ALI NIKNAFS

The Impact of Domain Knowledge on the Effectiveness of Requirements Engineering Activities

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OUTLINE

- Introduction
- Controlled Experiments
  - E1
  - E1+E2
- Case Study
- Conclusions

REQUIREMENTS ENGINEERING

The process of arriving at a ***specification*** of a set of ***features*** that need to be developed is referred to as ***requirements engineering*** (RE).

ROLE OF PEOPLE

- Boehm observed that the quality of the development **personnel** is the most powerful factor in determining an organization's software productivity.
- Currently, most decisions about staffing development teams arise from anecdotes and folklore, not from scientific studies.

THE RE GAP

- One issue in RE is the gap between what the customer **wants** and what the analyst **thinks** the customer wants.

- To bridge this gap, many believe that an analyst needs to know the customer's **problem domain** well to do RE well for a system in the domain.

- However, deep knowledge of the problem domain can lead to falling into the **tacit assumption tarpit**.

BENEFITS OF DOMAIN IGNORANCE

A domain ignorant has:

1. the ability to **think out of the domain's box**, leading to ideas that are independent of the domain assumptions,

2. the ability to ask questions that expose the domain's **tacit assumptions**, leading to a common explicit understanding.

IGNORANT

NOT

STUPID!

GOAL

To **form** the most **effective** teams of requirements engineers.

Requires answering the research question:

- Does a **mix** of DIs and DAs perform an RE activity more **effectively** than only DAs?

CONTROLLED

EXPERIMENTS

HYPOTHESIS

A team consisting of a ***mix*** of DIs and DAs is ***more effective*** in a requirements idea generation activity than is a team consisting of ***only DAs***.

EXPERIMENT CONTEXT

- Participants perform the ***requirement idea generation*** for some system.
- The units generated are ***requirements ideas***.
- The system is situated in some ***domain***.
- Each participant has a different amount of ***knowledge*** about the ***domain***. Each is either:
  - a ***domain ignorant*** (***DI***), or
  - a ***domain aware*** (***DA***).

DOMAIN SELECTION

- **B**i**D**irectional **W**ord **P**rocessing (BDWP)
- Participants were drawn from School of CS;
  - those from the Middle East are DAs.
  - those from elsewhere are DIs.
- Clearly divides the population more so than other domains I tried.

MIX OF DOMAIN FAMILIARITIES

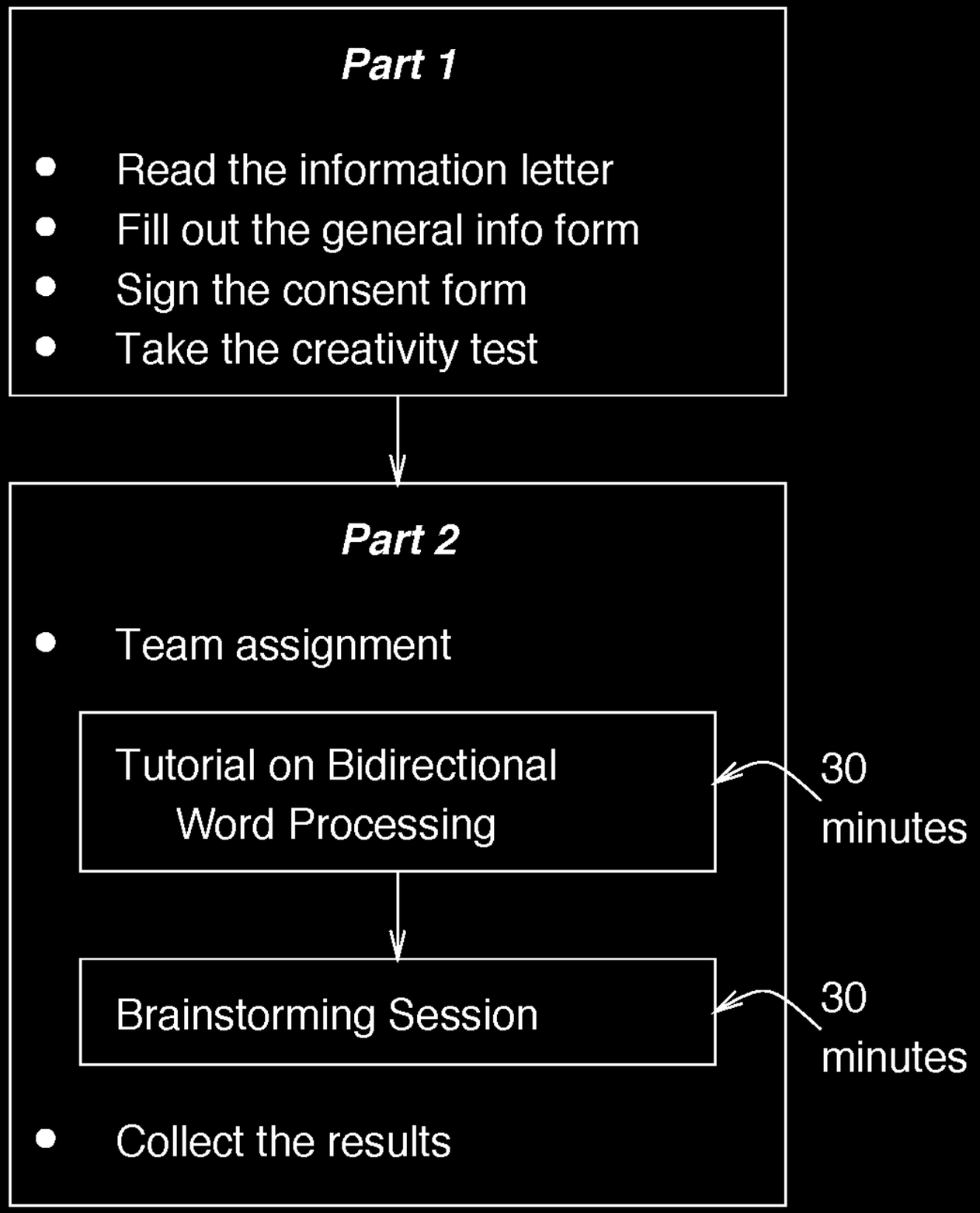
3I: a team consisting of **3 DIs** and 0 DAs,

2I: a team consisting of **2 DIs** and 1 DAs,

1I: a team consisting of **1 DIs** and 2 DAs, and

0I: a team consisting of **0 DIs** and 3 DAs.

PROCEDURE


Part 1
Read the information letter
Fill out the general info form
Sign the consent form
Take the creativity test
Part 2
Team assignment
Tutorial on Bidirectional Word Processing
30 minutes
Brainstorming Session
30 minutes
Collect the results

ANALYSIS METRICS

- ***Quantitative:***
  - Number of generated ideas
- ***Qualitative:***
  - Relevancy
  - Feasibility
  - Innovation

EVALUATION OF QUALITY

- To eliminate any **bias** in classifying an idea that might arise from the evaluator's knowing the domain familiarity mix of the team from which the idea came,
    - a list of all ideas generated by all teams was produced, and
    - sorted using the first letters of each idea.
- Each evaluator classifies the ideas in the full list.
- After evaluations were done, the each evaluator's classifications of each idea are **transferred** to the idea's occurrences in the individual team lists.
- Berry and I are experts in BDWP and did independent evaluations.

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EXPERIMENT 1 (E1)

INDEPENDENT VARIABLES

NAME	VARIABLE	VALUES
MIX	Mix of domain familiarities	0I,1I, 2I, 3I
CR	Average creativity score level	Low, Medium, High
REXP	Average RE experience	None, Some
IEXP	Average industrial experience	None, 1-2 years, More than 2 years

DEPENDENT VARIABLES

NAME	*VARIABLE*	*VALUES*
RAW	Raw number of ideas	Numeric
AVG_R	Average number of relevant ideas	Numeric
AVG_F	Average number of feasible ideas	Numeric
AVG_I	Average number of innovative ideas	Numeric

FINE-GRAINED HYPOTHESES

H_{MIX}: The effectiveness of a team in requirements idea generation is affected by the team's **MIX**.

