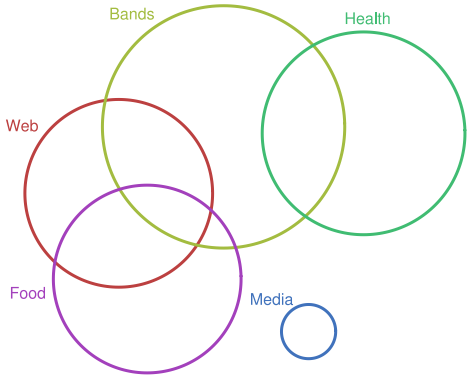
Question 16

- **Question:** Tick the check boxes where **more people** have exactly that combination of interests than **Bands and Web only**.
- **Check boxes to be ticked:** Bands and Food
- **Task Type:** Intersection comparison - Less than.
- **SNAP Data Set Used:** 15864197

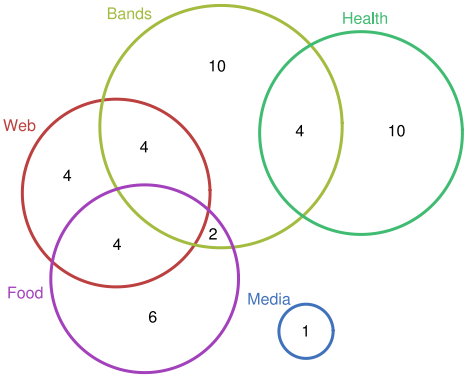
- ED-N



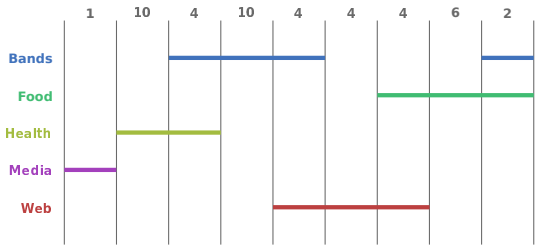
- ED-P



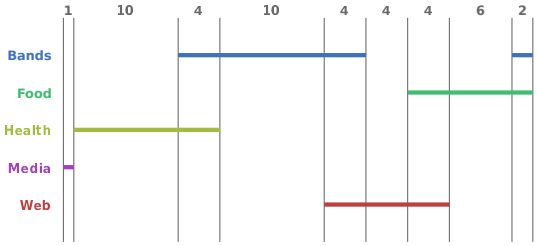
- ED-P&N



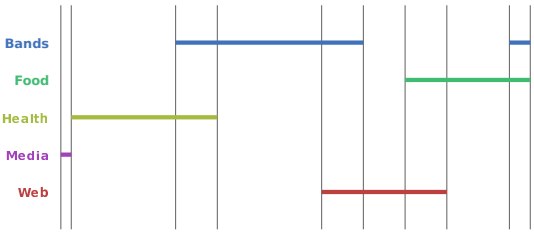
- LD-N



- LD-P

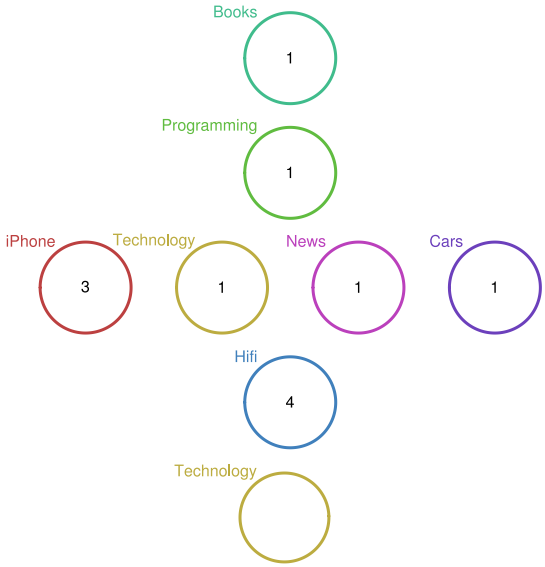

1
10
4
10
4
4
4
6
2
Bands
Food
Health
Media
Web

- LD-P&N

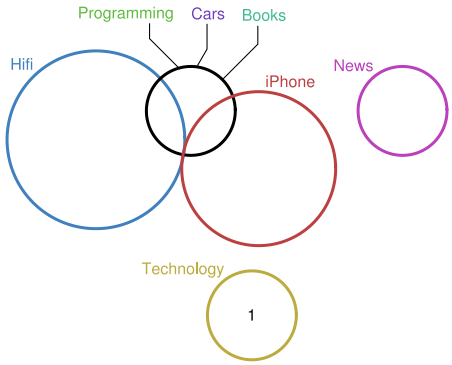

Bands
Food
Health
Media
Web

Question 17

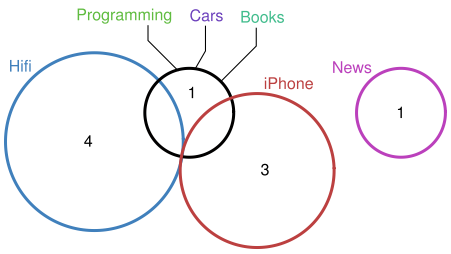
- **Question:** Tick the check boxes where the total number of people interested in that topic is **greater than** the total number of people interested in **Books**.
- **Check boxes to be ticked:** Hifi, iPhone
- **Task Type:** Set comparison - More than.
- **SNAP Data Set Used:** 1046661
- ED-N



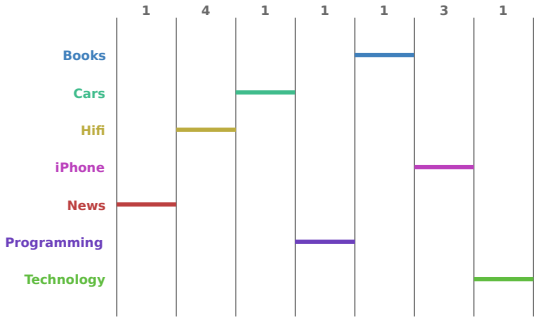
- ED-P



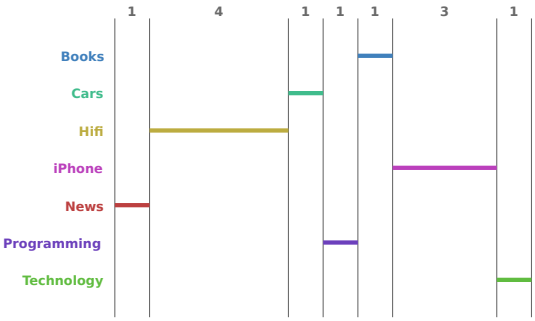
- ED-P&N



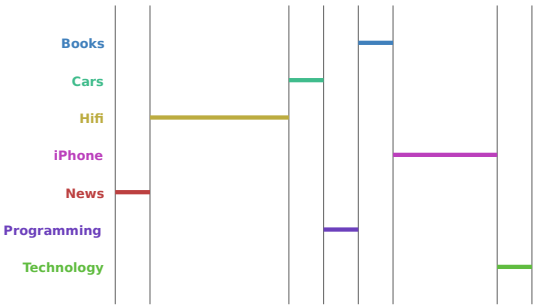
- LD-N


1
4
1
1
1
3
1
Books
Cars
Hifi
iPhone
News
Programming
Technology

- LD-P

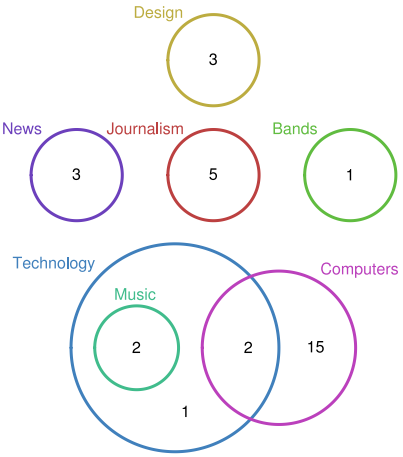

1
4
1
1
1
3
1
Books
Cars
Hifi
iPhone
News
Programming
Technology

- LD-P&N

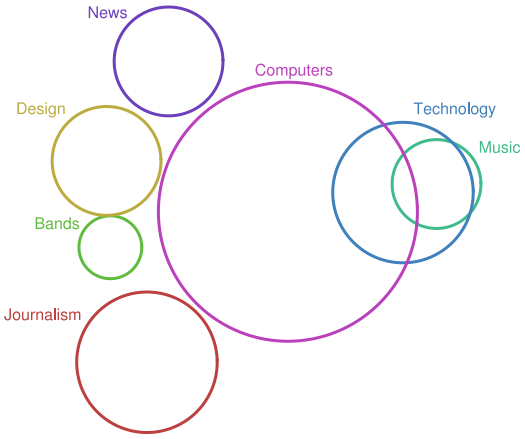

Books
Cars
Hifi
iPhone
News
Programming
Technology

Question 18

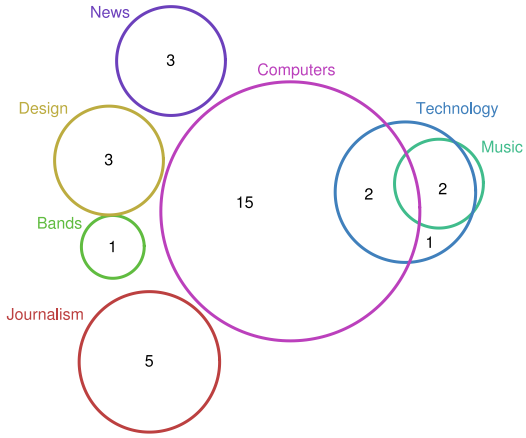
- **Question:** Tick the check boxes where the total number of people interested in that topic is **less than** the total number of people interested in **Journalism**.
- **Check boxes to be ticked:** Bands, Design, Music, News
- **Task Type:** Set comparison - Less than.
- **SNAP Data Set Used:** 124296976
- ED-N



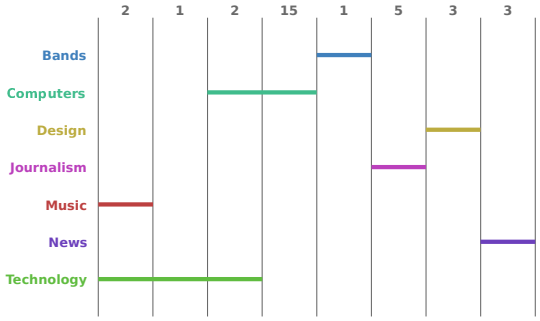
- ED-P



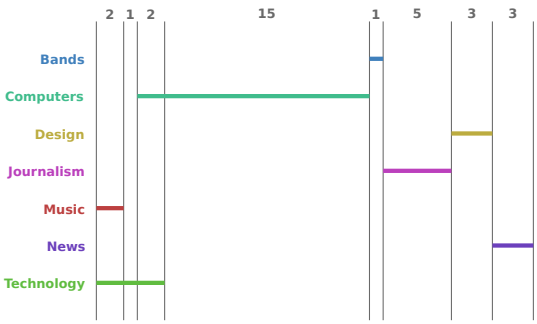
- ED-P&N



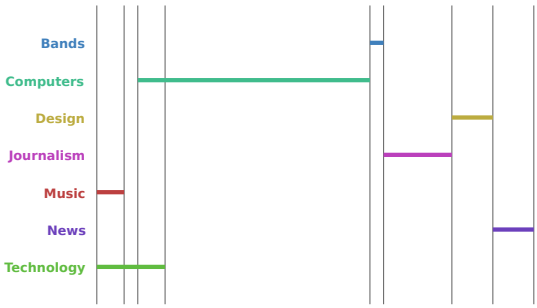
- LD-N


2
1
2
15
1
5
3
3
Bands
Computers
Design
Journalism
Music
News
Technology

- LD-P

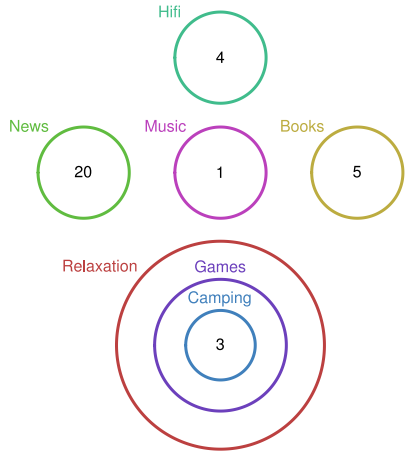

2
1
2
15
1
5
3
3
Bands
Computers
Design
Journalism
Music
News
Technology

- LD-P&N

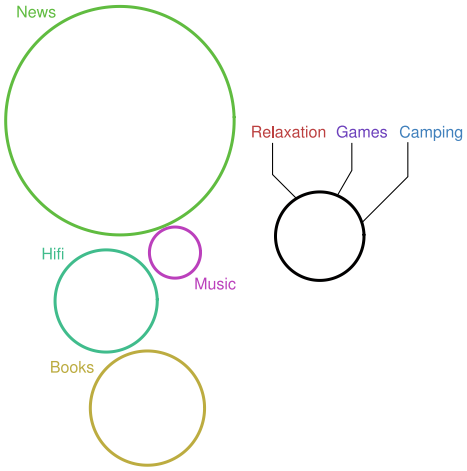

Bands
Computers
Design
Journalism
Music
News
Technology

Question 19

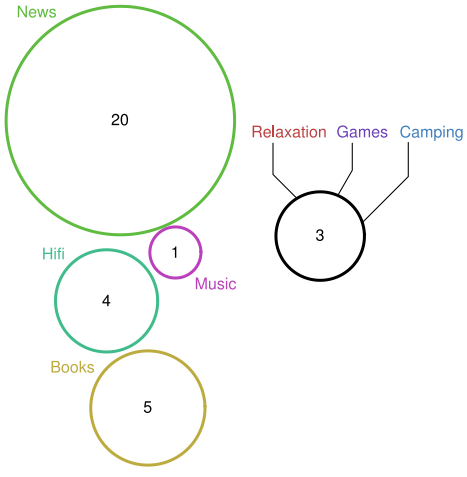
- **Question:** Tick the check boxes where **more people** have exactly that combination of interests than **Camping, Games and Relaxation only**.
- **Check boxes to be ticked:** News, Hifi, Books
- **Task Type:** Intersection comparison - More than.
- **SNAP Data Set Used:** 13747362
- ED-N



