Supplemental Material

CBE—Life Sciences Education

Becker *et al.*

Introduction

We strongly believe that teaching assistants are a vital part of the instructional team and have the potential to make large, positive impacts on students' experiences and learning outcomes. This is not an unfounded belief. We have shown, through a research project carried out over the 2013-2014 academic year, that the teaching strategies and instructional tools we will be training you to use were able to improve students' probability of passing the course by 66% compared to a control class.

As such, we take your role in instruction very seriously. We know you have the ability to make an enormous difference in your students' lives, and we expect you to give your teaching responsibilities the respect and effort that your students deserve.

Over the course of the quarter, you will be evaluated on your skill at a specific set of core instructional techniques, and whether you meet defined performance expectations. These evaluations, and your ability to improve based on feedback on your performance, will determine whether you are hired back for another quarter and/or whether you will receive a good recommendation for future teaching positions.

The performance expectations and instructional techniques are detailed in this document. Please do not hesitate to ask us any questions you may have about these techniques or your responsibilities for the course. Quality instruction is our passion - and we hope to help you develop your passion, along with your ability, during your time on the Bis2A team.

Performance Expectations

1. You will come to TA training every week prepared by having:
    - read the manual activity for the upcoming week,
    - looked at your students' OLI results for the pre-discussion, and
    - made PowerPoint slides with warm-up questions to address your students' top three misconceptions from the OLI.
2. You will start your discussions on time. Student work is due at the beginning of class and should be collected within the first 2-3 minutes of class in an organized manner.
3. You will make a good faith effort to know all of your students' names **by the second week of class**. Knowing and using your students' names is vital to creating a sense of community.
4. Your grades will be entered into the gradebook, and homeworks returned to your students, within one week of collecting each homework.
5. You will attend lectures at your agreed upon times and actively circulate the classroom to assist students with in-lecture question sets.
6. You will be available to proctor all mid-terms and finals for Bis2A. If you can not be available on a given day, you must find your own reliable substitute, and send their contact information to the coordinator.

Breakdown of Time Commitment

	Experienced TAs	**New TAs**
Preparation	1-2 hrs/week	2-3 hrs/week
TA training	2 hrs/week	2 hrs/week
Teaching	6 hrs/week	6 hrs/week
Grading	2-3 hrs/week	2-3 hrs/week
Office hours	2 hrs/week	1 hr/week
Lecture attendance	*8 hrs/qtr*	3 hrs/week
Exam proctoring	*3 hrs/qtr*	included in lecture attendance
Total	13-15 hrs/week + 11 hrs/qtr = 14-16 hrs/week	16-18 hrs/week

Instructional Techniques

1. Cold Call
2. Normalize Error
3. Right is Right
4. Circulate and Check for Understanding
5. Stretch-it
6. Praise Effort/Praise Improvement
7. Debrief
8. Without Apology

Theory and Practice:

1. Cold Call

Theory:

Students learn most when they are actively thinking about the material. The Cold Call technique maximizes student attentiveness, and therefore time-on-task, by requiring that every student be prepared to answer a question at any time. High rates of cold call (>1/3rd of students called on per class) have been shown to increase student voluntary participation, as well as increase student comfort with speaking in class (Dallimore, 2012). As opposed to volunteer response, which leads to a biased representation of class knowledge, Cold Call enables you to systematically check students' understanding by including all students in the conversation. Cold Call also

speeds up the rate of information flow, which further increases student attentiveness. Cold Call keeps you in control of your classroom.

Practice:

1. Tell students the first day of class that you will be calling on **every single one of them every single day** - and then do it. Do not be apologetic - this is for their benefit. Feedback from previous classes shows that even students who don't like the idea of Cold Call appreciate the increased energy that this brings to discussion, and the way it holds everyone accountable.
2. Cold Call should be your primary way of eliciting student response. Do not use it as a backup for when there are no volunteers.
3. Cold Call should be positive - it is not a punishment.
4. **Question. Pause. Name.** Asking the question before calling on someone maximizes the mental work the rest of the class is doing (because everyone starts to think about the question). In some cases, **Name. Pause. Question.** is appropriate - for example, when transitioning from whole class responses back to individual cold calling.
5. Precall - if you notice a student is having difficulty with a concept, tell them you are going to cold call them on it later in the discussion. This gives them a chance to prepare, while still holding them accountable.

2. Normalize Error

Theory:

Making errors is a natural part of the learning process. Framing errors as natural, and even beneficial to learning, is thought to help reduce student anxiety, leaving more mental energy available for thinking about the problem at hand. Some studies indicate that when learners are told not to worry about making mistakes, their ability to apply knowledge to new situations (adaptive transfer) may increase (Bell & Kozlowski, 2008, Keith & Frese, 2008). A focus on analyzing errors may also increase students' metacognitive skills, or ability to assess their own knowledge and thinking process (Keith & Frese, 2005).

Practice:

1. Have a few prepared phrases to use when students give you an unexpected answer. For example:
    - Thank you for giving that a try. It wasn't correct - but let's see if we can figure out why together.
    - (Name) just gave us something important to think about. Let's spend a minute defining these terms so we are all clear on the differences between X and Y.
    - I can see why you might think that. This concept is a little tricky. Let's take some time to think about this and discuss with your groups.

2. Be a deliberate thinker about your own mistakes. If you make an error in class, and catch yourself (or even better, if a student catches your mistake), don't gloss over it. Use it as tool to explicitly explore your thinking process and where you went wrong. Ask the class if anyone can tell you what the mistake was or what the underlying incorrect assumption was.
3. Important: Normalizing error does NOT mean accepting incorrect answers or telling students they are "close" to the correct answer when they are not. Normalizing error is about creating a classroom culture where errors are an acceptable first step towards getting to the correct answer. See Right is Right, below, on how to set a high standard for correctness and knowledge.

3. Right is Right

Theory:

Instructors often feel the need to reassure students who take the risk of answering a question in class, even when their answer is not correct. However, as soon as you've said "right" or "yes", many students will stop listening, even when there is an important distinction you want to make between the student's response and the correct answer. The Right is Right technique holds students to a high standard for accuracy. By consistently using this technique, you can reduce students' confusion and help them to develop their communication skills.

Practice:

1. Don't affirm a student's answer unless it is 100% correct (eg. Don't say, "You're right, but . . . ")
2. Always use correct vocabulary, and insist that your students use it too.
3. Insist that students answer the question you asked, not the one they wish you had asked, or thought you asked.

Examples:

- That's part of the answer. Can you give me the rest of it?
- Most of what you said was right - but you used one vocabulary word incorrectly. Can you correct that?
- I like most of what you're saying, but . . .
- That's a good start, but can you elaborate on that a little?
- That's a good example, but I asked for a definition. Can you give me a definition of . . . ?
- You're jumping a few steps ahead of us. Could you give me the answer to just this next step?

4. Circulate and Check for Understanding

Theory:

These two techniques should be used together to help monitor classroom-wide understanding of the material. Circulating through the classroom, and engaging with

students in their small groups or individually holds everyone responsible for their knowledge. Check for Understanding means gathering data from the class to see whether students are able to integrate and use the information that has been presented.

Practice (Circulate):

1. Break the plane (**move away from the front of class**) consistently and often.
2. Don't just walk around the room and look over students' shoulders - you should be able to engage any student or group in conversation at any time.
3. Try some of these conversation starters:
    - Can you tell me about the problem you're working on?
    - How do you know that's the answer?
    - (Name), can you explain to me why your group chose that answer?
    - It looks like there's some good debate over here. Tell me what you're thinking.
4. Circulate unpredictably - change directions and stop at different groups/people each time.
5. Monitor your time - sometimes a group may need a few minutes of your attention, sometimes 30 seconds will do.
6. Use this time for Precise Praise/Praise Effort/Praise Improvement

Practice (Check for Understanding):

1. Ask the same question multiple times (in different ways) until students are consistently answering it correctly. Use Stretch-It to make sure the information is integrated.
2. Vary the difficulty level of your questions and ask as many as you can. Every question a student answers is another data point for you.
3. When Circulating, listen and look for what types of errors students are making.
4. Use information from student responses and Circulation to re-direct your questioning and Debriefs.