H_{CR}: The effectiveness of a team in requirements idea generation is affected by the team's **CR**.

H_{REXP}: The effectiveness of a team in requirements idea generation is affected by the team's **REXP**.

H_{IEXP}: The effectiveness of a team in requirements idea generation is affected by the team's **IEXP**.

CONCLUSIONS

After ANOVA on **RAW**, **AVG_R**, and **AVG_F**, and non-parametric test on **AVG_I**,

- H_{MIX} is **accepted**:
  The effectiveness of a team in requirements idea generation **is** affected by the team's **MIX**.

- H_{CR} is **rejected**:
  The effectiveness of a team in requirements idea generation **is not** affected by the team's **CR**.

CONCLUSIONS

- ***H*_{REXP}** is **rejected**:
  The effectiveness of a team in requirements idea generation **is not** affected by the team's **REXP**.

- ***H*_{IEXP}** is **accepted**:
  The effectiveness of a team in requirements idea generation **is** affected by the team's **IEXP**.

THREATS TO VALIDITY

- ***Low Statistical Power*:** 20 teams would be enough to achieve statistical power of 0.80, but
  - the **unequal number** of teams in the mixes **reduces** statistical power.
- ***Population Validity:*** The experiment used student subjects instead of professional analysts, although the students are mostly co-op.

CONTROLLED

EXPERIMENT 1 (E1) + EXPERIMENT 2 (E2)

INDEPENDENT VARIABLES

NAME	*VARIABLE*	*VALUES*
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IREXP	Average industrial RE experience	None, Low, Medium, High
NCS	Number of participants with CS background	0,1,2,3
NSE	Number of participants studying SE	0,1,2,3
NGRAD	Number of graduate student participants	0,1,2,3

DEPENDENT VARIABLES

NAME	*VARIABLE*	*VALUES*
RAW	Raw number of ideas	Numeric
NRAW	Normalized RAW	Numeric
AVG_R	Average number of relevant ideas	Numeric
NR	Normalized AVG_R	Numeric
AVG_F	Average number of feasible ideas	Numeric
NF	Normalized AVG_F	Numeric
AVG_I	Average number of innovative ideas	Numeric
NI	Normalized AVG_I	Numeric

FACTOR ANALYSIS

NAME	*VARIABLE*	*VALUES*
MIX	Mix of domain familiarities	0,1,2,3
CR	Average creativity score level	Low, Medium, High
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NGRAD	Number of graduate student participants	0,1,2,3

FACTOR ANALYSIS

NAME	*VARIABLE*	*VALUES*
MIX	Mix of domain familiarities	0,1,2,3
CR	Average creativity score level	Low, Medium, High
EXP	Sum of REXP, IREXP, and IEXP	Low, Medium, High
EDU	Sum of NCS and NSE	Low, High
NGRAD	Number of graduate student participants	0,1,2,3

HYPOTHESES

H_{MIX}: The effectiveness of a team in requirements idea generation is affected by the team's ***MIX***.

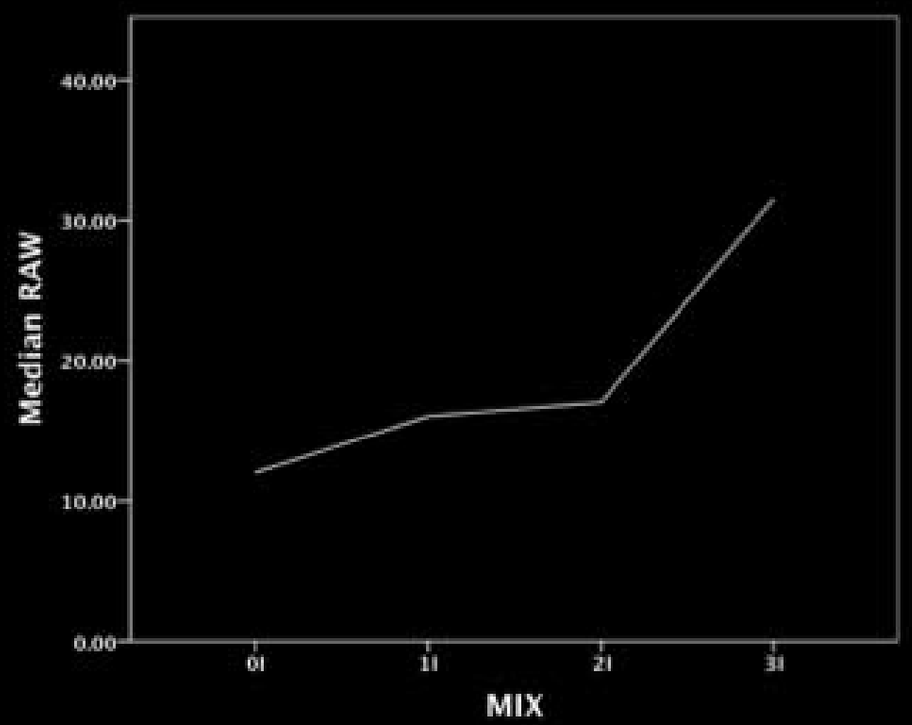
H_{CR}: The effectiveness of a team in requirements idea generation is affected by the team's ***CR***.

H_{EXP}: The effectiveness of a team in requirements idea generation is affected by the team's ***EXP***.

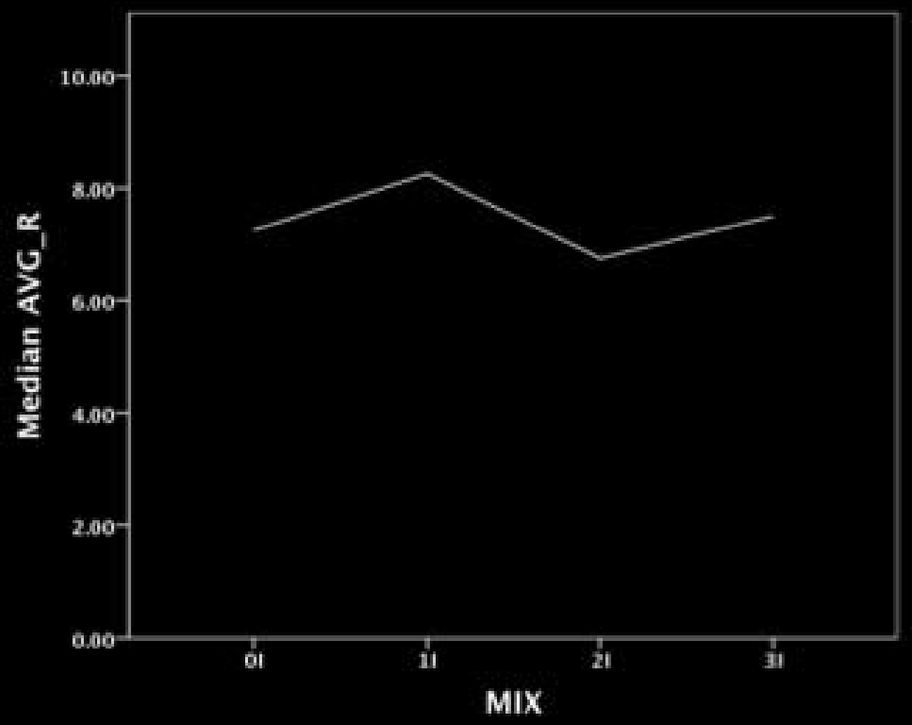
H_{EDU}: The effectiveness of a team in requirements idea generation is affected by the team's ***EDU***.

H_{NGRAD}: The effectiveness of a team in requirements idea generation is affected by the team's ***NGRAD***.