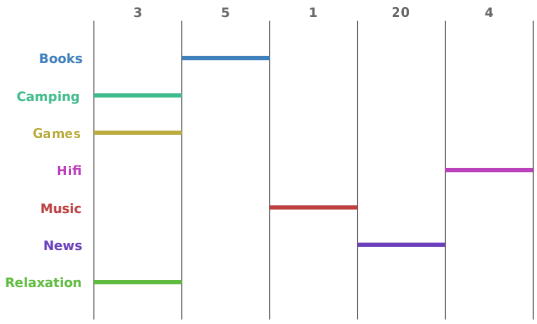
- ED-P



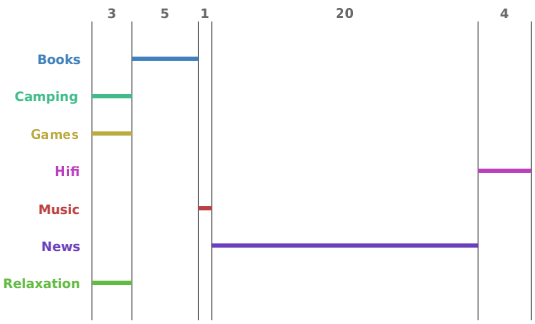
- ED-P&N



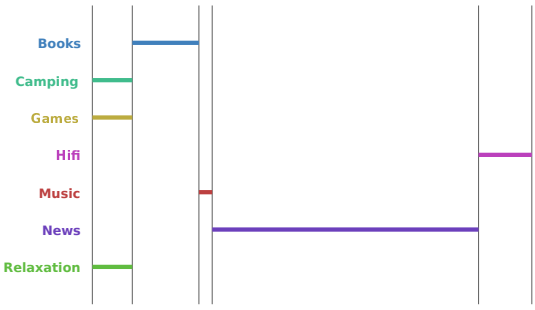
- LD-N


3
5
1
20
4
Books
Camping
Games
Hifi
Music
News
Relaxation

- LD-P

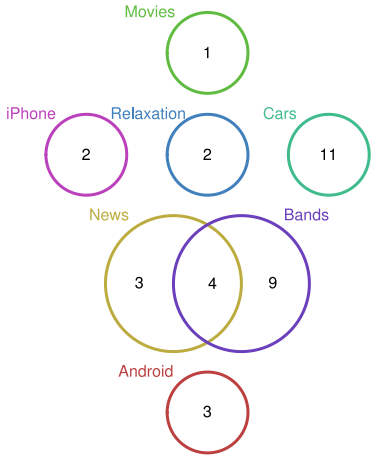

3
5
1
20
4
Books
Camping
Games
Hifi
Music
News
Relaxation

- LD-P&N

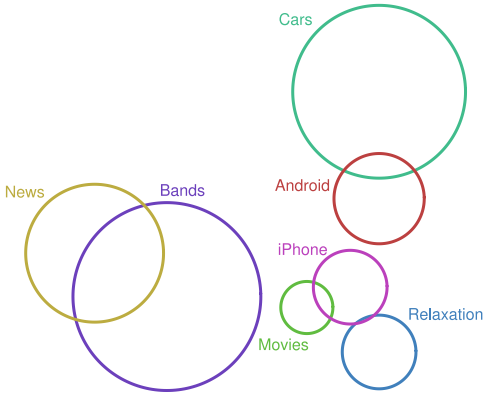

Books
Camping
Games
Hifi
Music
News
Relaxation

Question 20

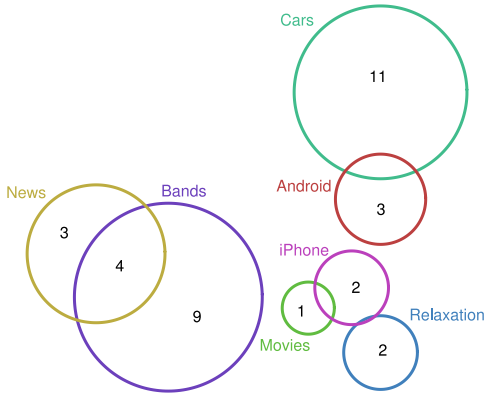
- **Question:** Tick the check boxes where **more people** have exactly that combination of interests than **iPhone only**.
- **Check boxes to be ticked:** Movies
- **Task Type:** Intersection comparison - Less than.
- **SNAP Data Set Used:** 23790454
- ED-N



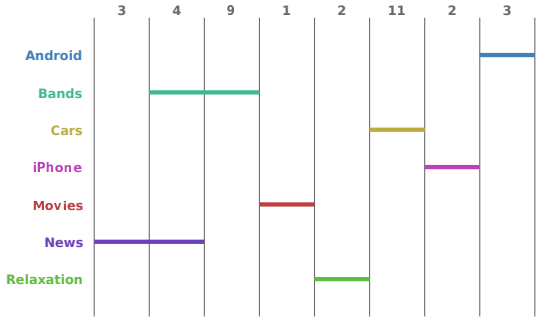
- ED-P



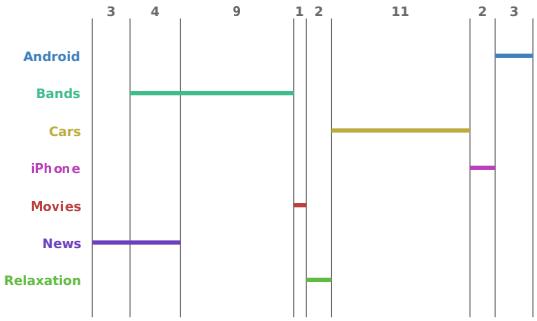
- ED-P&N



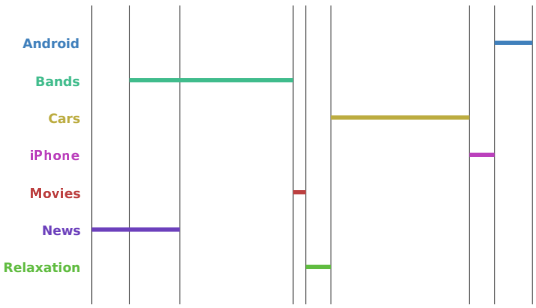
- LD-N


3
4
9
1
2
11
2
3
Android
Bands
Cars
iPhone
Movies
News
Relaxation

- LD-P


3
4
9
1
2
11
2
3
Android
Bands
Cars
iPhone
Movies
News
Relaxation

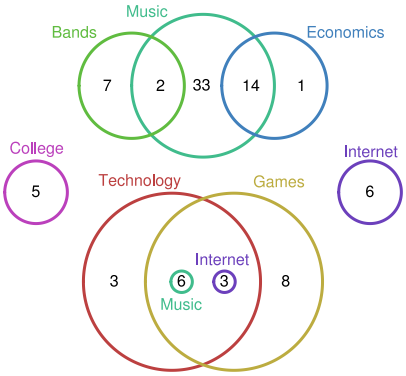
- LD-P&N


Android
Bands
Cars
iPhone
Movies
News
Relaxation

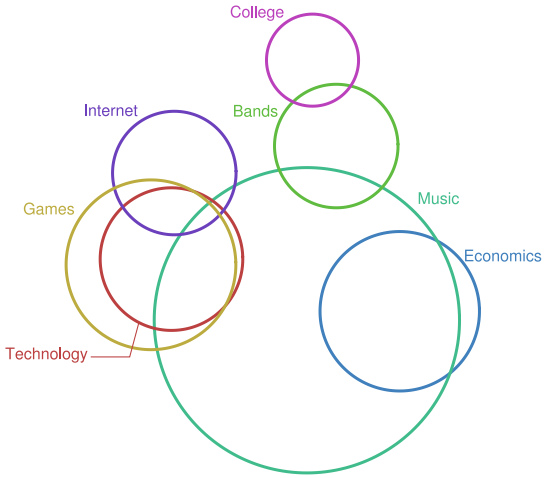
Question 21

- **Question:** Tick the check boxes where the total number of people interested in that topic is **greater than** the total number of people interested in **Bands**.
- **Check boxes to be ticked:** Games, Music
- **Task Type:** Set comparison - More than.
- **SNAP Data Set Used:** 13274152

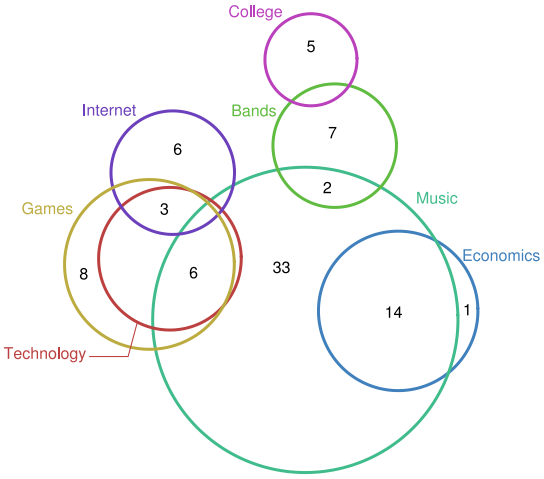
- ED-N



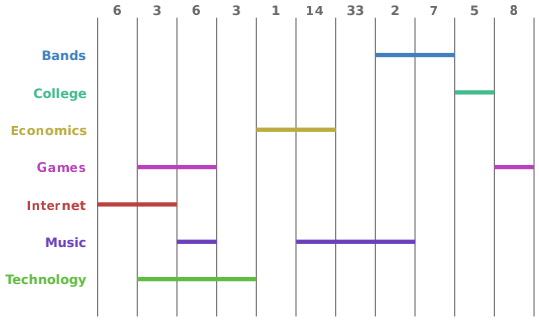
- ED-P



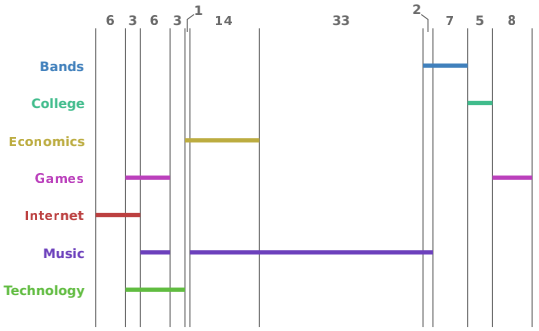
- ED-P&N



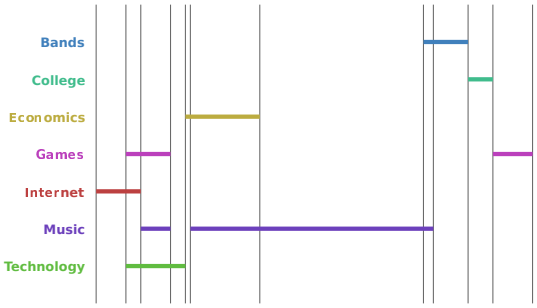
- LD-N


6 3 6 3 1 14 33 2 7 5 8
Bands
College
Economics
Games
Internet
Music
Technology

- LD-P

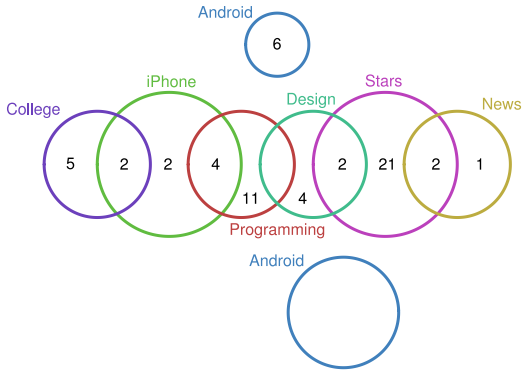

6 3 6 3 1 14 33 2 7 5 8
Bands
College
Economics
Games
Internet
Music
Technology

- LD-P&N

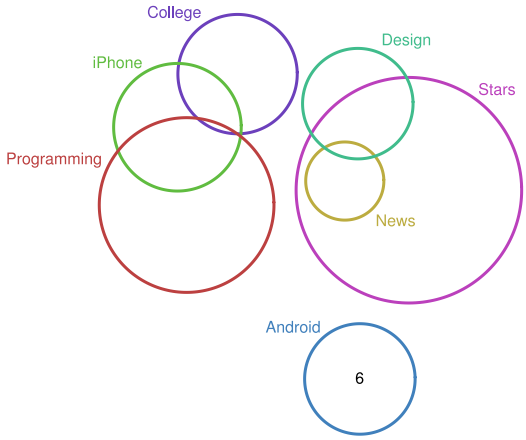

Bands
College
Economics
Games
Internet
Music
Technology

Question 22

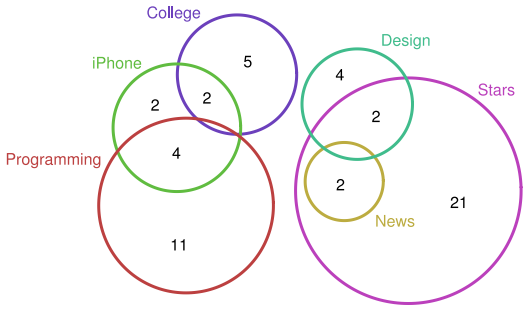
- **Question:** Tick the check boxes where the total number of people interested in that topic is **less than** the total number of people interested in **Design**.
- **Check boxes to be ticked:** News
- **Task Type:** Set comparison - Less than.
- **SNAP Data Set Used:** 16834201
- ED-N