5. Stretch-it

Theory:

A student answering your question correctly is not the end of the process. Once you've established a baseline of knowledge, it's time to build to higher levels of application and synthesis. The Stretch-it technique involves two factors: 1) getting students to stretch the boundaries of their knowledge by asking a related (often more difficult) follow-up question, and 2) asking students to explain the reasoning behind their initial answer. By engaging in directed Stretch-it, you help students develop the higher-order thinking skills they will need in order to apply the knowledge they have gained.

Practice:

1. Make it a habit to **ask students to explain *why*** they think the way they do. You might not do this for every question, but students should be aware that you're likely to ask them to explain their reasoning when calling on them.
2. When introducing a question, ask students to be prepared to explain why they chose their answer.
3. If some students are answering your lower-level (knowledge) questions easily, start incorporating some higher-level (application, prediction, synthesis) questions.
4. Use follow-up questions, either with the whole class, or with an individual student. Start with a simple question and then ask two or three more questions of increasing difficulty on the same topic.

6. Praise Effort/Praise Improvement

Theory:

Speaking broadly, students may have either a performance mindset, or a mastery mindset. With a performance mindset, students often prioritize avoiding the appearance of failure, rather than prioritizing learning itself (Bell & Kozlowski, 2008). This can lead to a resistance to taking risks (Elliot & Dweck, 1988), which, as discussed above (Normalize Error) can reduce learning and development of metacognitive skills. By including praise based on effort, we can move our students towards a mastery mindset, shifting their focus away from avoiding looking stupid towards the learning process itself. Similarly, praising improvement explicitly recognizes student growth, moving them away from a fixed mindset ("I'm just no good at this.") to a growth mindset ("If I work hard, I can become good at this.") (Dweck, 2007).

Practice:

1. Praise publicly or privately, depending on the situation.
2. Praise needs to be (and sound) sincere.
3. Praising for effort and improvement doesn't mean you can never praise for knowledge ("Yes. That's *exactly* the right answer. Great job!"), but be conscious of how you are using the three different types of praise in your classroom. Overuse of praise for knowledge can create a classroom culture of a fixed, performance mindset - where students believe that they "just aren't good at this" and so shouldn't bother to try.

7. Debrief

Theory:

Knowing the correct answer isn't enough. In order to be able to incorporate new knowledge into their mental model, students need to understand both why the correct answer was correct (Nielson, 2012; Smith, 2011) **and why the incorrect answers are wrong** (deWinstanley & Bjork, 2002; Turpen & Finkelstein, 2010).

Practice:

1. Before moving on from a multiple-choice question, ask students to explain why each incorrect answer was wrong (or why the commonly chosen wrong answer is wrong).
2. Ask students what would need to be different about the question in order for a particular (incorrect) answer choice to be correct.
3. Ask students what misconception or error is represented by a particular (incorrect) answer choice.

8. Without Apology

Theory:

You may sometimes be tempted to sympathize with students that you find some of the material "boring" or that the learning style for this class takes more effort than for their other classes. While both of these things may be true, recognize that the curriculum and teaching methods for this course (lecture and discussion) are highly planned and based on a large body of current research in education, cognitive science, and psychology. This learning style **is** hard, and that's why it works. If the students don't believe that their TA believes in these methods, they won't either. In fact, they will begin to question everything you do, wasting valuable time that is better spent thinking and practicing. Don't hurt your students' chances of success by undercutting the implementation of these techniques.

Practice:

1. We know these techniques work. Make it clear to your students that we're giving them the best instruction possible.
2. You can acknowledge that this stuff (both the material and the techniques) is hard. It **is** hard. But it's hard because they're using the brains, they're making them work, and that's the only way anyone ever learns anything.

References:

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Turpen, C., & Finkelstein, N. D. (2010). The construction of different classroom norms during Peer Instruction: Students perceive differences. *Physical Review Special Topics - Physics Education Research*, *6*(2), 020123. doi:10.1103/PhysRevSTPER.6.020123

Notes for practice adapted from Moylan, J. (2012). Quick Reference Guide to Teach Like a Champion By Doug Lemov.

TA name: **Observation date:** **Observation topic:**

Class starts:

Instruction starts:

		Individual	Group	Total	% CC 0 or 1	% CC > 1
Total # of participation events	V					
	CC					
Total # of different students	V			*		
	CC			*		

Observation	**Tally marks**		**Total**
RIGHT is RIGHT *Hold to high standard of accuracy.*			
STRETCH IT ***Encouragement*** *for students to focus on logic (priming)*			
Explain logic *- students explicitly asked to explain reasoning*			
Prior Knowledge *- students explicitly asked to connect to previous knowledge*			
CIRCULATE *Interacting with small groups*	# interactions	# groups	
NO APOLOGY *Positive framing of work (+/-)*	(+)	(-)	Ratio
FOLLOW UP/ DEBRIEF ***INSTRUCTOR*** *explains why incorrect answers were incorrect*			
STUDENT *explains why incorrect answers were incorrect*			

+POSITIVE feedback *count*	Class	Total	Student	Total
Effort				
Improvement				
Knowledge				
- NEGATIVE feedback *count*	Class	Total	Student	Total
Effort				
Improvement				
Knowledge				
NORMALIZE ERROR *Explicitly remind students that errors are natural and useful*				

Notes:

1) *Do not disturb or interrupt the class for any reason unless specifically asked to participate by the TA.*
2) *Mark cold-calls, volunteers, group participation, small group interactions and absences on seating chart provided by the TA.*
3) *Use back of observation sheet for general observations.*
4) ** Total number of different students participating is not the sum of individual and group.*

Pre-observation self-evaluation

The following questions are meant to provide a framework for structuring classroom observations. Please answer as accurately and completely as possible. Your answers will help us focus our feedback on specific aspects of teaching that will be most helpful for you individually.

1) What are you actively working to improve this week (e.g. organization, mastery of content, consistent use of techniques, etc.)?

2) List any instructional techniques that you feel particularly strong in. Give an example of how you have used them in class:

3) Name one or two instructional techniques you would like to improve.
   We will work on setting personalized goals for these techniques in our one-on-one meeting.

4) Are you having any classroom management and/or disciplinary issues?
   If there are specific students you feel need special attention, and you would like to discuss strategies for helping them, please let us know.

During our visit to your classroom, we will be unobtrusive and not interact with you or the students in any way unless you request our participation. We will be quantifying your classroom practices and looking for ways to increase use of the eight core techniques listed in your instructional guide. This observation is meant to help you grow as an instructor and provide the most effective learning environment for your students as possible.