IMPACT OF MIX



(a) RAW



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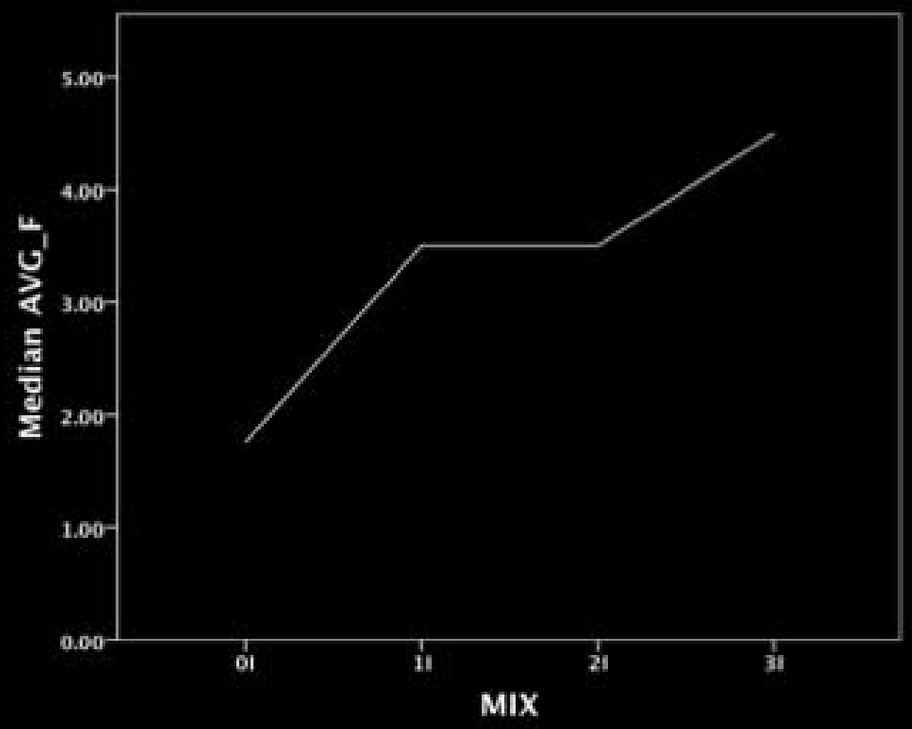

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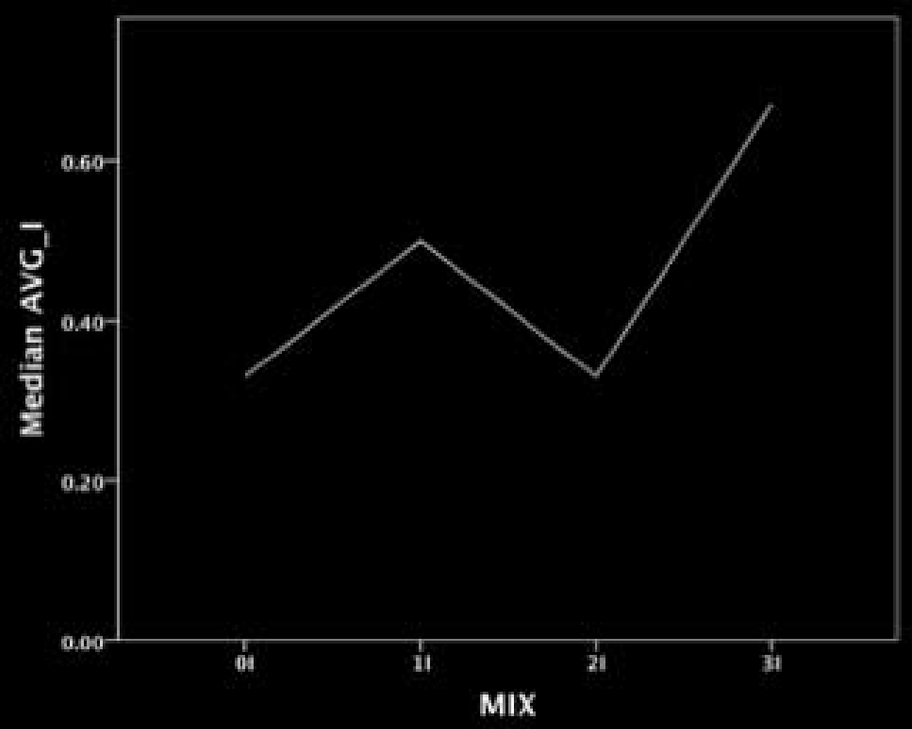
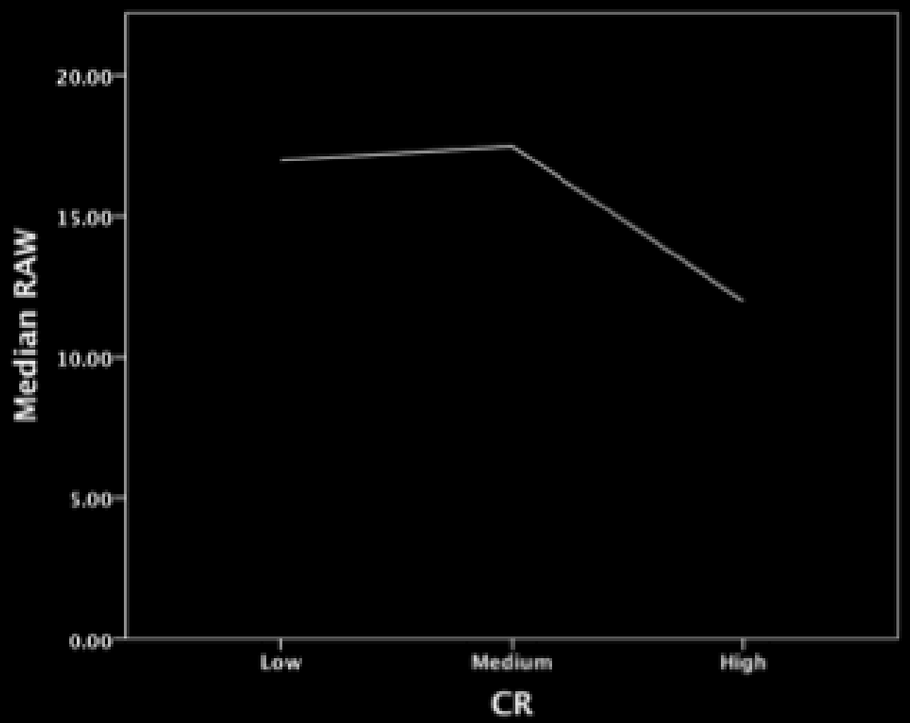


(d) AVG_I

IMPACT OF CR



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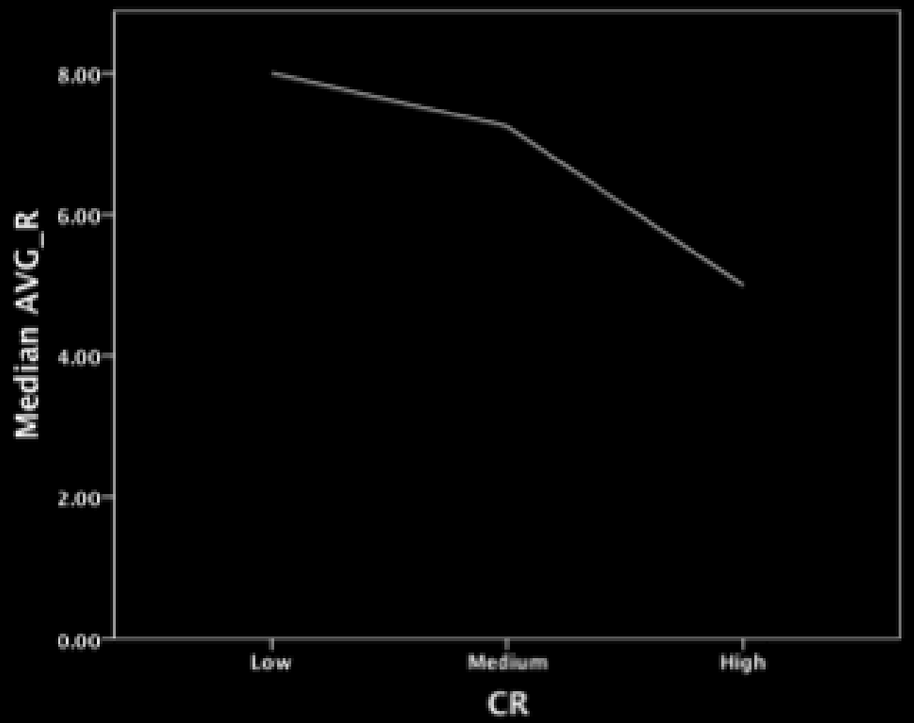