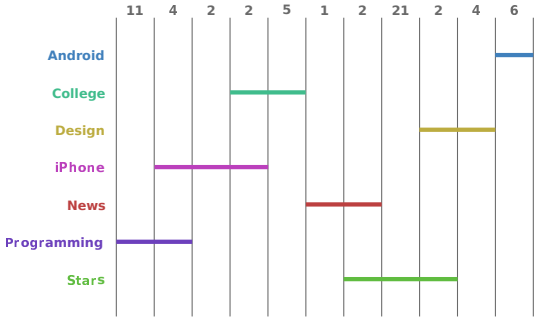
- ED-P



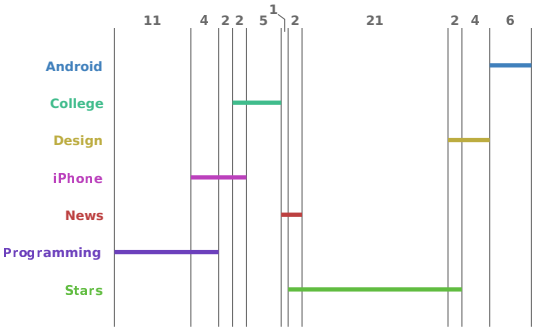
- ED-P&N



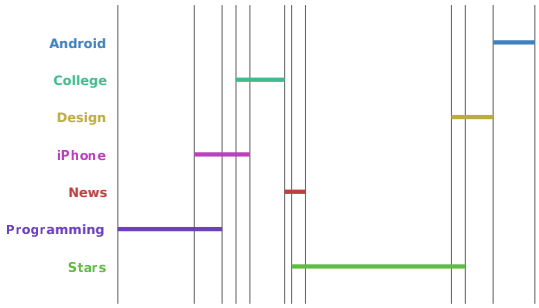
- LD-N


11 4 2 2 5 1 2 21 2 4 6
Android
College
Design
iPhone
News
Programming
Stars

- LD-P


11 4 2 2 5 1 2 21 2 4 6
Android
College
Design
iPhone
News
Programming
Stars

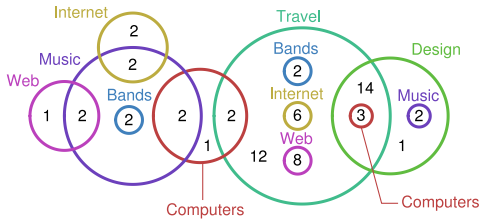
- LD-P&N


Android
College
Design
iPhone
News
Programming
Stars

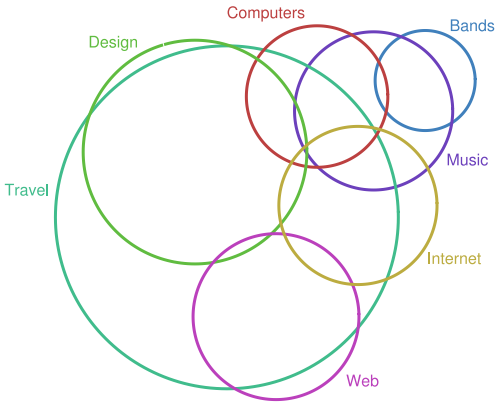
Question 23

- **Question:** Tick the check boxes where **more people** have exactly that combination of interests than **Computers, Design and Travel only**.
- **Check boxes to be ticked:** Internet and Travel
- **Task Type:** Intersection comparison - More than.
- **SNAP Data Set Used:** 29514951

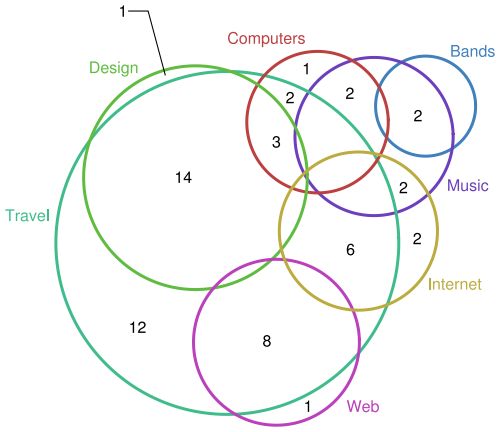
- ED-N



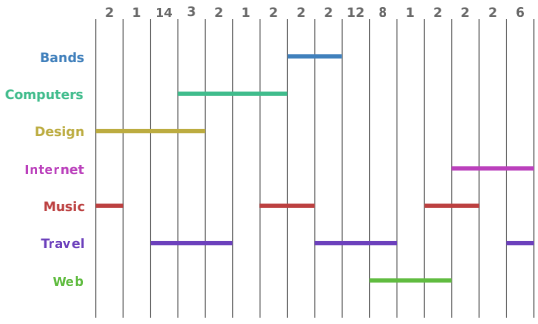
- ED-P



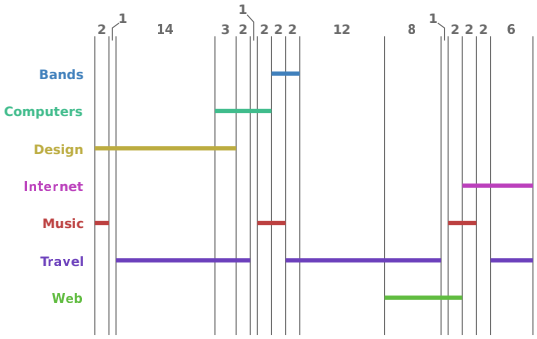
- ED-P&N



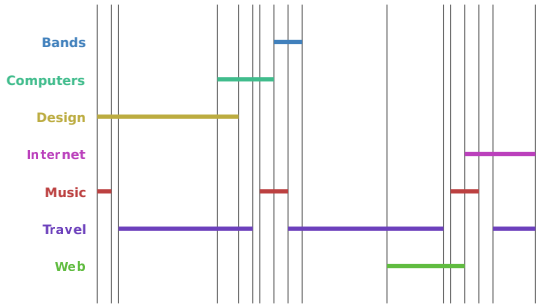
- LD-N



- LD-P

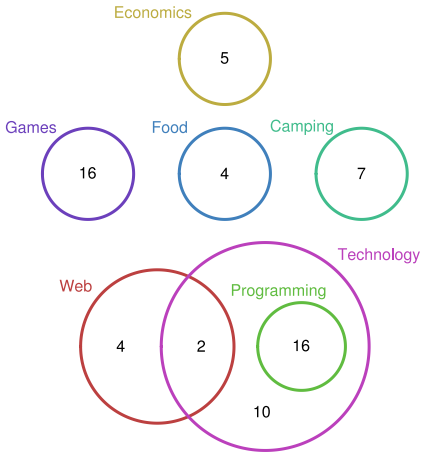

2 1 14 3 2 1 2 2 2 12 8 1 2 2 2 6
Bands
Computers
Design
Internet
Music
Travel
Web

- LD-P&N

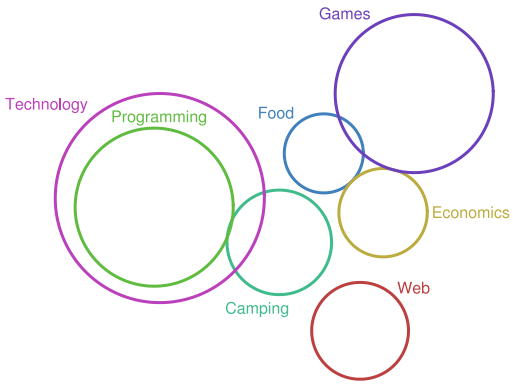

Bands
Computers
Design
Internet
Music
Travel
Web

Question 24

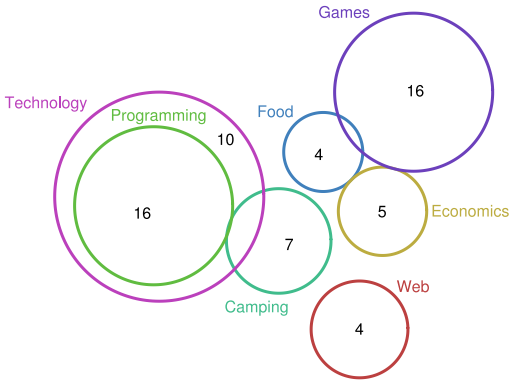
- **Question:** Tick the check boxes where **more people** have exactly that combination of interests than **Camping only**.
- **Check boxes to be ticked:** Camping, Food, Economics
- **Task Type:** Intersection comparison - Less than.
- **SNAP Data Set Used:** 17767841
- ED-N



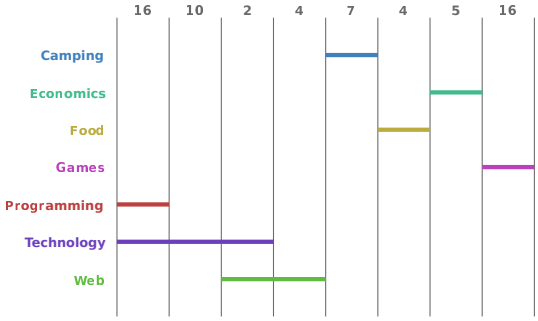
- ED-P



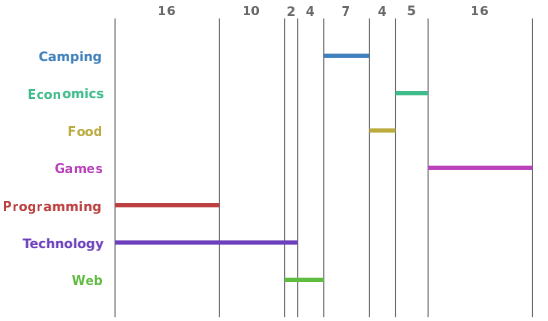
- ED-P&N



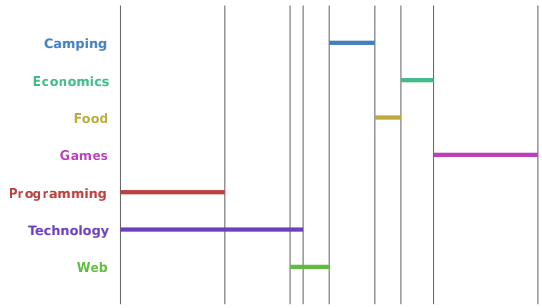
- LD-N


16
10
2
4
7
4
5
16
Camping
Economics
Food
Games
Programming
Technology
Web

- LD-P


16
10
2
4
7
4
5
16
Camping
Economics
Food
Games
Programming
Technology
Web

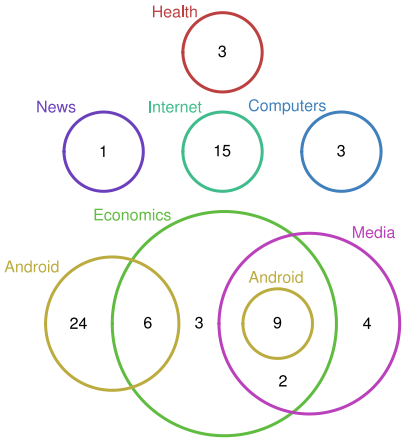
- LD-P&N


Camping
Economics
Food
Games
Programming
Technology
Web

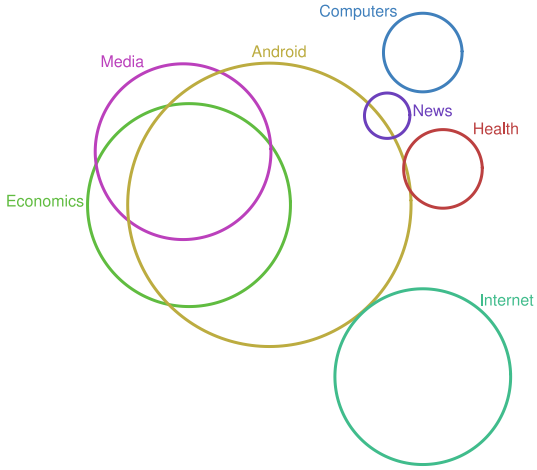
Question 25

- **Question:** Tick the check boxes where the total number of people interested in that topic is **greater than** the total number of people interested in **Health**.
- **Check boxes to be ticked:** Economics, Internet, Media
- **Task Type:** Set comparison - More than.
- **SNAP Data Set Used:** 22121627