Please let us know if there is anything else we can do to make the observation process more helpful for you:

TA name: **Coder name:**

Class date: **Date coded:**

Section:

Technique Codes						
RIGHT is RIGHT	Same					
	Diff					
STRETCH IT						
Follow-up	Same					
	Diff					
Explain logic	Same					
	Diff					
CIRCULATE		Pass	Mod	Act		
NO APOLOGY		(+)	(-)	Ratio		
NORMALIZE ERROR						

Feedback Codes				
+POSITIVE feedback	Class	Total	Individual	Total
Effort				
Improvement				
Knowledge				
- NEGATIVE feedback	Class	Total	Individual	Total
Effort				
Improvement				
Knowledge				

Participation Codes						
		Individual	Group	Total		
Participation events	V					
	CC					
	Q					
Different students	V			*	% CC	% Part.
	CC			*		

Notes:

1) *Mark cold-calls, volunteers, group participation, small group interactions and absences on seating chart.*
2) ** Total number of different students participating is not the sum of individual and group.*

General Instructions

Logistics:

1. Code in pencil and make final, clean copy in pen.
2. Code only the 1st hour of each class. This will span multiple video clips.
3. After finishing an observation, enter it in the "Video_coding_progress" spreadsheet and enter your code tallies into the "Video_code_log" spreadsheet. Make sure you enter in the correct slot (you are assigned either "coder 1" or "coder 2"). **NEVER CHANGE ANOTHER PERSON'S ENTRY.**
4. At least once a week, meet with your coding partner to discuss discrepancies. If you notice major differences in your codes (>3 events different for any code, eg. You coded 13 Participation - Individual - Cold call, but your partner coded 17), try to resolve them. This is most important for uncommon codes. Small differences are ok, they likely reflect one of you simply missing an event or two. Larger differences probably reflect a difference in understanding of the codes. If you notice major inconsistencies, please contact me right away. We can set up a meeting to discuss and get both of you on the same page.
5. After you have met to discuss each video, enter the date in "Date validated" in the "Video_coding_progress" spreadsheet. Update your codes to reflect any changes made after discussing with your partner.
6. You can drop off completed code sheets as any time to the designated envelope outside my office door. Take a picture of each code sheet first so that we retain a copy in case a paper copy gets lost. Do not leave code sheets anywhere but the designated envelope.
7. Email me to get a new code disk.

General notes:

1. In classrooms with undergraduate learning assistants, LAs might circulate and/or lead part of the class. Mark all of their activities as you would the instructor, but use an "s" (lower case s) as the symbol instead of a normal tally mark.

Code definitions

Family 1 - Participation events

Family 1 codes are marked on classroom maps and then tallied at the end of the observation period.

Mark the following on the classroom maps in location corresponding to student seat:

C - Individual - Cold call
V - Individual - Volunteer
Q - Individual - Student question
A - Absent (Student must be absent the entire observation period to count as Absent.)
(C) - Group - Cold call
(V) - Group - Volunteer
~~C~~ - Individual - Cold call - non-responsive
~~(C)~~ - Group - Cold call - non-responsive

Code definitions:

Participation event - Individual - Cold call

Instructor calls on a student who is not raising their hand or otherwise indicating that they would like to volunteer. The student has not had an opportunity to discuss this specific question with their group. If student does not respond or responds with *only* "I don't know" - mark as non-responsive.

Participation event - Individual - Volunteer

Instructor calls on a student who is raising their hand or otherwise indicating that they would like to volunteer. If a single student yells out an answer without being called on specifically, this also counts. The student has not had an opportunity to discuss this specific question with their group.

Participation event - Individual - Student question

A single student asks the instructor a question during whole-class discussion time. They may or may not raise their hand. This counts even if the instructor does not respond to the question.

Participation event - Group - Cold call

Instructor calls on a student who is not raising their hand or otherwise indicating that they would like to volunteer. The student has had an opportunity to discuss this specific question with their group. If student does not respond or responds with *only* "I don't know" - mark as non-responsive.

Participation event - Group - Volunteer

Instructor calls on a group which is not volunteering but does not specify who in that group needs to answer. The student(s) who answer

are considered group volunteers. When an instructor asks for a group to volunteer to answer a question, this also counts.

Family 2 - Feedback

Positive/negative feedback must be explicitly positive or negative. The following neutral feedback comments do not count regardless of the instructor's tone:

"Correct." "Yes." "That's the right answer."
"Incorrect." "No." "That's not the right answer."

Code definitions:

Positive feedback - Individual - Effort
Instructor praises an individual for effort. Examples: "I can tell you're trying hard." "Thank you for trying to answer that." "You must really be studying."

Positive feedback - Individual - Knowledge
Instructor praises an individual for knowing the answer. Examples: "Great job." "You really know your stuff." "You're so smart."

Positive feedback - Individual - Improvement
Instructor praises an individual for improvement. Examples: "You seem a lot more comfortable with this this week." "I'm really happy with your improvement."

Positive feedback - Whole class - Effort
Instructor praises whole class for effort. Examples: "You guys really did the reading this week." "Great effort, guys."

Positive feedback - Whole class - Knowledge
Instructor praises whole class for knowing the answer. Examples: "Great job guys." "You all really know your stuff." "You guys are so smart."

Positive feedback - Whole class - Improvement
Instructor praises whole class for improvement. Examples: "You all seem a lot more comfortable with this this week." "I'm really happy with how much you're all improving."

Negative feedback - Individual - Effort
Instructor makes a negative statement to an individual about effort. Examples: "You're not trying." "You need to try harder." "You must not be doing the reading."

Negative feedback - Individual - Knowledge
Instructor makes a negative statement to an individual about not knowing the answer. Examples: "You really don't know this." "That's a bad answer."

Negative feedback - Individual - Improvement

Instructor makes a negative statement to an individual about lack of improvement. Example: “You’re doing worse this week.”

Negative feedback - Whole class - Effort

Instructor makes a negative statement to the whole class about effort. Examples: “You’re all not trying.” “You all need to try harder.” “Many of you aren’t doing the reading.”

Negative feedback - Whole class - Knowledge

Instructor makes a negative statement to the whole class about not knowing the answer. Example: “I’m really disappointed that none of you know this.”

Negative feedback - Whole class - Improvement

Instructor makes a negative statement to the whole class about lack of improvement. Example: “You’re all doing worse this week.”

Family 3 - Technique

Right-is-Right - Same student

Student gives an incorrect, partially incorrect, or incomplete answer. Instructor asks them additional questions or gives them prompts to guide them to the correct answer. This should be coded once per student, even if multiple follow-up questions are asked. This counts even if student never gets correct answer, or doesn’t respond. If student was originally a **Cold call**, this doesn’t count as an additional **Participation** event. If student was originally a **Volunteer**, the first additional question counts as a **Cold call** and subsequent questions do not count as additional **Participation** events.

Right-is-Right - Different student

Student gives an incorrect, partially incorrect, or incomplete answer. Instructor asks a different student to supply the correct or complete answer. This should be coded once per student, even if multiple follow-up questions are asked. This counts even if student never gets correct answer, or doesn’t respond. This also counts as a new **Participation** event (**Volunteer** or **Cold call** depending on situation). Mark **Participation** event non-responsive if no response is given.

Stretch-it - Same student - Follow-up

Student gives an answer that is accepted by the instructor. Instructor then asks same student another related question. If student was originally a **Cold call**, this doesn’t count as additional **Participation** event. If student was originally a **Volunteer**, the first additional question counts as a **Cold call** and subsequent questions do not count as additional **Participation** events. This counts even if student doesn’t respond.

Stretch-it - Different student - Follow-up

Student gives an answer that is accepted by the instructor. Instructor then asks a different student another related question. This counts as one new **Participation** event per student, even if multiple follow-up questions are asked. This counts even if student doesn't respond (mark **Participation** event non-responsive).

Stretch-it - Same student - Explain logic

Student gives an answer which the instructor may or may not accept. Instructor then asks the same student to explain their reasoning (usually involves the word "why"). This counts even if the student doesn't respond. If student was originally a **Cold call**, this doesn't count as additional **Participation** events. If student was originally a volunteer, this counts as a new **Cold call**.

Stretch-it - Different student - Explain logic

Student gives an answer which the instructor may or may not accept. Instructor then asks a different student to explain their reasoning (usually involves the word "why"). This counts even if the student does not give a response (mark **Participation** event non-responsive). This counts as one new **Participation** event per student, even if multiple follow-up questions are asked.

Circulate - Passive

Instructor moves around the room but does not interact with any groups. Code this once for each time the instructor makes a lap around the room.

Circulate - Moderate

Instructor moves around the room answering student questions. Instructor does not initiate contact with students/groups. For every group that the instructor talks to, but did not initiate contact with, code this once. This may happen more than once for each group in a class period.

Circulate - Active

Instructor moves around the room and interacts with students/groups. Instructor initiates contact with students/groups. For every group that the instructor talks to, and initiated contact with, code this once. This may happen more than once for each group in a class period.