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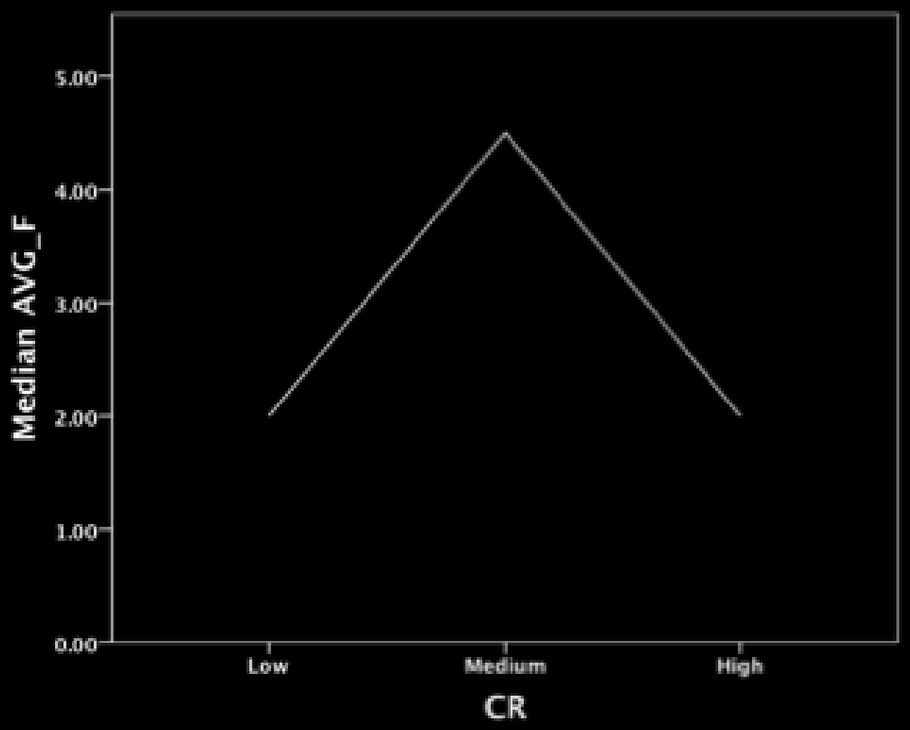

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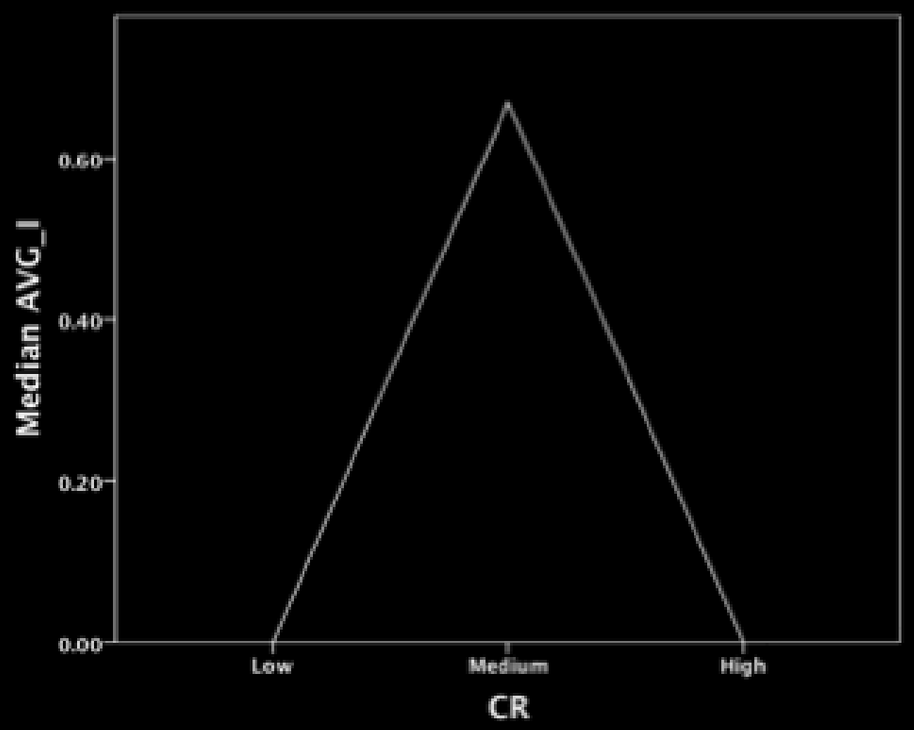
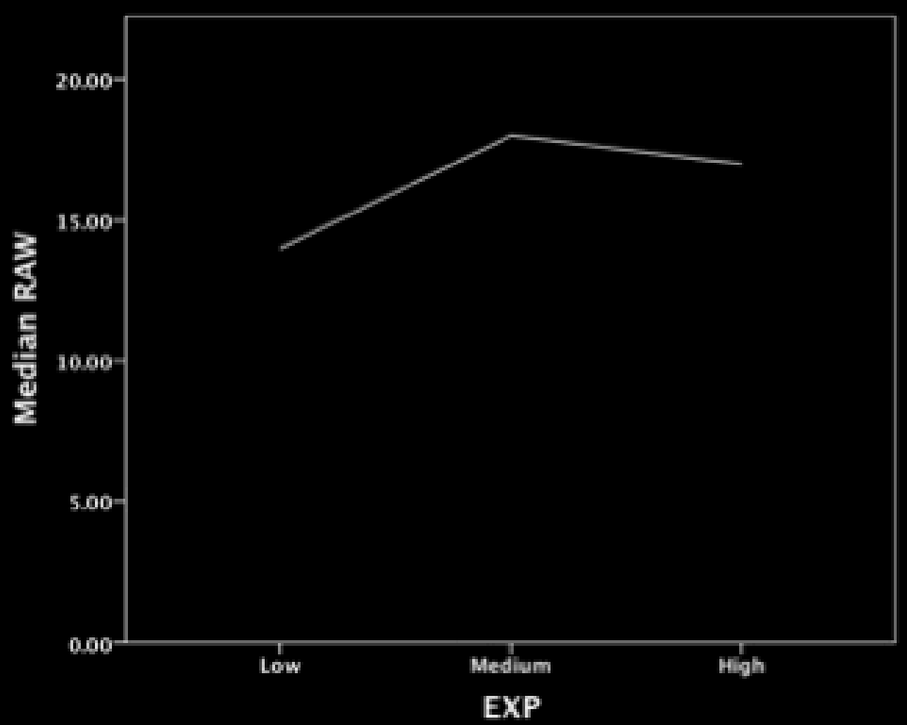