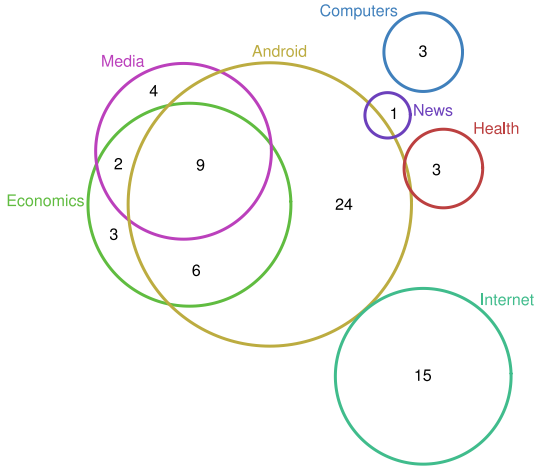
- ED-N



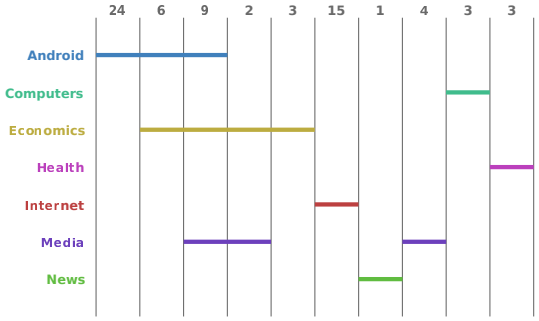
- ED-P



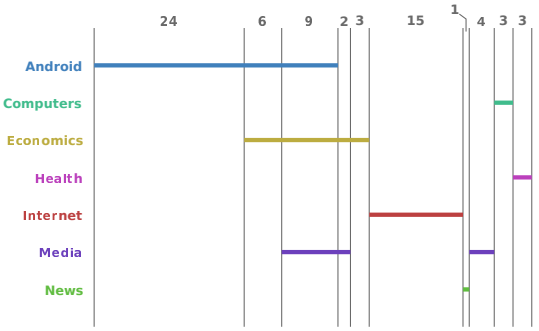
- ED-P&N



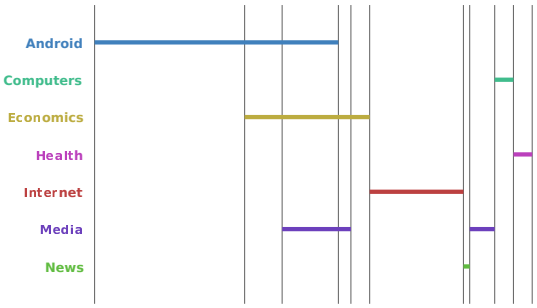
- LD-N


24 6 9 2 3 15 1 4 3 3
Android
Computers
Economics
Health
Internet
Media
News

- LD-P

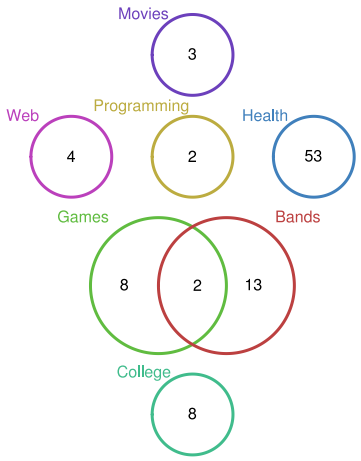

24 6 9 2 3 15 1 4 3 3
Android
Computers
Economics
Health
Internet
Media
News

- LD-P&N

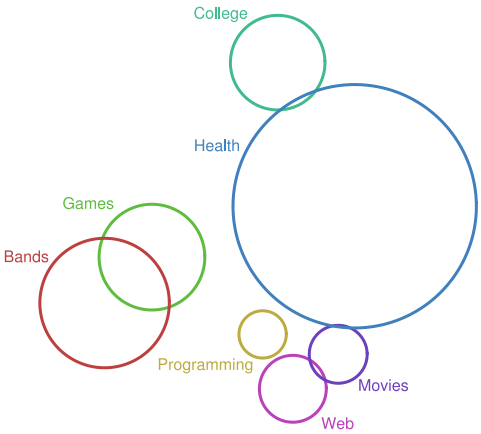

Android
Computers
Economics
Health
Internet
Media
News

Question 26

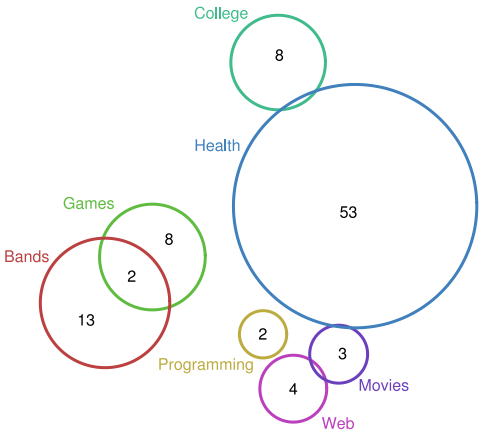
- **Question:** Tick the check boxes where the total number of people interested in that topic is **less than** the total number of people interested in **Health**.
- **Check boxes to be ticked:** Bands, Games, Movies, Programming
- **Task Type:** Set comparison - Less than.
- **SNAP Data Set Used:** 2029971
- ED-N



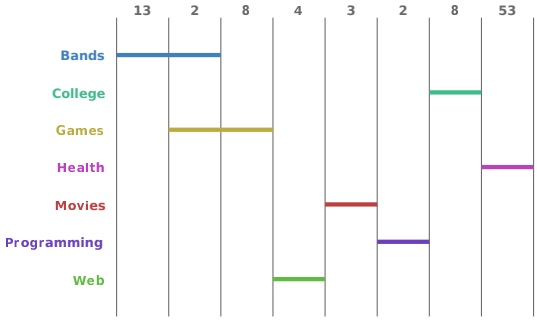
- ED-P



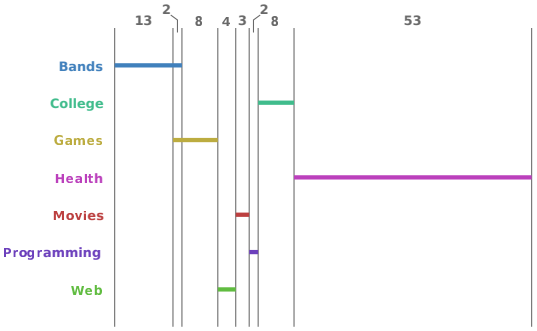
- ED-P&N



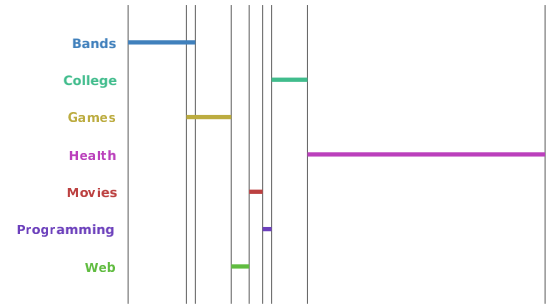
- LD-N


13
2
8
4
3
2
8
53
Bands
College
Games
Health
Movies
Programming
Web

- LD-P

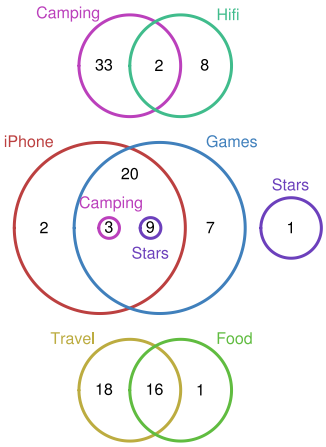

13
2
8
4
3
2
8
53
Bands
College
Games
Health
Movies
Programming
Web

- LD-P&N

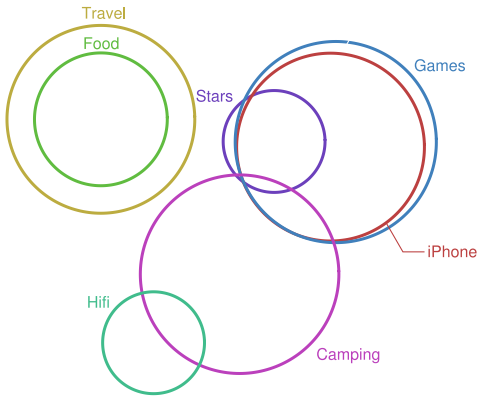

Bands
College
Games
Health
Movies
Programming
Web

Question 27

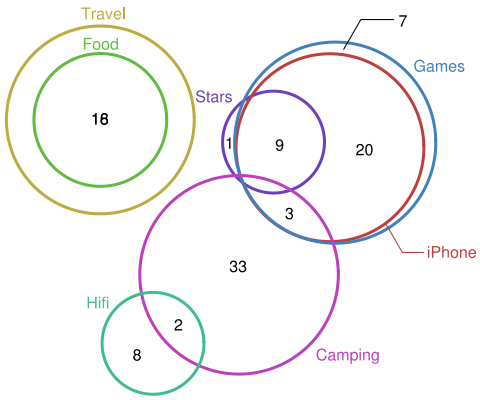
- **Question:** Tick the check boxes where **more people** have exactly that combination of interests than **Hifi only**.
- **Check boxes to be ticked:** Games and iPhone, Food and Travel
- **Task Type:** Intersection comparison - More than.
- **SNAP Data Set Used:** 629863
- ED-N



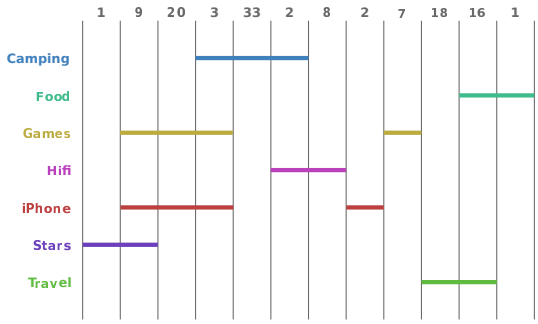
- ED-P



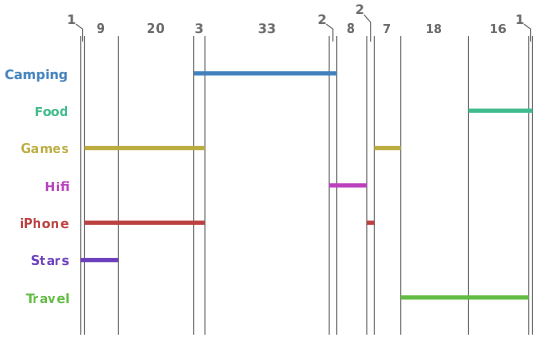
- ED-P&N



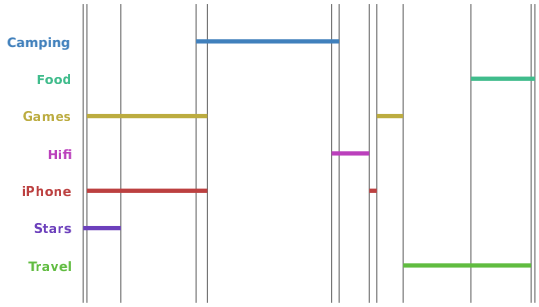
- LD-N


1 9 20 3 33 2 8 2 7 18 16 1
Camping
Food
Games
Hifi
iPhone
Stars
Travel

- LD-P


1 9 20 3 33 2 2 8 7 18 16 1
Camping
Food
Games
Hifi
iPhone
Stars
Travel

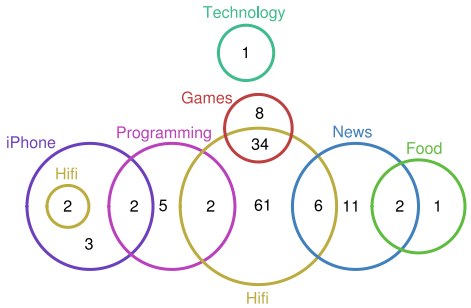
- LD-P&N


Camping
Food
Games
Hifi
iPhone
Stars
Travel

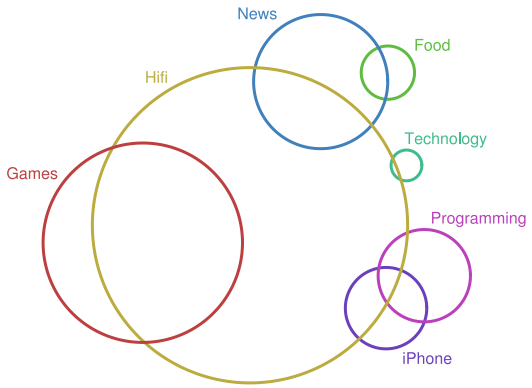
Question 28

- **Question:** Tick the check boxes where **more people** have exactly that combination of interests than **Food only**.
- **Check boxes to be ticked:** None of the above
- **Task Type:** Intersection comparison - Less than.
- **SNAP Data Set Used:** 30031265