No apology (+)

Instructor introduces an event, material, or policy in a positive way. Examples: "We are going to change groups now so that you have a chance to meet everyone in the class." "This material is really difficult, but that just means you'll be really proud of yourself when you learn it."

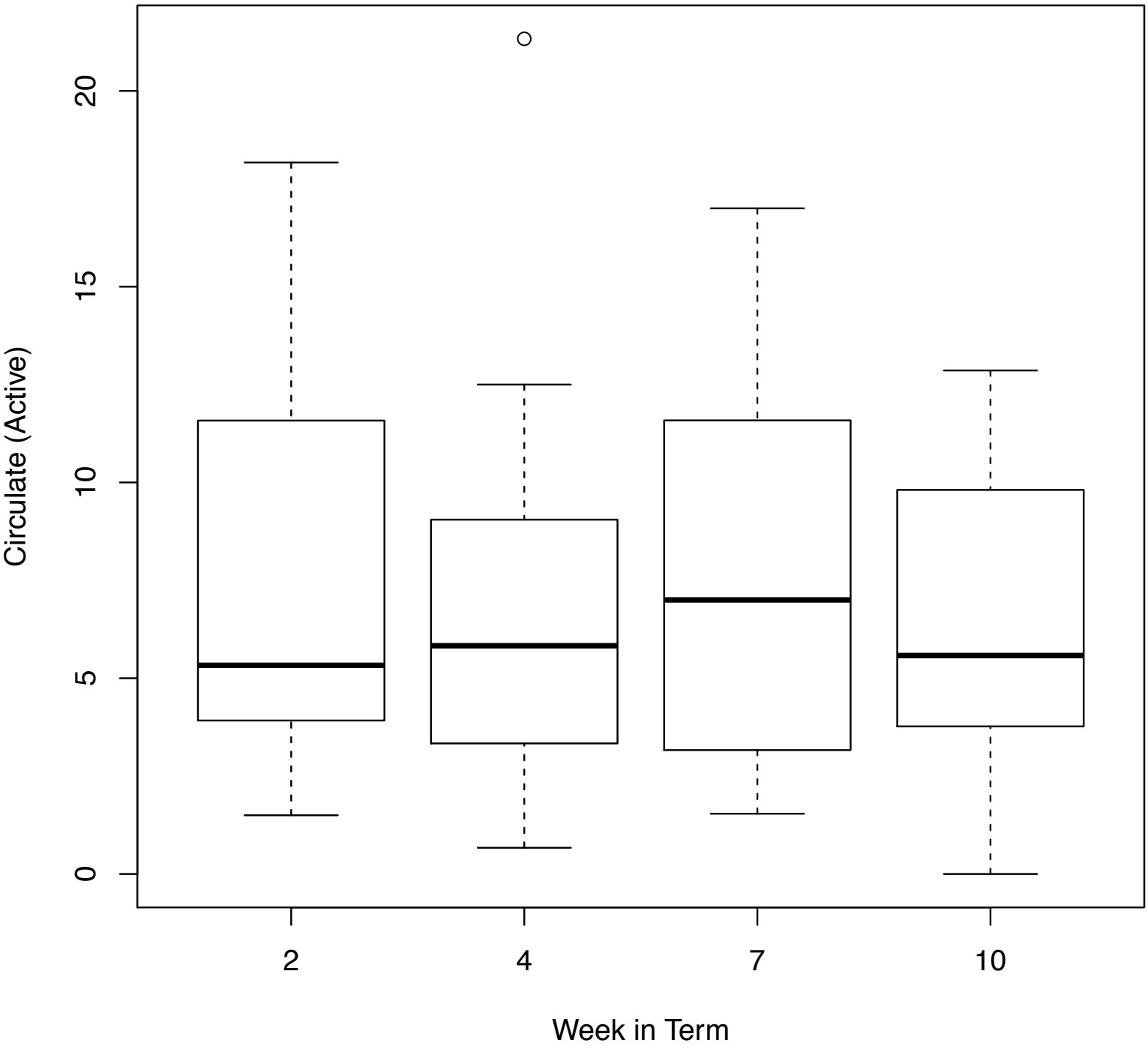
Apology (-)

Instructor introduces an event, material or policy in a negative way. Examples: “Sorry guys, but I have to make you change groups this week.” “This material is really difficult, sorry, but it’s a required part of the class.”

Normalize error

Instructor responds to a student’s incorrect or partially incorrect answer, or resistance to answering, in a positive way. Examples: “That wasn’t correct, but I’m really glad you gave it a try.” “It’s ok to make mistakes.” “Making mistakes is how we learn.” “Thanks for trying.” **Note:** This last example is also an example of **Positive feedback - Effort** and should be double-coded.

Part I: Boxplots of technique frequency and participation levels by week.



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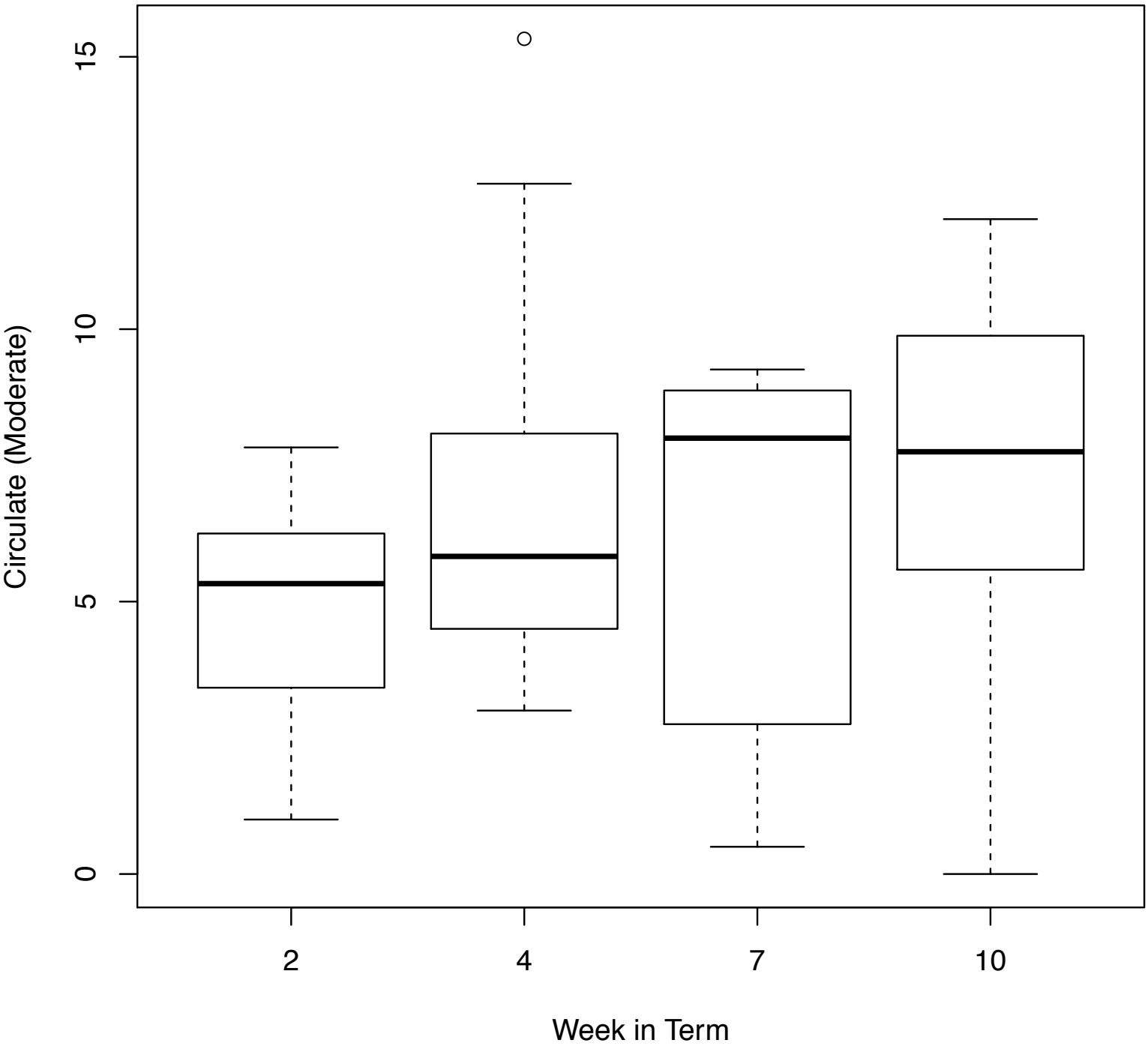