(d) AVG_I

IMPACT OF EXP



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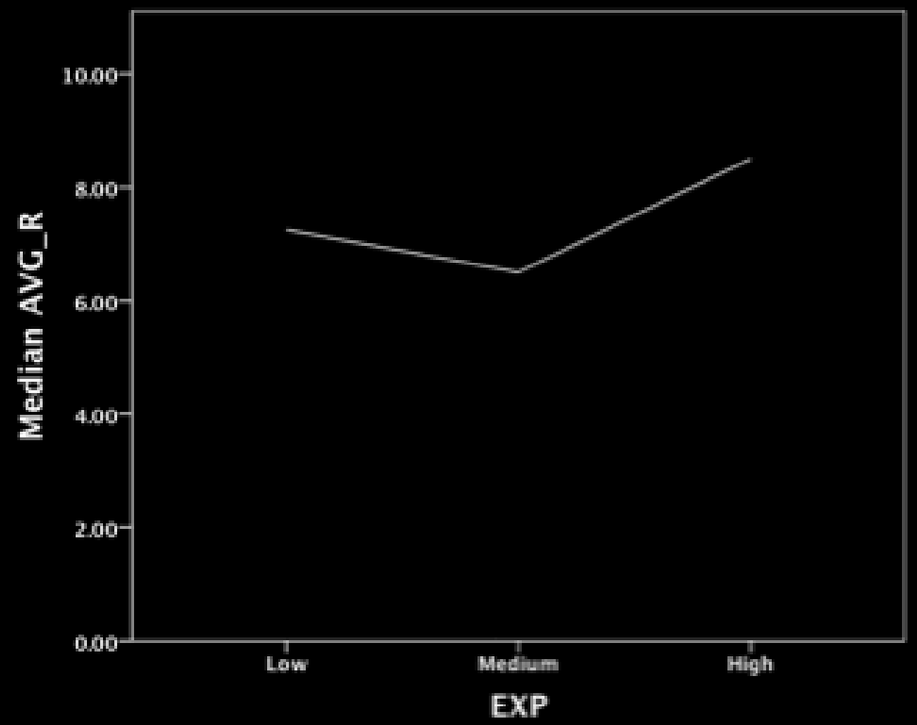

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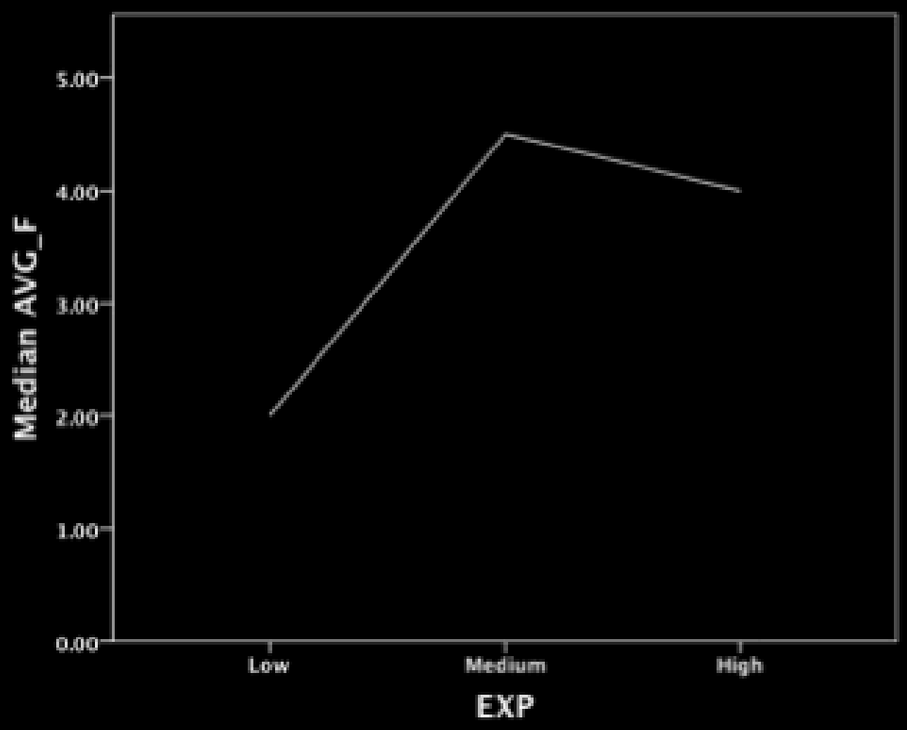

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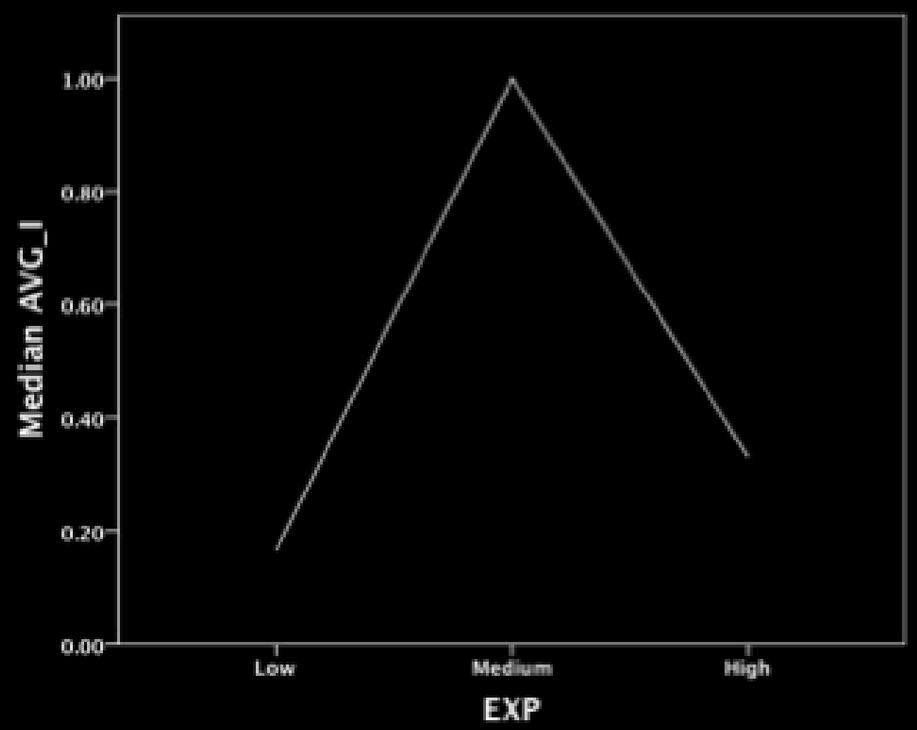
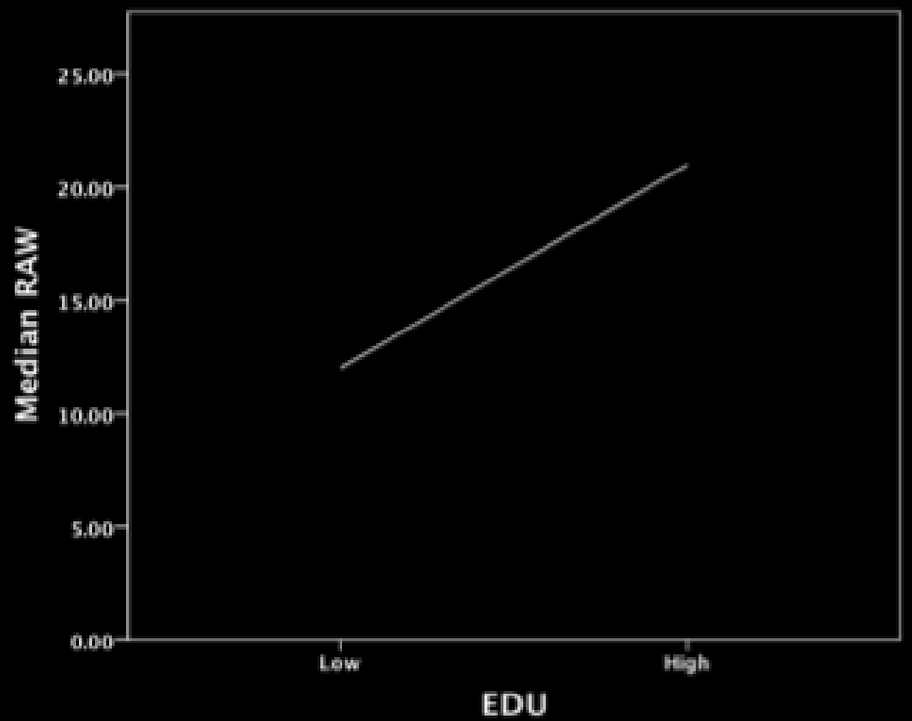
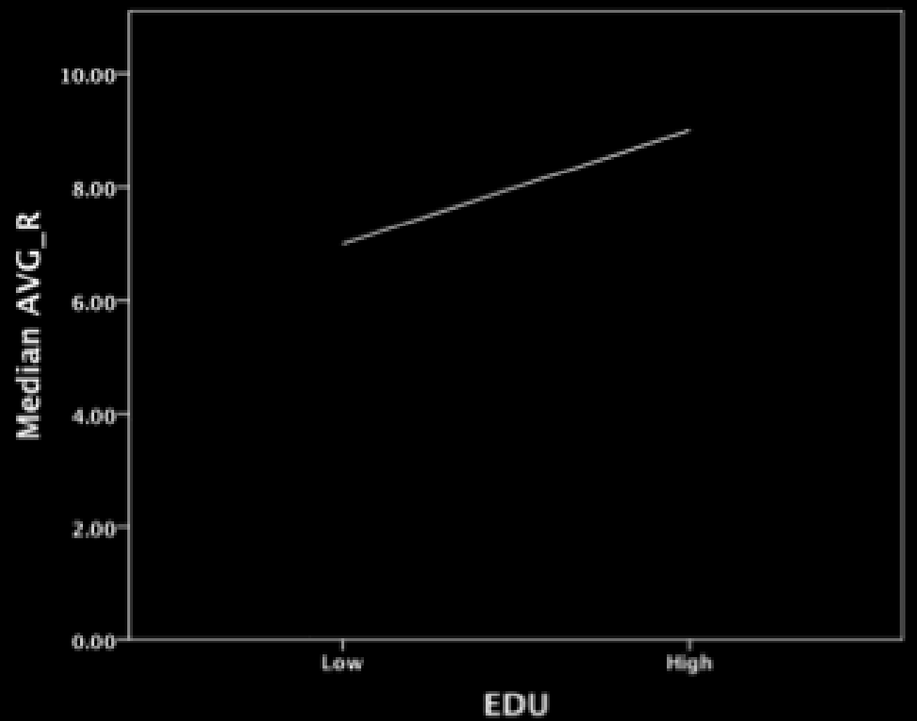