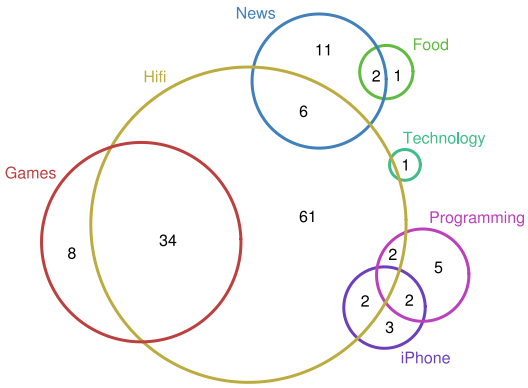
- ED-N



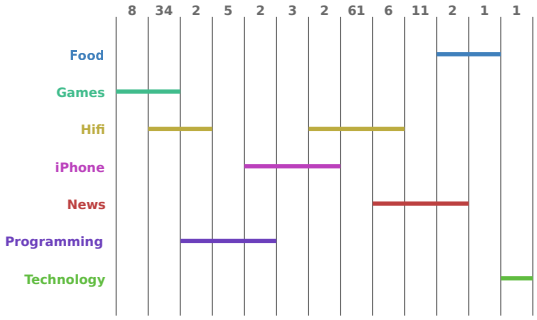
- ED-P



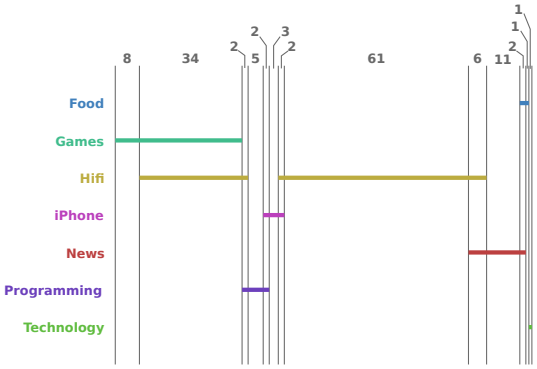
- ED-P&N



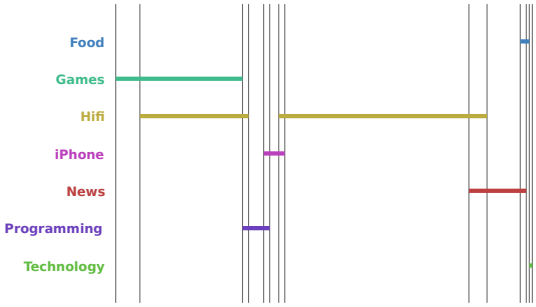
- LD-N



- LD-P


8
34
2
2
5
3
2
61
6
11
1
1
2
Food
Games
Hifi
iPhone
News
Programming
Technology

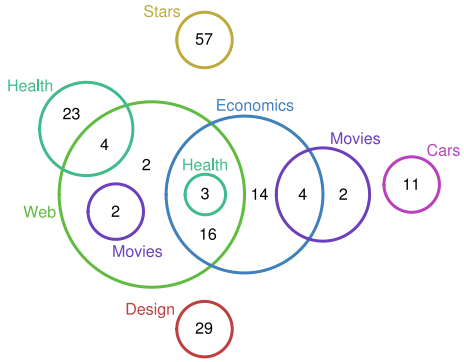
- LD-P&N


Food
Games
Hifi
iPhone
News
Programming
Technology

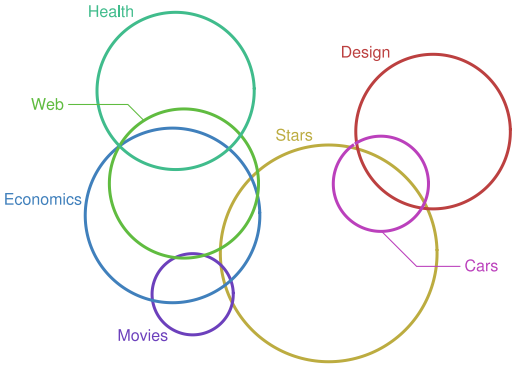
Question 29

- **Question:** Tick the check boxes where the total number of people interested in that topic is **greater than** the total number of people interested in **Web**.
- **Check boxes to be ticked:** Design, Health, Stars
- **Task Type:** Set comparison - More than.
- **SNAP Data Set Used:** 20436059

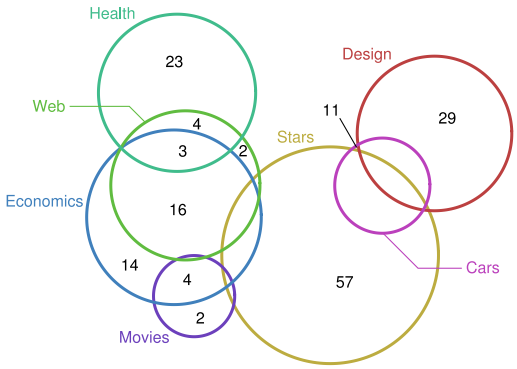
- ED-N



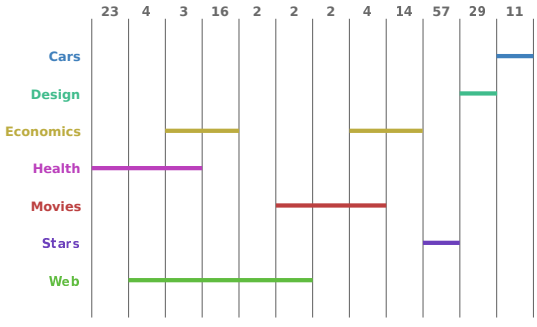
- ED-P



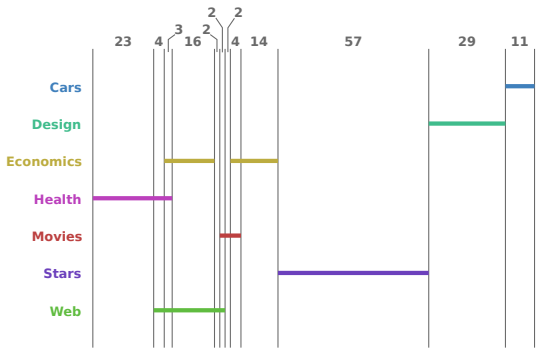
- ED-P&N



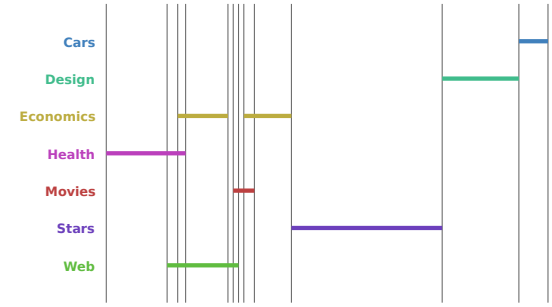
- LD-N



- LD-P


2
2
3
2
23
4
16
4
14
57
29
11
Cars
Design
Economics
Health
Movies
Stars
Web

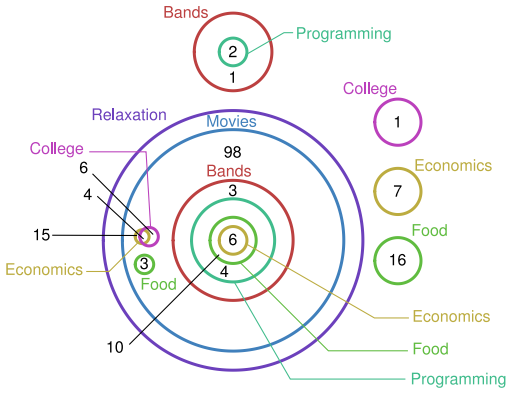
- LD-P&N


Cars
Design
Economics
Health
Movies
Stars
Web

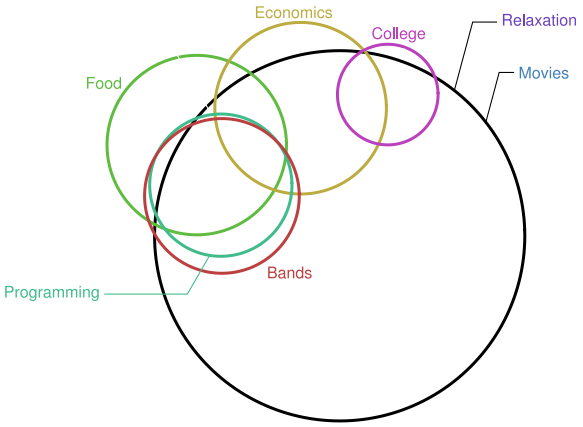
Question 30

- **Question:** Tick the check boxes where the total number of people interested in that topic is **less than** the total number of people interested in **Economics**.
- **Check boxes to be ticked:** College, Programming
- **Task Type:** Set comparison - Less than.
- **SNAP Data Set Used:** 30207757

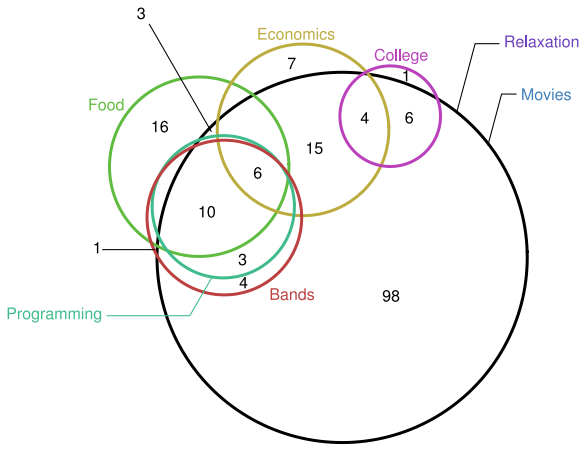
- ED-N



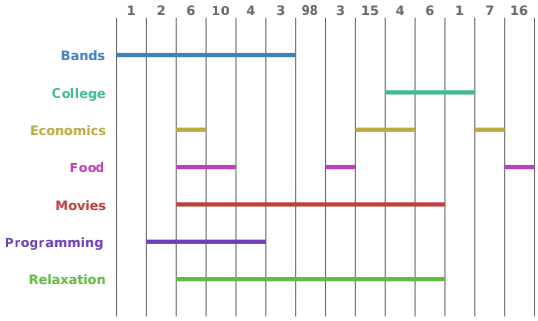
- ED-P



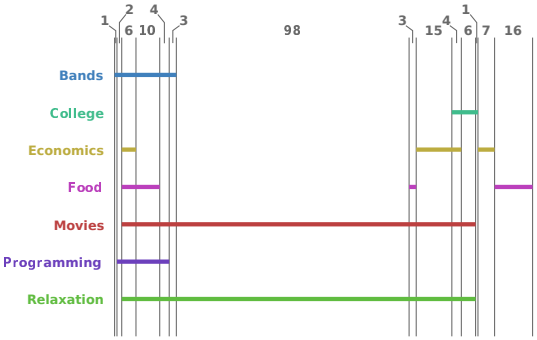
- ED-P&N



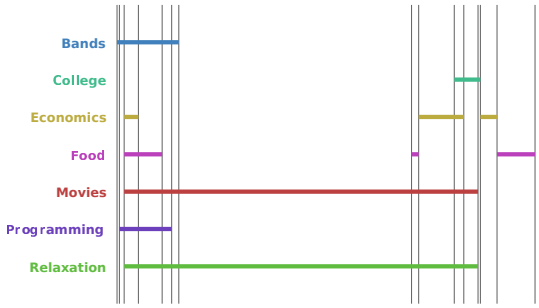
- LD-N


1 2 6 10 4 3 98 3 15 4 6 1 7 16
Bands
College
Economics
Food
Movies
Programming
Relaxation