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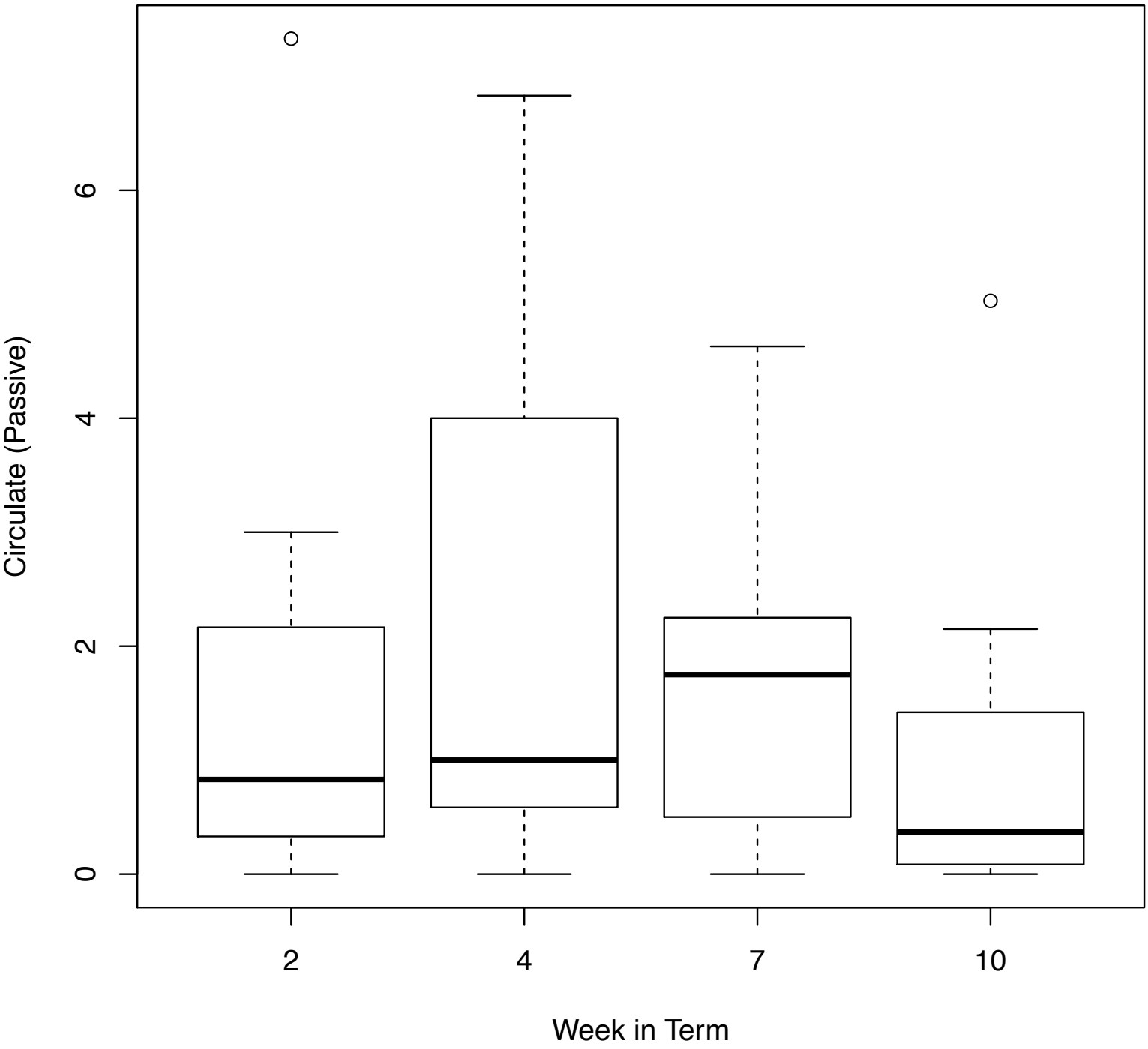

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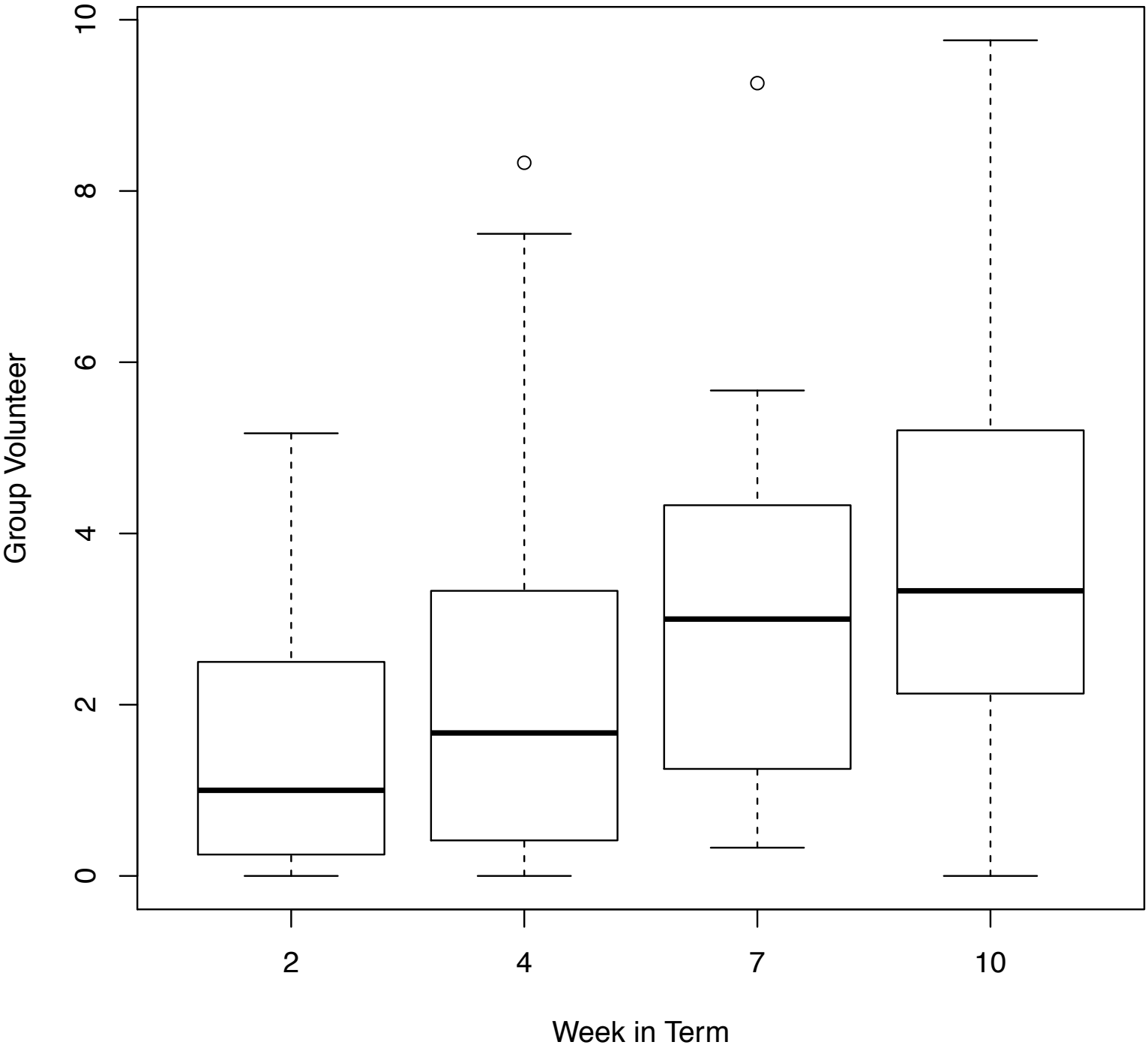