(d) AVG_I

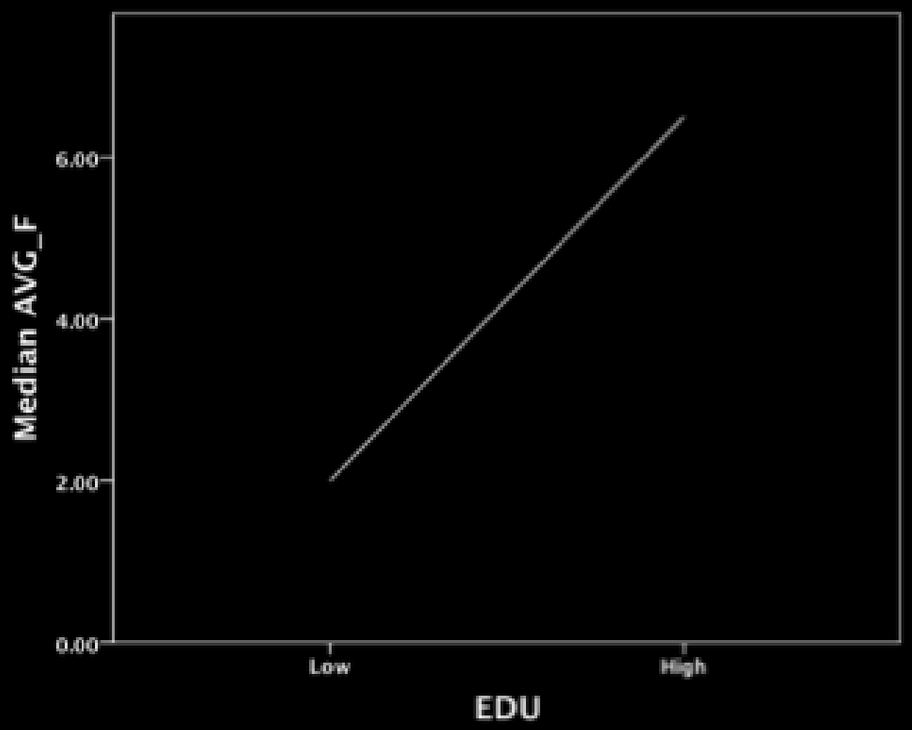
IMPACT OF EDU



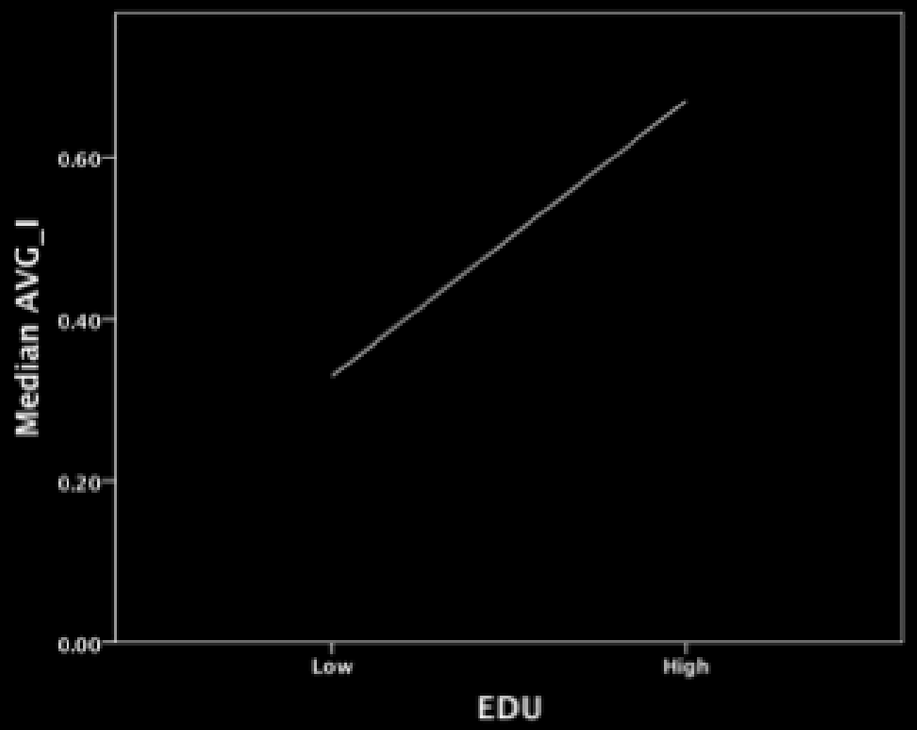
(a) RAW



(b) AVG_R

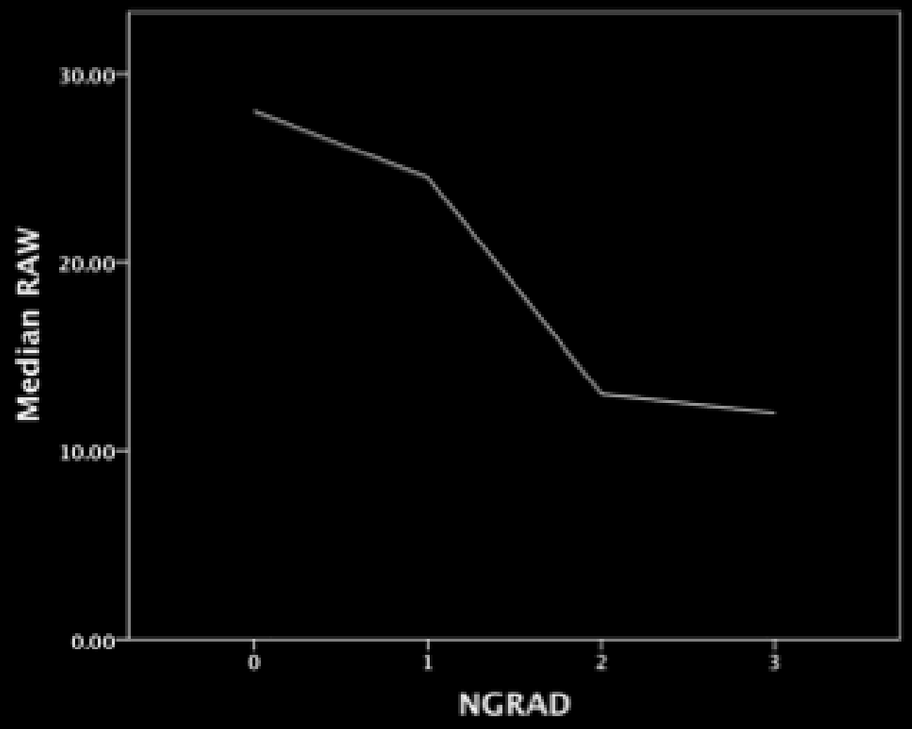


(c) AVG_F

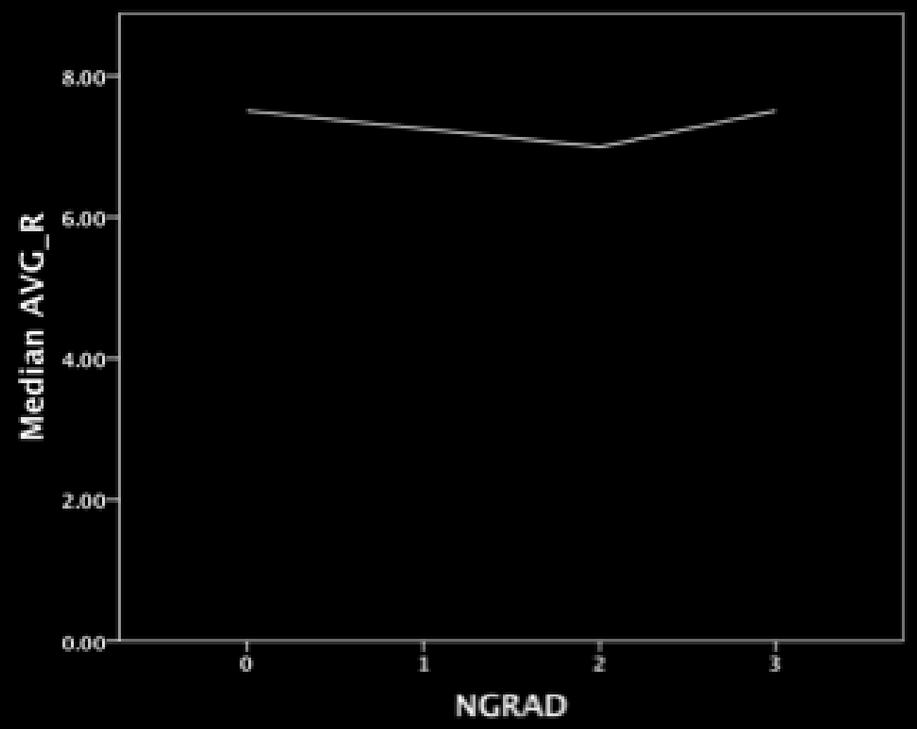


(d) AVG_I