- LD-P


1 2 4 3 98 3 4 1
6 10 15 6 7 16
Bands
College
Economics
Food
Movies
Programming
Relaxation

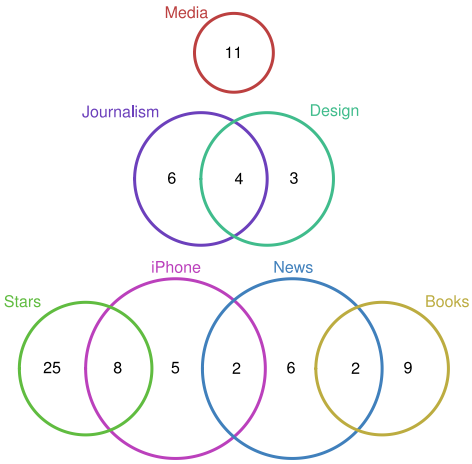
- LD-P&N


Bands
College
Economics
Food
Movies
Programming
Relaxation

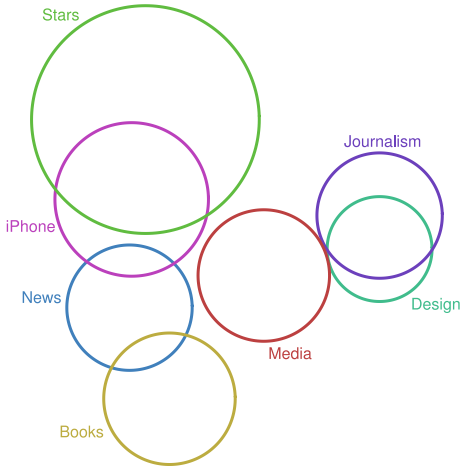
Question 31

- **Question:** Tick the check boxes where **more people** have exactly that combination of interests than **Stars only**.
- **Check boxes to be ticked:** None of the above
- **Task Type:** Intersection comparison - More than.
- **SNAP Data Set Used:** 14060856

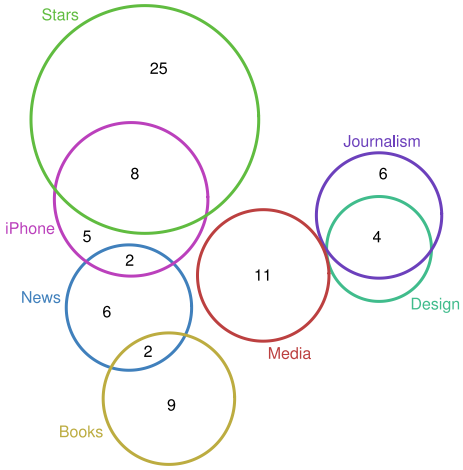
- ED-N



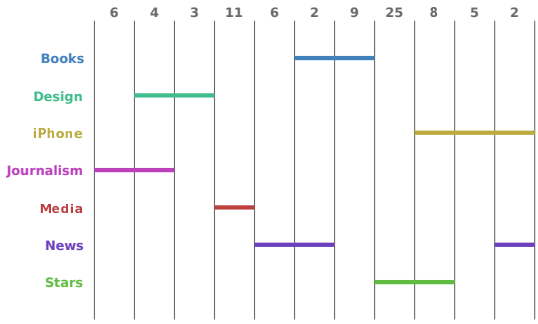
- ED-P



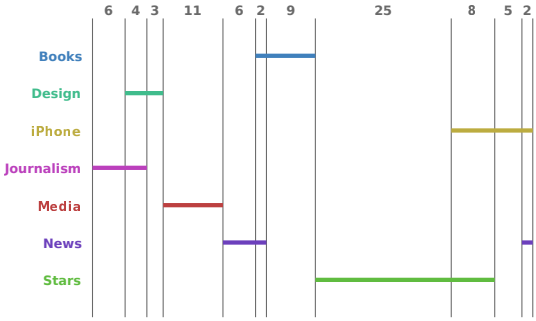
- ED-P&N



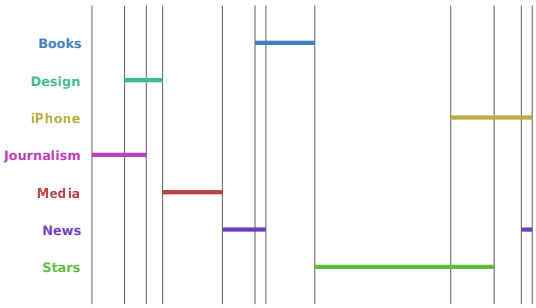
- LD-N


6 4 3 11 6 2 9 25 8 5 2
Books
Design
iPhone
Journalism
Media
News
Stars

- LD-P


6 4 3 11 6 2 9 25 8 5 2
Books
Design
iPhone
Journalism
Media
News
Stars

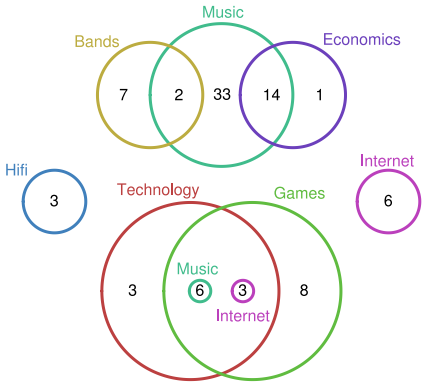
- LD-P&N


Books
Design
iPhone
Journalism
Media
News
Stars

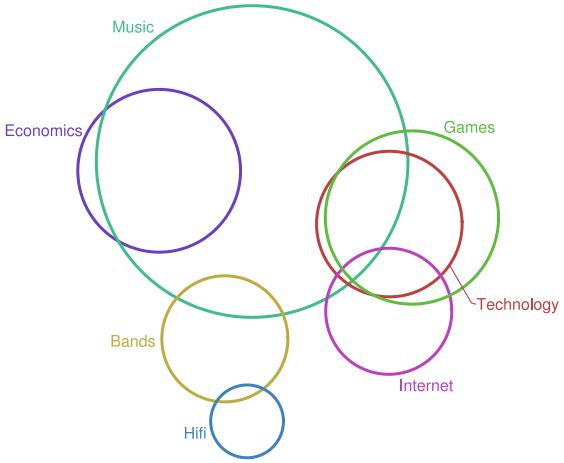
Question 32

- **Question:** Tick the check boxes where **more people** have exactly that combination of interests than **Games, Internet and Technology only**.
- **Check boxes to be ticked:** None of the above
- **Task Type:** Intersection comparison - Less than.
- **SNAP Data Set Used:** 13274152

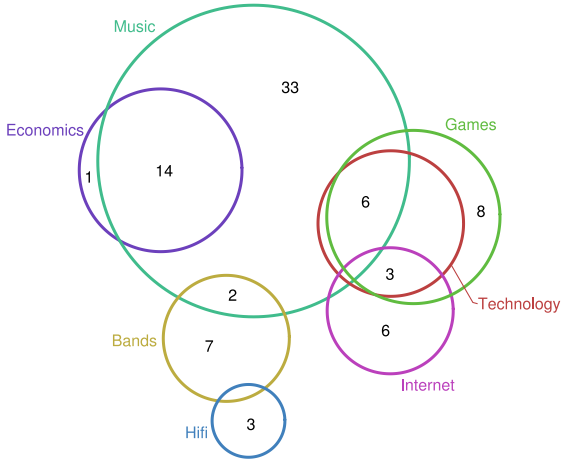
- ED-N



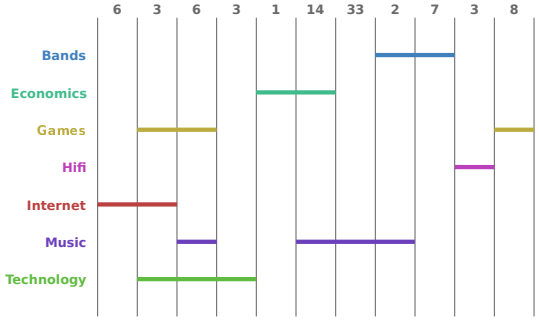
- ED-P



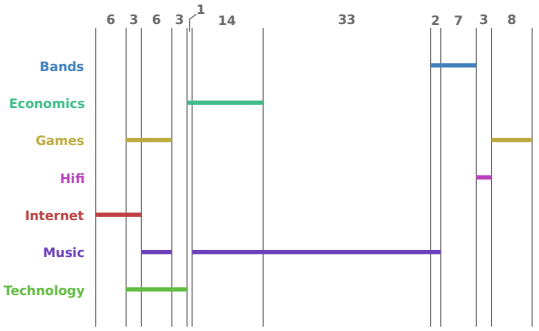
- ED-P&N



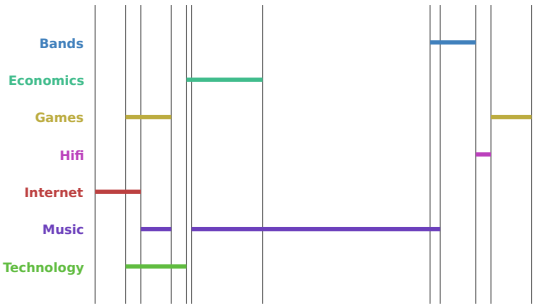
- LD-N


6 3 6 3 1 14 33 2 7 3 8
Bands
Economics
Games
Hifi
Internet
Music
Technology

- LD-P


6 3 6 3 1 14 33 2 7 3 8
Bands
Economics
Games
Hifi
Internet
Music
Technology

- LD-P&N


Bands
Economics
Games
Hifi
Internet
Music
Technology

Appendix D
Data Collection Method

Amazon Mechanical Turk was used to crowdsource participants from the general population [1], [6]. In MTurk, the tasks are called HITS - Human Intelligence Tasks - which are completed by anonymous participants. They are paid if they *successfully* complete the HIT. Crowdsourcing is a robust and upcoming method used by the research community for studies of the kind reported on in this paper [2], [6]. The HITs were based on the template provided by [4].

In both the training phase and the main study phase, each question was displayed on a separate page of the HIT. Participants could not return to pages and subsequent pages were not revealed until the previous answer was submitted. Unlike the training questions, which were presented in the same order for all participants to ensure consistent training, in the main study the questions were randomly ordered to reduce the impact of learning effect and fatigue. Participants were instructed to "maintain concentration on the HIT and answer questions without delay, unless a question explicitly allows you to take a break, in which case you can have a rest before continuing".

It is recognised that some MTurk participants do not give questions their full attention, or have difficulties with the language used, and this is hard to control [1]. We call such participants *inattentive*. To reduce the impact of language issues, a system qualification was used, allowing only participation from people based in the USA with a HIT approval rate of 95%. Another technique to identify inattentive participants is to include questions that require careful reading yet are trivial to answer [5]. In our study, we included two such questions. They asked participants to select all five options, including the none of the above checkbox, as their answer and were told if they failed to do so that they may not be paid for the HIT. Participants were classified as inattentive if failed to click all checkboxes on either of the two inattentive participant-identifying questions. Attentive participants were paid $3.70 for taking part.

All data obtained from inattentive participants was removed before analysis and these two questions always appeared on the 14^{th} and 28^{th} pages of the HIT. In total, the HIT had 40 pages: a consent page, four training pages, 32 main study questions, two inattentive questions, and a final page that collected demographic information.

Appendix E
Statistical Methods

Here we present in detail the statistical models used for the first two studies, each of which included three treatment groups. The models used for the last study were simpler, as there were only two treatments.

For each of the three empirical studies, we employed two local odds ratios generalized estimating equations models [7] to analyse the accuracy data. An ANOVA calculation was not appropriate for these data as they violated the normality assumption of an ANOVA test. The non-parametric version of ANOVA, Kruskal-Wallis, was also not appropriate, as the responses for each individual are correlated, and thus not independent. The first model, for the first two studies, was employed to answer RQ1, RQ2 and RQ3, compared the visualization types overall irrespective of task category:

$$\log\left[\frac{\Pr(Y_{ik}\leq j)}{1-\Pr(Y_{ik}\leq j)}\right] \;=\; \beta_{0j}+\beta_1 x_{ik1}+\beta_2 x_{ik2}$$

where

- $\Pr(Y_{ik}\leq j)$ is the probability for subject i to provide at most $j-1$ correct answers to question k and where $j=1,...,5$[1].
- x_{ik1} is the indicator that the diagram given to subject i for answering question k was *proportional*, and
- x_{ik2} is the indicator that the diagram given to subject i for answering question k was *both proportional and numerical*

for $i=1,\ldots,n$, given n participants, and $k=1,\ldots,32$. With this model, we could determine whether the odds of providing j or fewer correct answers for one of the visualization types (proportional, numerical, or both) was

1. j takes values from 1 to 5 since, for each question, there are 5 checkboxes which need to be correctly checked or not.

significantly different from others while taking into account the expected correlation among the responses provided by each individual participant.