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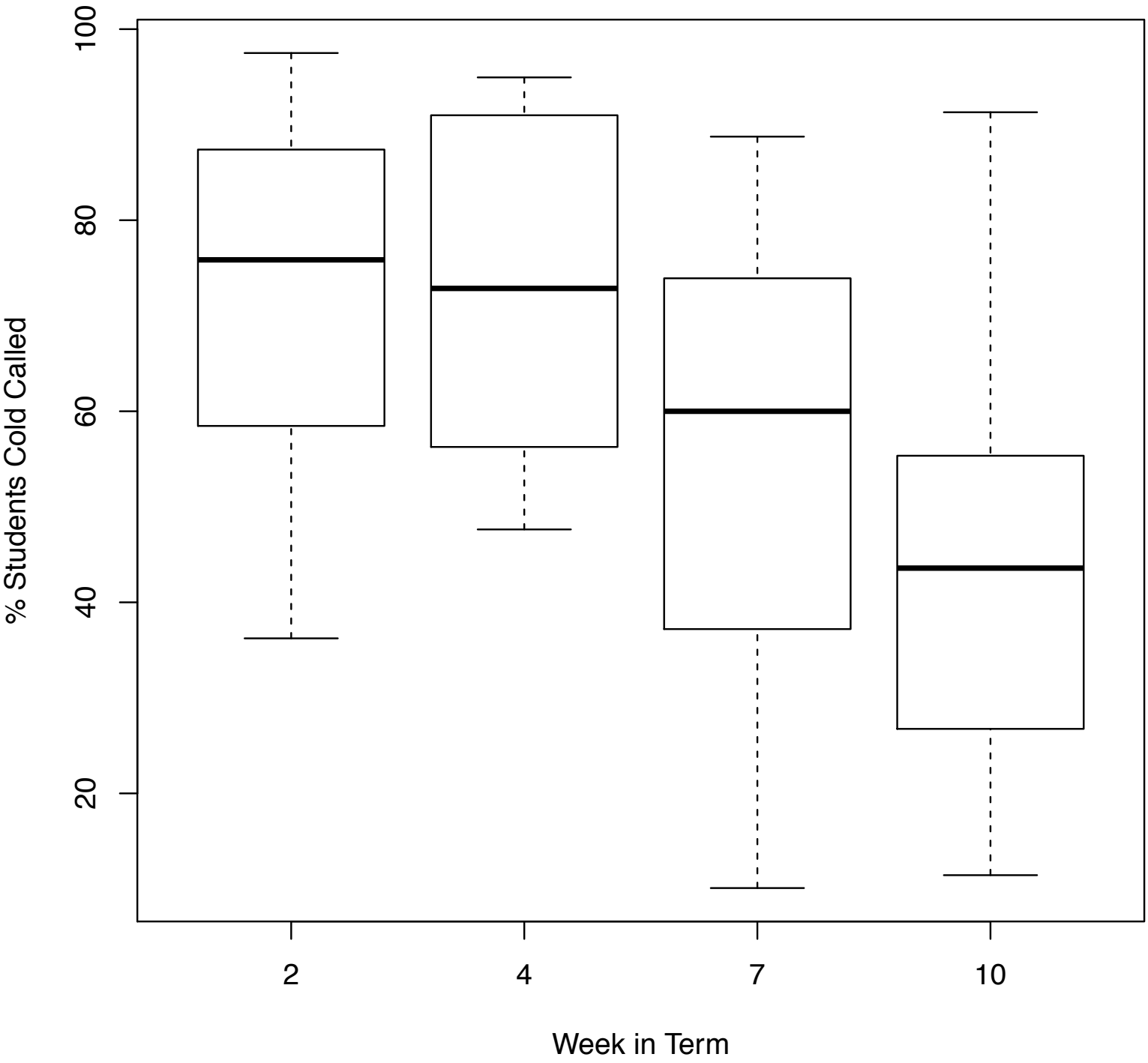

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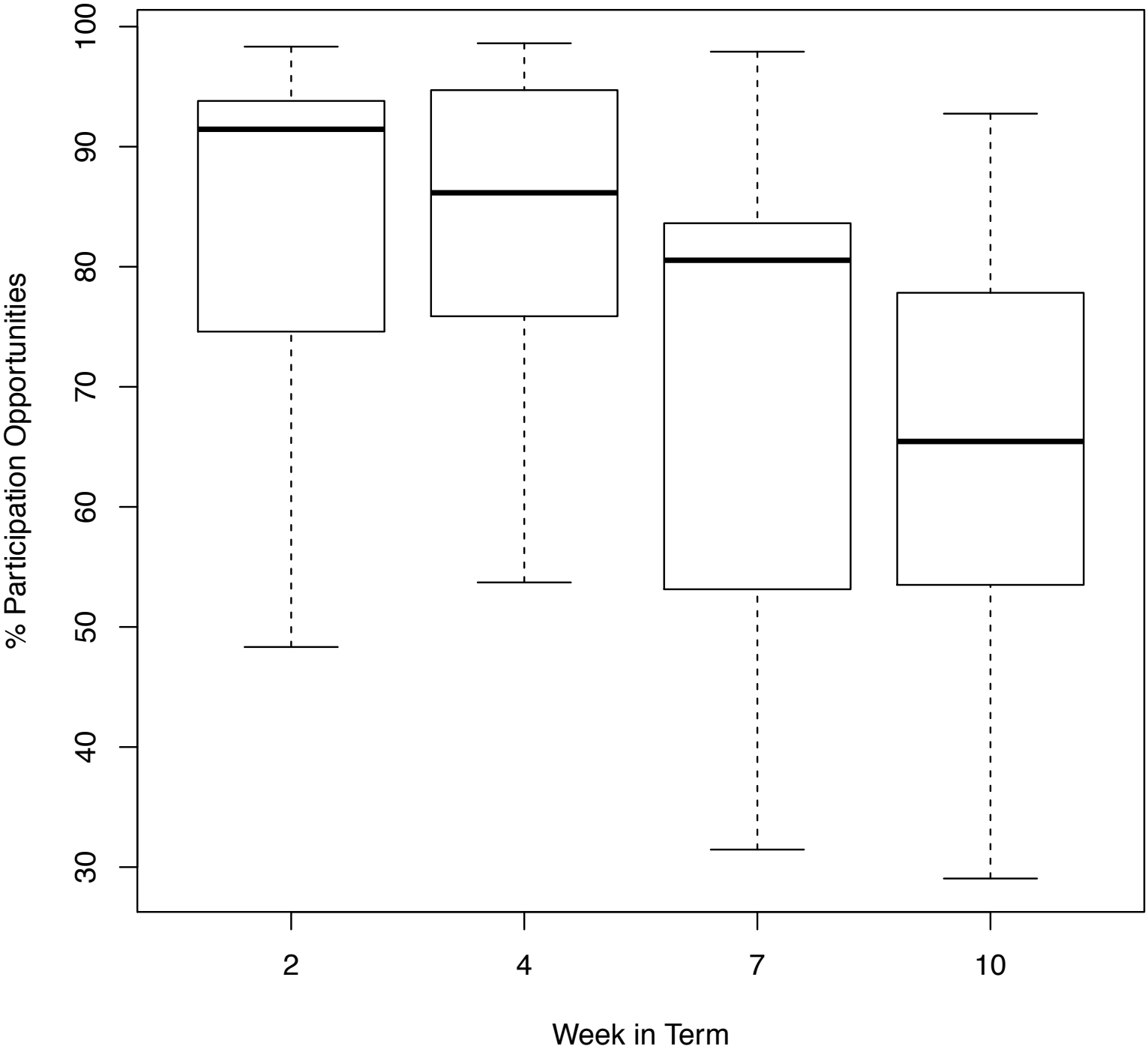