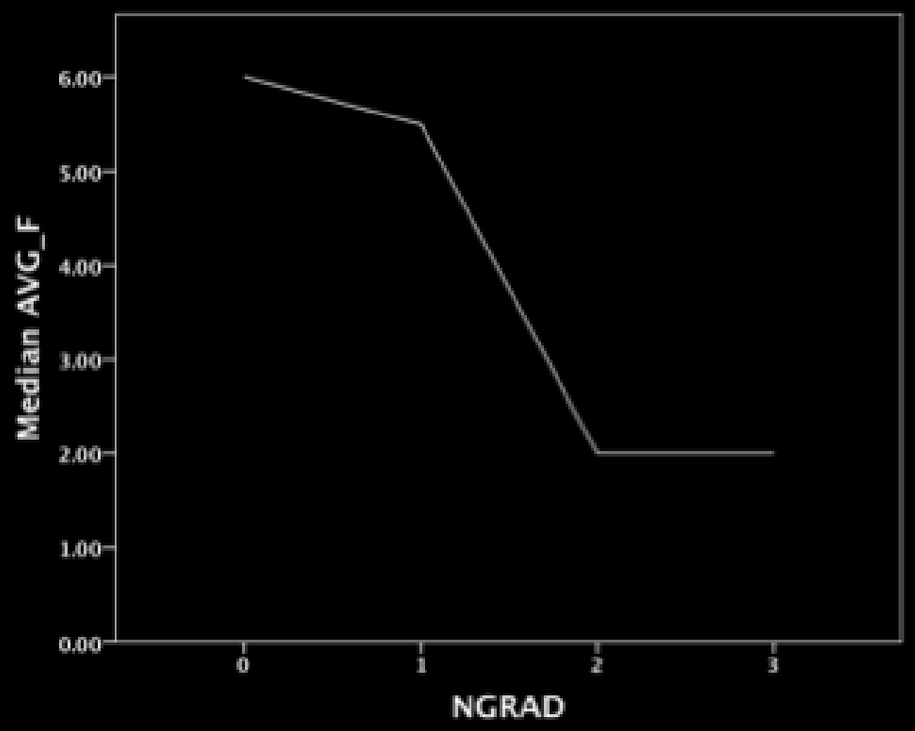
IMPACT OF NGRAD



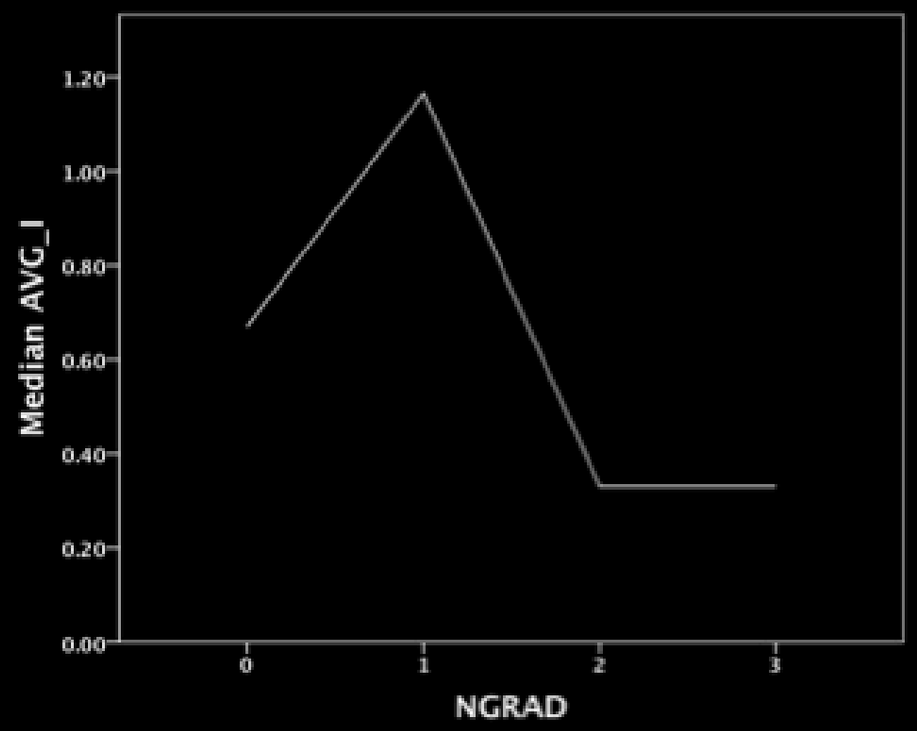
(a) RAW



(b) AVG_R



(c) AVG_F



(d) AVG_I

STATISTICAL ANALYSIS RESULTS

MIX: no significant effect on any dependent variable.