The second model, for the first two studies, was employed to see whether the answers to RQ1, RQ2 and RQ3 still held when we take into account task category (set or intersection):

$$\log\left[\frac{\Pr(Y_{ik}\leq j)}{1-\Pr(Y_{ik}\leq j)}\right] = \beta_{0j}+\beta_1 x_{ik1}+\beta_2 x_{ik2}+\beta_3 x_{ik3}+ \beta_4(x_{ik1}\times x_{it3})+\beta_5(x_{ik2}\times x_{ik3})$$

where the variables are as above and, in addition, x_{ik3} is the indicator that the diagram given to subject i for answering question k was of type *I*. This model allowed us to estimate the odds of providing j or fewer correct answers with one combination of visualization type and task category compared to other combinations and determine whether significant differences existed.

For the time data, we used two generalized estimation models [3] that allowed us to estimate whether the time taken to provide answers was significantly different. Again we present details of the two models used for the first two studies. Following a similar approach for the accuracy data, the first of the two models directly addressed RQ1, RQ2 and RQ3 and the more complex model delved deeper into the data to see whether task category was important. The more complex model is given here, which accounts for the different combinations of visualization type (proportional, numerical, or both) and task category (set or intersection):

$$\log(t_{ik}) = \delta_0+\delta_1 x_{ik1}+\delta_2 x_{ik2}+\delta_3 x_{ik3}+ \delta_4(x_{ik1}\times x_{ik3})+\delta_5(x_{ik2}\times x_{ik3})$$

where

- t_{ik} is the time needed for subject i to answer question k, and
- x_{ik1}, x_{ik2} and x_{it3} are defined in the previous model

for $i = 1,\ldots,n$, given n participants, and $k = 1,\ldots,32$. This model allowed us to estimate the ratio of times of answering a question, given a pair of combinations of visualization type and task category. The simpler model excluded all terms involving x_{ik3}.

Statistical output is included in the submitted supplementary material. We report on the main findings in the associated paper.

Appendix F
Study A (ED) - Statistical Analysis

Here we present the statistical models used specifically for study 1 and the associated output.

Models

For the overall comparison, the following model was fitted to the accuracy data

$$\log\left[\frac{\Pr(Y_{ik}\leq j)}{1-\Pr(Y_{ik}\leq j)}\right] = \beta_{0j}+\beta_1 x_{ik1}+\beta_2 x_{ik2}$$

where

- $\Pr(Y_{ik}\leq j)$ is the probability for participant i to provide at most $j-1$ correct answers to question k and where $j = 1,2,3,4,5$.
- x_{ik1} is the indicator that the diagram given to participant i for answering question k was *ED-P*,
- x_{ik2} is the indicator that the diagram given to participant i for answering question k was *ED-P&N*

for $i = 1,\ldots,277$ and $j = 1,\ldots,32$.

For the overall comparison, the following model was fitted to the time data

$$\log(t_{ik}) = \delta_0 + \delta_1 x_{ik1} + \delta_2 x_{ik2}$$

where

- t_{ik} is the time needed for participant i to answer question k,
- x_{ik1} and x_{ik2} are defined in the previous model

for $i = 1, \ldots, 277$ and $k = 1, \ldots, 32$.

For the set and intersection comparisons, following model was fitted to the accuracy data

$$\log\left[\frac{\Pr(Y_{ik} \leq j)}{1 - \Pr(Y_{ik} \leq j)}\right] = \beta_{0j} + \beta_1 x_{ik1} + \beta_2 x_{ik2} + \beta_3 x_{ik3} + \beta_4 (x_{ik1} \times x_{ik3}) + \beta_5 (x_{ik2} \times x_{ik3})$$

where

- $\Pr(Y_{ik} \leq j)$ is the probability for participant i to provide at most $j - 1$ correct answers to question k and where $j = 1, 2, 3, 4, 5$.
- x_{ik1} is the indicator that the diagram given to participant i for answering question k was *ED-P*,
- x_{ik2} is the indicator that the diagram given to participant i for answering question k was *ED-P&N*
- x_{ik3} is the indicator that the diagram given to participant i for answering question k was of type I

for $i = 1, \ldots, 277$ and $j = 1, \ldots, 32$.

For the set and intersection comparisons, the following model was fitted to the time data

$$\log(t_{ik}) = \delta_0 + \delta_1 x_{ik1} + \delta_2 x_{ik2} + \delta_3 x_{ik3} + \delta_4 (x_{ik1} \times x_{ik3}) + \delta_5 (x_{ik2} \times x_{ik3})$$

where

- t_{ik} is the time needed for participant i to answer question k,
- x_{ik1}, x_{ik2} and x_{ik3} are defined in the previous model

for $i = 1, \ldots, 277$ and $k = 1, \ldots, 32$.

Overall results

The accuracy analysis:

```
# ED-P vs ED-N
ComparisonStats(fitmodel,c(0, 0, 0, 0, 0, 1, 0))
```

```
## Estimate   95% LB   95% UB  p-value
## 1.315777 1.058239 1.635991 0.013500
```

```
# ED-P&N vs ED-N
ComparisonStats(fitmodel,c(0, 0, 0, 0, 0, 0, 1))
```

```
##  Estimate    95% LB    95% UB   p-value
## 0.8866999 0.6888363 1.1413985 0.3506000
```

```
# ED-P vs ED-P&N
ComparisonStats(fitmodel,c(0, 0, 0, 0, 0, 1, -1))
```

```
## Estimate   95% LB   95% UB  p-value
## 1.483904 1.183448 1.860640 0.000600
```

The inference will be based on the model based estimated odds ratios (the value under Estimate). The results will be declared statistically significant only if the corresponding p-value is less than 0.05 and/or if the corresponfing 95% confidence interval does not contain 1. The two middle columns correspond to the lower and the upper bound

of the 95% confidence interval for the odds ratios. The interpretation of the above analysis is the following: The estimated odds of having j or less correct answers with *ED-P* diagrams is 1.3158 times that with *ED-N* diagrams (p-value = 0.0135). The estimated odds of having j or less correct answers with *ED-P* diagrams is 1.4839 times that with *ED-P&N* diagrams (p-value = 0.0006). In other words, *ED-N* and *ED-P&N* diagrams are more likely to produce a higher ammount of correct answers than *ED-P* diagrams.

The fitted probabilities for j for each group are

```
X1 <- matrix(fitted(fitmodel)[c(1000,8000,3000),],3,6)
rownames(X1) <- dataset1$diagram[c(1000,8000,3000)]
colnames(X1) <- 0:5
X1
```

```
##                  0         1         2         3         4
## ED-P    0.02431216 0.03763469 0.07304745 0.1789546 0.1394637
## ED-P&N  0.01651485 0.02609171 0.05255504 0.1405389 0.1228714
## ED-N    0.01858585 0.02920467 0.05824127 0.1520142 0.1286269
##                5
## ED-P   0.5465874
## ED-P&N 0.6414281
## ED-N   0.6133271
```

The time analysis:

```
# ED-P vs ED-N
ComparisonStats(fittimemodel,c(0, 1, 0))
```

```
##  Estimate    95% LB    95% UB   p-value
## 0.7809330 0.7081761 0.8611648 0.0000000
```

```
# ED-P&N vs ED-N
ComparisonStats(fittimemodel,c(0, 0, 1))
```

```
##  Estimate    95% LB    95% UB   p-value
## 0.9125743 0.8188579 1.0170163 0.0980000
```

```
# ED-P vs ED-P&N
ComparisonStats(fittimemodel,c(0, 1, -1))
```

```
##  Estimate    95% LB    95% UB   p-value
## 0.8557473 0.7741852 0.9459021 0.0023000
```

The inference will be based on the model based estimated ratios (the value under Estimate). The results will be declared statistically significant only if the corresponding p-value is less than 0.05 and/or if the corresponfing 95% confidence interval does not contain 1. The p-values and the 95% confidence intervals suggest that participants needed less time with *ED-P* diagrams than with *ED-P&N* or *ED-N* diagrams and that there is no significance difference between *ED-P&N* and *ED-N* diagrams.

Set cardinalities results

Accuracy comparisons:

```
# (ED-P and type S) vs (ED-N and type S)
ComparisonStats(fitmodel,c(0, 0, 0, 0, 0, 1, 0, 0, 0, 0))
```

```
##  Estimate    95% LB    95% UB   p-value
## 0.8069548 0.6083496 1.0703979 0.1367000
```

```
# (ED-P&N and type S) vs (ED-N and type S)
ComparisonStats(fitmodel,c(0, 0, 0, 0, 0, 0, 1, 0, 0, 0))
```

```
##  Estimate    95% LB    95% UB   p-value
## 0.5059211 0.3544472 0.7221277 0.0002000
```

```
# (ED-P and type S) vs (ED-P&N and type S)
ComparisonStats(fitmodel,c(0, 0, 0, 0, 0, 1,-1, 0, 0, 0))
```

```
## Estimate   95% LB   95% UB  p-value
## 1.595021 1.094169 2.325136 0.015200
```

The inference will be based on the model based estimated odds ratios (the value under Estimate). The results will be declared statistically significant only if the corresponding p-value is less than 0.05 and/or if the corresponfing 95% confidence interval does not contain 1. The two middle columns correspond to the lower and the upper bound of the 95% confidence interval for the odds ratios. The interpretation of the above analysis is the following: For type S diagrams, the estimated odds of having j or less correct answers with *ED-P* diagrams is 0.8070 times that with *ED-N* diagrams (p-value = 0.1367). The estimated odds of having j or less correct answers with *ED-P* diagrams is 1.5950 times that with *ED-P&N* diagrams (p-value = 0.0152). In other words, for type S, *ED-N* and *ED-P&N* diagrams are more likely to produce a higher ammount of correct answers than *ED-P* diagrams and there is no difference between *ED-N* and *ED-P&N* diagrams.

Time comparisons:

```
# (ED-P and type S) vs (ED-N and type S)
ComparisonStats(fittimemodel,c(0, 1, 0, 0, 0, 0))
```

```
##  Estimate    95% LB    95% UB   p-value
## 0.6839369 0.6223542 0.7516133 0.0000000
```

```
# (ED-P&N and type S) vs (ED-N and type S)
ComparisonStats(fittimemodel,c(0, 0, 1, 0, 0, 0))
```

```
##  Estimate    95% LB    95% UB   p-value
## 0.8750651 0.7878886 0.9718872 0.0127000
```

```
# (ED-P and type S) vs (ED-P&N and type S)
ComparisonStats(fittimemodel,c(0, 1,-1, 0, 0, 0))
```

```
##  Estimate    95% LB    95% UB   p-value
## 0.7815840 0.7073398 0.8636211 0.0000000
```

The inference will be based on the model based estimated ratios (the value under Estimate). The results will be declared statistically significant only if the corresponding p-value is less than 0.05 and/or if the corresponfing 95% confidence interval does not contain 1. For type I, the p-values and the 95% confidence intervals suggest that participants needed less time with *ED-P* diagrams than with *ED-P&N* or *ED-N* diagrams, and that participants needed less time with *ED-P&N* than *ED-N* diagrams.

Intersection cardinalities results

Accuracy analysis:

```
# (ED-P and type I) vs (ED-N and type I)
ComparisonStats(fitmodel,c(0, 0, 0, 0, 0, 1, 0, 0, 1, 0))
```

```
## Estimate   95% LB   95% UB  p-value
## 1.862365 1.445066 2.400170 0.000000
```

```
# (ED-P&N and type I) vs (ED-N and type I)
ComparisonStats(fitmodel,c(0, 0, 0, 0, 0, 0, 1, 0, 0, 1))
```

```
## Estimate   95% LB   95% UB  p-value
## 1.266412 0.944948 1.697235 0.113900
```

```
# (ED-P and type I) vs (ED-P&N and type I)
ComparisonStats(fitmodel,c(0, 0, 0, 0, 0, 1,-1, 0, 1,-1))
```

Time analysis:

```
# (ED-P and type I) vs (ED-N and type I)
ComparisonStats(fittimemodel,c(0, 1, 0, 0, 1, 0))
```

```
##  Estimate    95% LB    95% UB   p-value
## 0.8916851 0.7972190 0.9973450 0.0448000
```

```
# (ED-P&N and type I) vs (ED-N and type I)
ComparisonStats(fittimemodel,c(0, 0, 1, 0, 0, 1))
```

```
##  Estimate    95% LB    95% UB   p-value
## 0.9516914 0.8449521 1.0719146 0.4146000
```

```
# (ED-P and type I) vs (ED-P&N and type I)
ComparisonStats(fittimemodel,c(0, 1,-1, 0, 1,-1))
```

```
##  Estimate    95% LB    95% UB   p-value
## 0.9369478 0.8377156 1.0479345 0.2542000
```

Appendix G
Study B (LD) - Statistical models and output

Here we present the statistical models used specifically for study 2 and the associated output.