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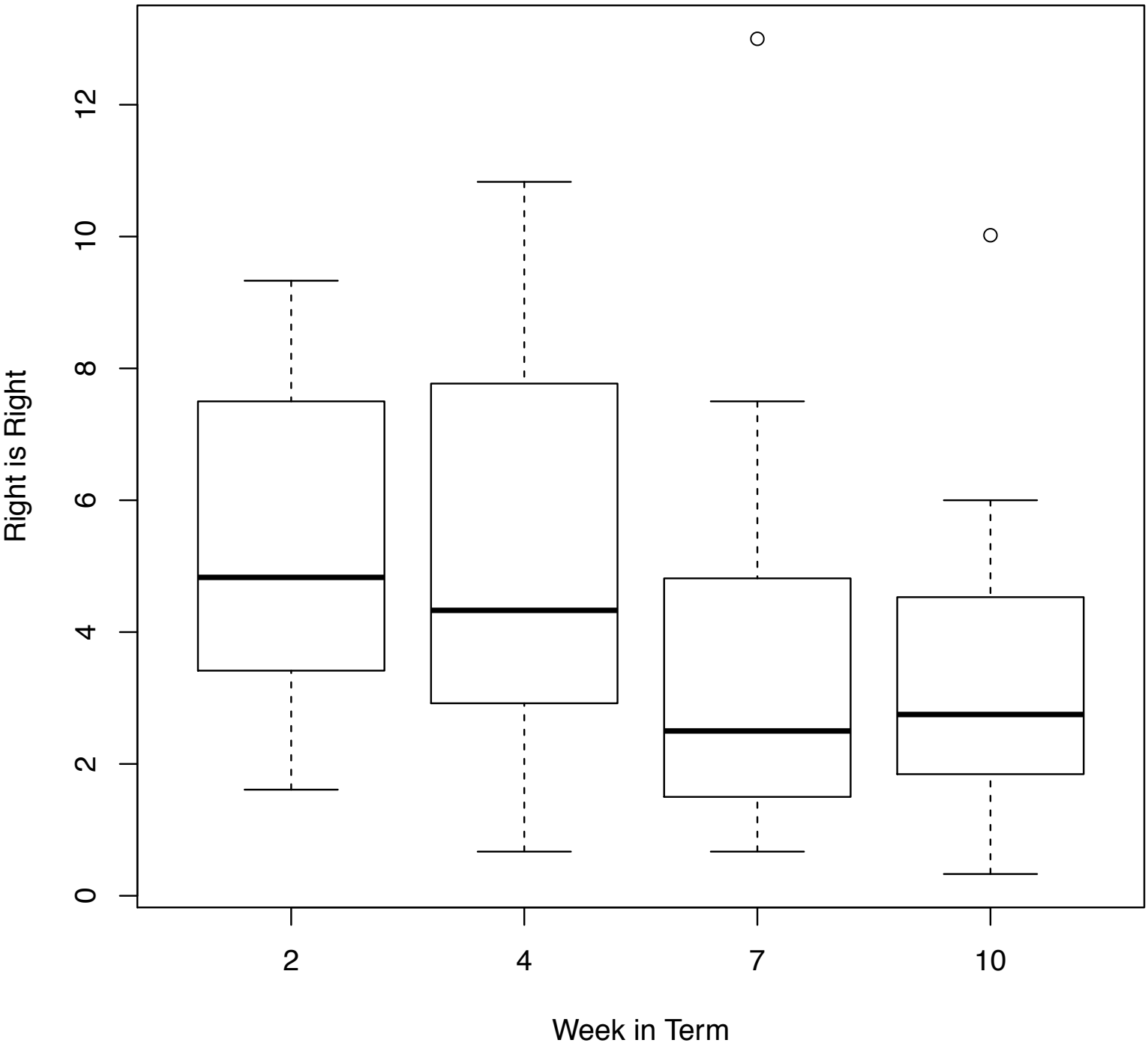
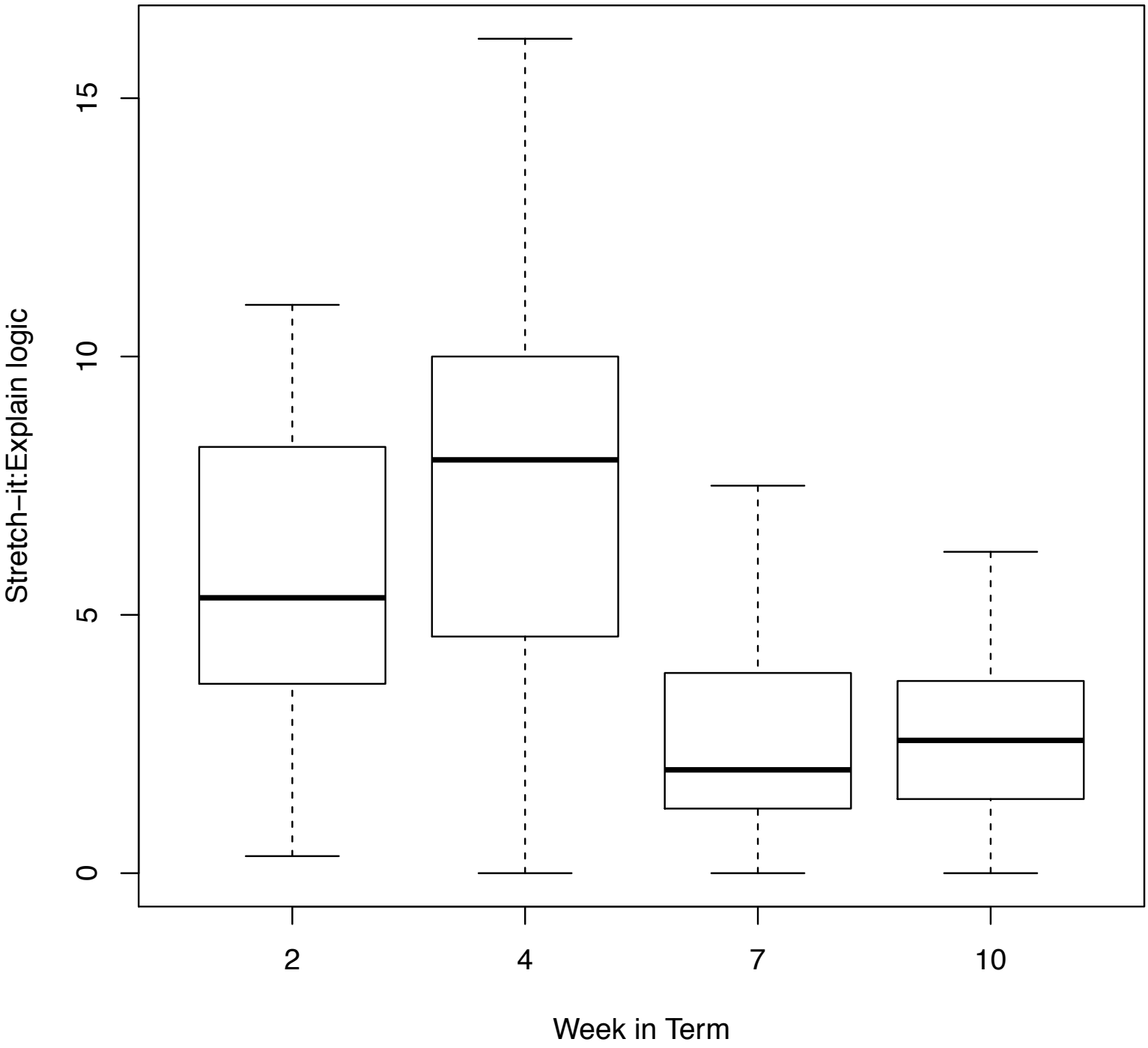


Part I: Boxplots of technique frequency and participation levels by week.