CR: no significant effect on any dependent variable.

EXP: a significant effect on **only one** dependent variable, **NI**.

EDU: a significant effect on three dependent variables, **NRAW**, **NF** and **NI**.

NGRAD: a significant effect on three dependent variables, **NRAW**, **NF**, and **NI**.

CONCLUSIONS

- In general, teams with at least **one DI** were more effective than teams with **no DIs**.

- Teams with a **medium** level of **CR** were more effective than the others.

- Teams with **no REXP** were at least as effective as teams with **some REXP**.

- A team's **IREXP** was **positively correlated** with the effectiveness of a team.

CONCLUSIONS

- A team's **IEXP** was **positively correlated** with the effectiveness of a team.
- Considering **educational background**,
  - teams with **NCS of 2** were generally most effective,
  - teams with **NSE of 2** were generally most effective.

CONCLUSIONS

IMPACT OF THE RESULTS ON THE HYPOTHESES

- ***H_{MIX}***:
  - The initial observations revealed that the effectiveness of a team is **positively affected** by the team's **MIX**.
  - The statistical analysis showed that it **is statistically significant** only **in conjunction** with **EXP** and **EDU**.
  - Therefore, ***H_{MIX}*** is **weakly rejected**.

CONCLUSIONS

IMPACT OF THE RESULTS ON THE HYPOTHESES

- ***H_{CR}***:
  - The initial observations revealed that the effectiveness of a team is **positively affected** by the team's **CR**.
  - The statistical analysis showed **no significant effect** of this variable.
  - Therefore, ***H_{CR}*** is **rejected**.

CONCLUSIONS

IMPACT OF THE RESULTS ON THE HYPOTHESES

- ***H_{EDU}***:
  - The initial observations revealed that the effectiveness of a team is **positively affected** by the team's **NCS** and **NSE**.
  - The statistical analysis showed that the effect of **NCS** and **NSE** is **statistically significant**.
  - Therefore, ***H_{EDU}*** is **strongly accepted**.

CONCLUSIONS

IMPACT OF THE RESULTS ON THE HYPOTHESES

- ***H_{EXP}***:
  - The initial observations revealed that the effectiveness of a team is
    - **positively affected** by the team's **IEXP** and **IREXP**, and
    - **negatively affected** by the team's **REXP**.
- The statistical analysis showed **no significant effect** of **IEXP** and **IREXP**, and **REXP** showed a **small effect**.
- Therefore, ***H_{EXP}*** is **rejected**.

CONCLUSIONS

IMPACT OF THE RESULTS ON THE HYPOTHESES

- ***H_{NGRAD}***:
  - The initial observations revealed that the effectiveness of a team is **negatively affected** by the team's **NGRAD**.
  - The statistical analysis showed that the effect of this variable is **statistically significant**.
  - Therefore, ***H_{NGRAD}*** is **strongly accepted.**

THREATS TO VALIDITY

- The ratios of the ideas in E1 and E2 are different.
    - The differences might be due to the changes in the classifiers.
- To find the cause:

1. Data were adjusted.
2. Graphs of
    - the correlations between the **original data** and the dependent variables

    were compared with

    - the correlations between the **adjusted data** and the dependent variables were

THREATS TO VALIDITY

- The correlation graphs did not show any significant difference or have a slight difference in strength but the same direction with the corresponding graphs of the unadjusted data.
- Naturally, DAs are better in generating relevant and feasible ideas. Since E2 had significantly more DAs, it is anticipated that the data of E2 had more relevant and feasible ideas.
    - The difference between the ratios of the ideas in E1 and E2 is due to the changes in the **participants** not the **classifiers**.

AN INDUSTRIAL

CASE STUDY

GOAL OF THE STUDY

- To corroborate the conclusions of the controlled experiments, by:
  - getting one group with a **mix** of DAs and DIs to carry out the **idea generation** part of a requirements idea brainstorming session, and
  - then asking the DA members of the group to **compare** the case study session with previous DA-only sessions.

PARTICIPANTS

- ***Eight*** participants
- ***Four*** C developers (DAs)
- ***Four*** UW affiliates (DIs)

PROCEDURE

1. The session started by a brief description of the system given by the supervisor among the DAs.

2. During the session, I monitored generated ideas ***only*** to analyze the relation between ideas.

- For each idea, I noted

    1. ***who*** generated it,

    2. was it ***new*** (relative to the session), and

    3. which idea, if any, it was ***built on***.

OBSERVATIONS

- The DAs were **less active** than the DIs in the **beginning** of the session.

- The DAs became **more active after** DIs threw out some ideas.

- Many ideas offered by DIs appeared to be from **outside D's box**.

- DAs **built on** many of these apparent **out-of-the-box** ideas.

CONCLUSIONS

- The DIs were generating **out-of-the-box** ideas.
- The DAs were interested in **technical details**, as they were seeking only implementable ideas.
- DAs are **tied** to solutions that they are already familiar with.
- There were indications that the DIs may have generated some ideas that were **innovative** to C.
- Finally, the experience suggest that, brainstorming groups should be composed of **domain experts** and **new employees**.

COMPARING E1 AND E1+E2

- In E1, all of the participants were computer science or software engineering students.
  - The results suggest that those RE teams with a **mix of domain familiarities** are more effective than teams composed of only one domain familiarity.
- E1 suffered from **unequal** numbers of teams with different mixes of domain familiarities, and therefore, the statistical test results were weak.

COMPARING E1 AND E1+E2

- E2, was conducted using the same plan used for E1 with the goal of having an **equal** number of teams of all mixes of domain familiarity.
- It was necessary to include participants other than Computer Science and Software Engineering students in E2.
- After combining the data of E1 and E2, there were an equal number of teams with the different mixes of domain familiarities, and therefore the statistical tests would be more reliable.

COMPARING E1 AND E1+E2

- The initial observations of the results of E1+E2 are not very different from those of E1.
- But the statistical analysis results shows some differences with the statistical analysis of E1.
- E1 data showed some support for accepting $\boldsymbol{H_{MIX}}$.
- E1+E2 did not provide any support for accepting $\boldsymbol{H_{MIX}}$.

WHY E1 AND E1+E2 RESULTS ARE DIFFERENT?

1. Type I error occurred during E1:

    - the **null hypothesis** is in fact **true** and there is really **no effect** of the mix of domain familiarities.

2. Type II error occurred during E1+E2:

    - the **null hypothesis** is really **false** and the effectiveness of a team is really **affected** by the team's mix of domain familiarities.

CS VS. GENERAL HIGH TECH

Why E1 and E1+E2 results are different?

- Maybe differences between the **educational background** of the participants affected the results.

FUTURE WORK

- Replication of the controlled experiment to
  - increase data points,
  - improve external validity,
  - improve internal validity.
- Apply the study to other disciplines, esp. those that need **tacit assumptions** to be surfaced. e.g. knowledge management.
- Replication within industry, surveys and examination of project histories.

FUTURE WORK

- Testing level of **domain familiarity**.
- Investigate the impact of participants' knowledge of domains **different** from the domain of the system under study.

THANKS!