Models

For the overall comparison, the following model was fitted to the accuracy data

$$\log\left[\frac{\Pr(Y_{ik} \leq j)}{1-\Pr(Y_{ik} \leq j)}\right] = \beta_{0j} + \beta_1 x_{ik1} + \beta_2 x_{ik2}$$

where

- $\Pr(Y_{ik} \leq j)$ is the probability for participant i to provide at most $j-1$ correct answers to question k and where $j = 1, 2, 3, 4, 5$.
- x_{ik1} is the indicator that the diagram given to participant i for answering question k was *LD-P*,
- x_{ik2} is the indicator that the diagram given to participant i for answering question k was *LD-P&N*

for $i = 1, \ldots, 272$ and $k = 1, \ldots, 32$.

For the overall comparison, the following model was fitted to the time data

$$\log(t_{ik}) = \delta_0 + \delta_1 x_{ik1} + \delta_2 x_{ik2}$$

where

- t_{ik} is the time needed for participant i to answer question k,
- x_{ik1} and x_{ik2} are defined in the previous model

for $i = 1, \ldots, 272$ and $k = 1, \ldots, 32$.

For the set and intersection comparisons, the following model was fitted to the accuracy data

$$\log\left[\frac{\Pr(Y_{ik} \leq j)}{1-\Pr(Y_{ik} \leq j)}\right] = \beta_{0j} + \beta_1 x_{ik1} + \beta_2 x_{ik2} + \beta_3 x_{ik3} + \beta_4 (x_{ik1} \times x_{ik3}) + \beta_5 (x_{ik2} \times x_{ik3})$$

where

- $\Pr(Y_{ik} \leq j)$ is the probability for participant i to provide at most $j-1$ correct answers to question k and where $j = 1, 2, 3, 4, 5$.
- x_{ik1} is the indicator that the diagram given to participant i for answering question k was *LD-P*,
- x_{ik2} is the indicator that the diagram given to participant i for answering question k was *LD-P&N*
- x_{ik3} is the indicator that the diagram given to participant i for answering question k was of type I

for $i = 1, \ldots, 272$ and $k = 1, \ldots, 32$.

For the set and intersection comparisons, the following model was fitted to the time data

$$\log(t_{ik}) = \delta_0 + \delta_1 x_{ik1} + \delta_2 x_{ik2} + \delta_3 x_{ik3} + \delta_4 (x_{ik1} \times x_{ik3}) + \delta_5 (x_{ik2} \times x_{ik3})$$

where

- t_{ik} is the time needed for participant i to answer question k,
- x_{ik1}, x_{ik2} and x_{ik3} are defined in the previous model

for $i = 1, \ldots, 272$ and $k = 1, \ldots, 32$.

Overall results

Accuracy analysis:

```
# LD-P vs LD-N
ComparisonStats(fitmodel,c(0, 0, 0, 0, 0, 1, 0))
```

```
##  Estimate    95% LB    95% UB   p-value
## 1.1348457 0.9399509 1.3701512 0.1882000
```

```
# LD-P&N vs LD-N
ComparisonStats(fitmodel,c(0, 0, 0, 0, 0, 0, 1))
```

```
##  Estimate    95% LB    95% UB   p-value
## 1.1018091 0.8897432 1.3644198 0.3741000
```

```
# LD-P vs LD-P&N
ComparisonStats(fitmodel,c(0, 0, 0, 0, 0, 1, -1))
```

```
##  Estimate    95% LB    95% UB   p-value
## 1.0299840 0.8456953 1.2544318 0.7690000
```

There is no difference between the three types of diagrams.

Time analysis:

```
# LD-P vs LD-N
ComparisonStats(fittimemodel,c(0, 1, 0))
```

```
##  Estimate    95% LB    95% UB   p-value
## 0.8134194 0.7435824 0.8898155 0.0000000
```

```
# LD-P&N vs LD-N
ComparisonStats(fittimemodel,c(0, 0, 1))
```

```
##  Estimate    95% LB    95% UB   p-value
## 0.9797777 0.8980481 1.0689453 0.6457000
```

```
# LD-P vs LD-P&N
ComparisonStats(fittimemodel,c(0, 1, -1))
```

```
##  Estimate    95% LB    95% UB   p-value
## 0.8302082 0.7636182 0.9026049 0.0000000
```

Participants needed less time with *LD-P* diagrams than with *LD-P&N* or *LD-N* diagrams and that there is no significance difference between *LD-P&N* and *LD-N* diagrams.

Set cardinalities results

Accuracy analysis:

```
# (LD-P and type S) vs (LD-N and type S)
ComparisonStats(fitmodel,c(0, 0, 0, 0, 0, 1, 0, 0, 0, 0))
```

```
##  Estimate    95% LB    95% UB   p-value
## 1.0263526 0.7901575 1.3331515 0.8454000
```

```
# (LD-P&N and type S) vs (LD-N and type S)
ComparisonStats(fitmodel,c(0, 0, 0, 0, 0, 0, 1, 0, 0, 0))
```

```
##  Estimate    95% LB    95% UB   p-value
## 1.2253349 0.9403471 1.5966931 0.1324000
```

```
# (LD-P and type S) vs (LD-P&N and type S)
ComparisonStats(fitmodel,c(0, 0, 0, 0, 0, 1,-1, 0, 0, 0))
```

```
##  Estimate    95% LB    95% UB   p-value
## 0.8376098 0.6365894 1.1021079 0.2057000
```

For type *S*, there is no difference among the three types of diagrams.

Time analysis:

```
# (LD-P and type S) vs (LD-N and type S)
ComparisonStats(fittimemodel,c(0, 1, 0, 0, 0, 0))
```

```
##  Estimate    95% LB    95% UB   p-value
## 0.7846409 0.7208330 0.8540971 0.0000000
```

```
# (LD-P&N and type S) vs (LD-N and type S)
ComparisonStats(fittimemodel,c(0, 0, 1, 0, 0, 0))
```

```
##  Estimate    95% LB    95% UB   p-value
## 0.9970524 0.9150658 1.0863846 0.9462000
```

```
# (LD-P and type S) vs (LD-P&N and type S)
ComparisonStats(fittimemodel,c(0, 1,-1, 0, 0, 0))
```

```
##  Estimate    95% LB    95% UB   p-value
## 0.7869606 0.7257799 0.8532986 0.0000000
```

For type *S*, participants needed less time with *LD-P* diagrams than with *LD-P&N* or *LD-N* and there is no significance difference between *LD-P&N* and *LD-N* diagrams.

Intersection cardinalities results

Accuracy analysis:

```
# (LD-P and type I) vs (LD-N and type I)
ComparisonStats(fitmodel,c(0, 0, 0, 0, 0, 1, 0, 0, 1, 0))
```

```
##  Estimate    95% LB    95% UB   p-value
## 1.2038819 0.9449141 1.5338235 0.1332000
```

```
# (LD-P&N and type I) vs (LD-N and type I)
ComparisonStats(fitmodel,c(0, 0, 0, 0, 0, 0, 1, 0, 0, 1))
```

```
##  Estimate    95% LB    95% UB   p-value
## 1.0341693 0.7835026 1.3650321 0.8125000
```

```
# (LD-P and type I) vs (LD-P&N and type I)
ComparisonStats(fitmodel,c(0, 0, 0, 0, 0, 1,-1, 0, 1,-1))
```

```
##  Estimate    95% LB    95% UB   p-value
## 1.1641052 0.9025326 1.5014869 0.2419000
```

Time analysis:

```
# (LD-P and type Z) vs (LD-N and type Z)
ComparisonStats(fittimemodel,c(0, 1, 0, 0, 1, 0))
```

```
##  Estimate    95% LB    95% UB   p-value
## 0.8432534 0.7600814 0.9355265 0.0013000
```

```
# (LD-P&N and type Z) vs (LD-N and type Z)
ComparisonStats(fittimemodel,c(0, 0, 1, 0, 0, 1))
```

```
##  Estimate    95% LB    95% UB   p-value
## 0.9628023 0.8730566 1.0617733 0.4477000
```

```
# (LD-P and type Z) vs (LD-P&N and type Z)
ComparisonStats(fittimemodel,c(0, 1,-1, 0, 1,-1))
```

```
##  Estimate    95% LB    95% UB   p-value
## 0.8758324 0.7958562 0.9638455 0.0067000
```

Appendix H
Study C (ED vs LD) - Statistical models and output

Here we present the statistical models used specifically for study 3 and the associated output.

Models

For the overall comparison, the following regression model was fitted to the accuracy data

$$\log\left[\frac{\Pr(Y_{ik} \leq j)}{1-\Pr(Y_{ik} \leq j)}\right] = \beta_{0j} + \beta_1 x_{ik1}$$

where

- $\Pr(Y_{ik} \leq j)$ is the probability for participant i to provide at most $j-1$ correct answers to question k and where $j = 1, 2, 3, 4, 5$.
- x_{ik1} is the indicator that an *ED-P&N* diagram was given to participant i for answering question k,

for $i = 1, \ldots, 185$ and $k = 1, \ldots, 32$.

For the overall comparison, the following regression model was fitted to the time data

$$\log(t_{ik}) = \delta_0 + \delta_1 x_{ik1}$$

where

- t_{ik} is the time needed for participant i to answer question t,
- x_{ik1} is defined as in the model for the accuracy data

for $i = 1, \ldots, 185$ and $k = 1, \ldots, 32$.

For the set and intersection comparisons, the following regression model was fitted to the accuracy data

$$\log\left[\frac{\Pr(Y_{ik} \leq j)}{1-\Pr(Y_{ik} \leq j)}\right] = \beta_{0j} + \beta_1 x_{ik1} + \beta_2 x_{ik2} + \beta_3 (x_{ik1} \times x_{ik2})$$

where

- $\Pr(Y_{ik} \leq j)$ is the probability for participant i to provide at most $j-1$ correct answers to question k and where $j = 1, 2, 3, 4, 5$.
- x_{ik1} is the indicator that an *ED-P&N* diagram was given to participant i for answering question k,
- x_{ik2} is the indicator that the k-th question given to participant i was type I

for $i = 1, \ldots, 185$ and $k = 1, \ldots, 32$.

For the set and intersection comparisons, the following regression model was fitted to the time data

$$\log(t_{ik}) = \delta_0 + \delta_1 x_{ik1} + \delta_2 x_{ik2} + \delta_3 (x_{ik1} \times x_{ik2})$$

where

- t_{ik} is the time needed for participant i to answer question k,
- x_{ik1} and x_{ik2} are defined as in the model for the accuracy data

for $i = 1, \ldots, 185$ and $k = 1, \ldots, 32$.

Overall results

Accuracy analysis:

```
# (ED-P&N) vs (LD-P)
ComparisonStats(fitmodel, c(0, 0, 0, 0, 0, 1))
```

```
##  Estimate    95% LB    95% UB   p-value
## 0.7814704 0.6249702 0.9771602 0.0306000
```

The *ED-P&N* diagrams are better than *LD-P* when the questions type is ignored.

Time analysis:

```
# (ED-P&N) vs (LD-P)
ComparisonStats(fittimemodel, c(0, 1))
```

```
## Estimate   95% LB   95% UB  p-value
## 1.159591 1.037295 1.296306 0.009200
```

The time needed with a *ED-P&N* diagram is 1.15 times that needed with a *LD-P* diagram when the question type was ignored.

Set cardinalities results

Accuracy analysis:

```
# (ED-P&N and typeS) vs (LD-P and typeS)
ComparisonStats(fitmodel, c(0, 0, 0, 0, 0, 1, 0, 0))
```

```
##  Estimate    95% LB    95% UB   p-value
## 0.9628247 0.6884480 1.3465527 0.8248000
```

There is no difference between *ED-P&N* and *LD-P* diagrams with for questions of type *S*.

Time analysis:

```
# (ED-P&N and typeS) vs (LD-P and typeS)
ComparisonStats(fittimemodel, c(0, 1, 0, 0))
```

```
## Estimate   95% LB   95% UB  p-value
## 1.255564 1.130982 1.393870 0.000000
```

To answer questions of type *S*, the time needed with a *ED-P&N* diagram is 1.26 times that needed with a *LD-P* diagram.

Intersection cardinalities results

Accuracy analysis:

```
# (ED-P&N and typeI) vs (LD-P and typeI)
ComparisonStats(fitmodel, c(0, 0, 0, 0, 0, 1, 0, 1))
```

```
##  Estimate    95% LB    95% UB   p-value
## 0.6571699 0.5113266 0.8446114 0.0010000
```

For questions of type *I*, *ED-P&N* diagrams are more likely to increase the number of correct answers when comprared to *LD-P* diagrams.

Time analysis:

```
# (ED-P&N and typeI) vs (LD-P and typeI)
ComparisonStats(fittimemodel, c(0, 1, 0, 1))
```

```
##  Estimate    95% LB    95% UB   p-value
## 1.0709541 0.9448343 1.2139088 0.2836000
```

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