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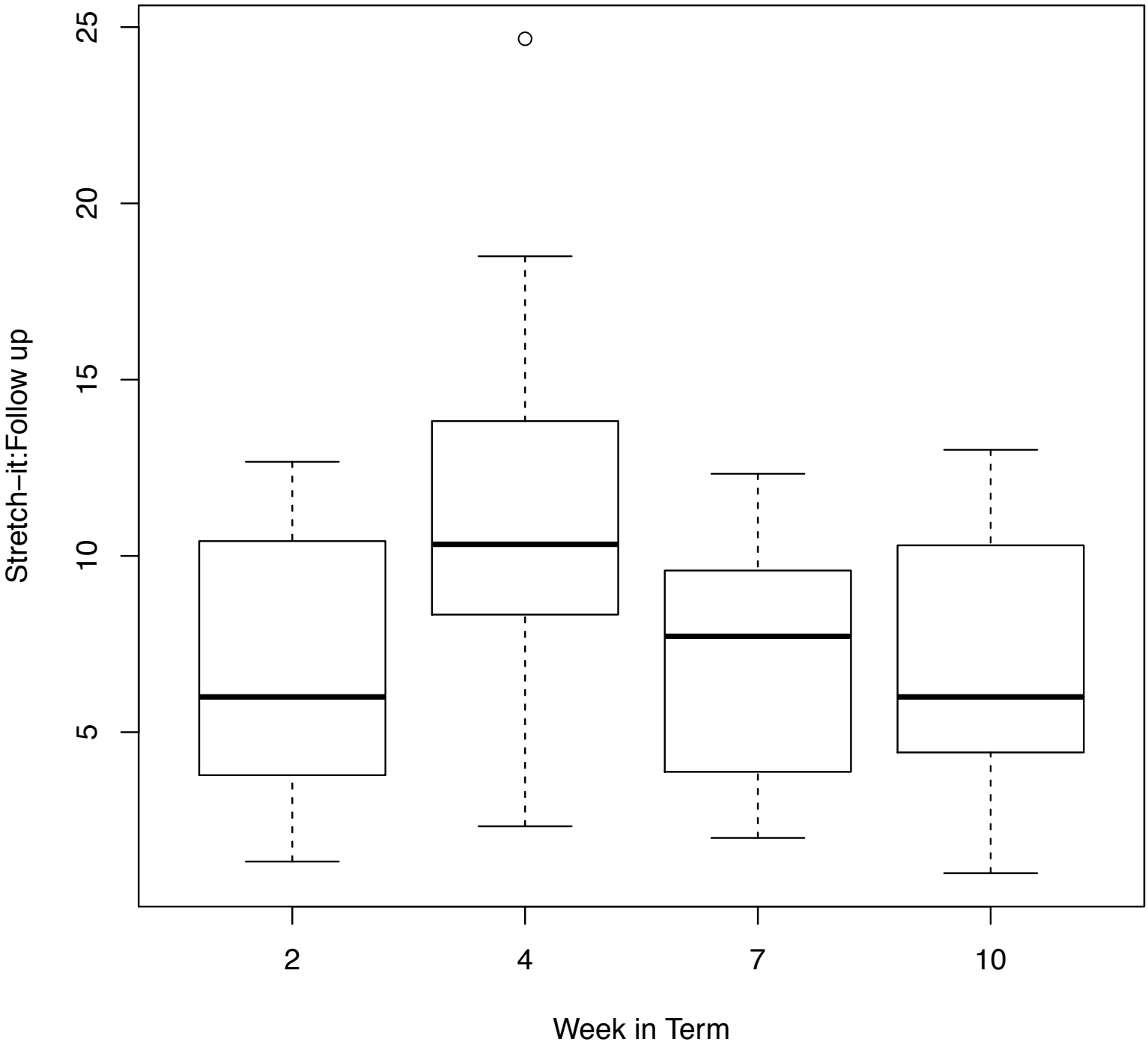

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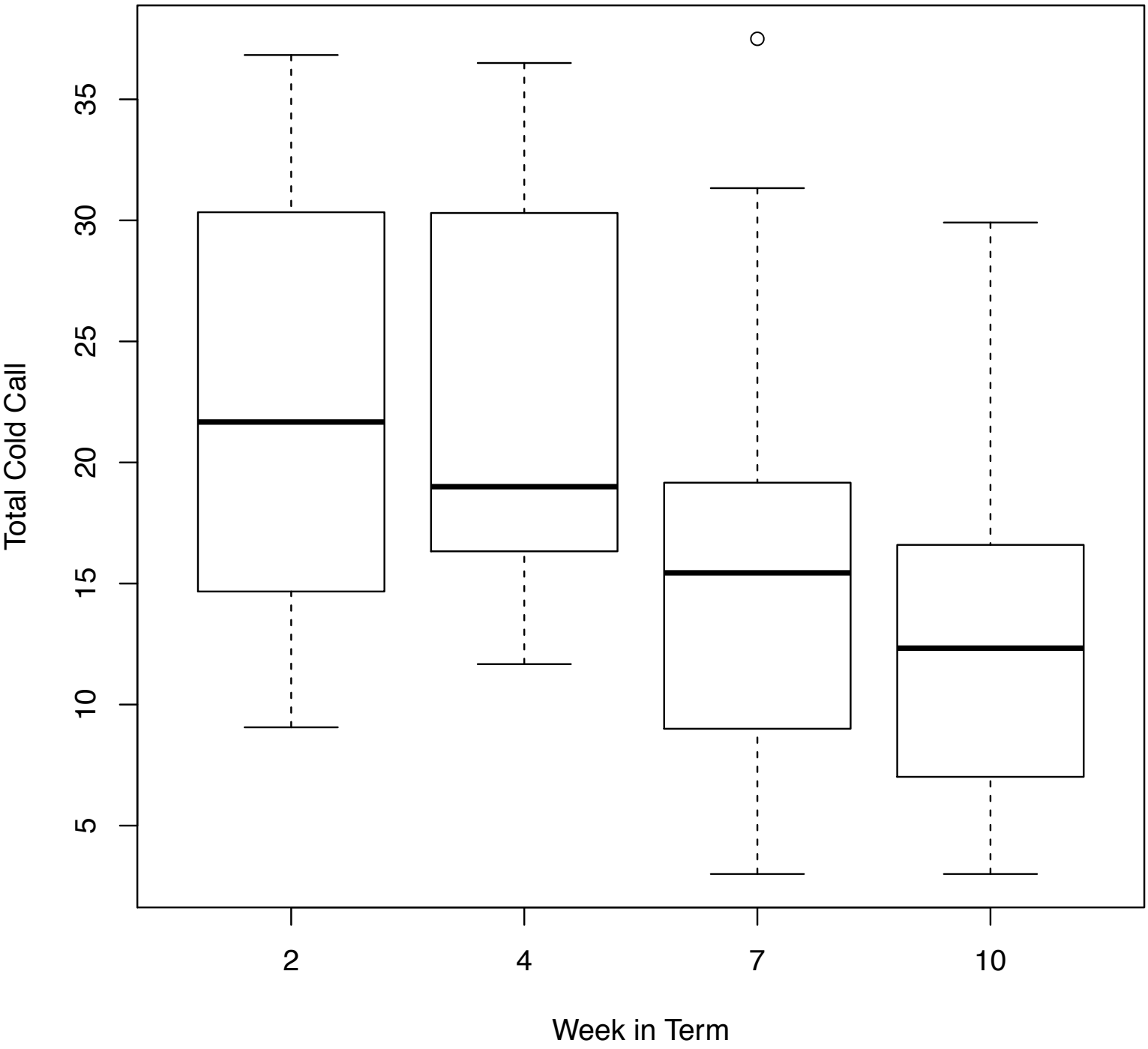

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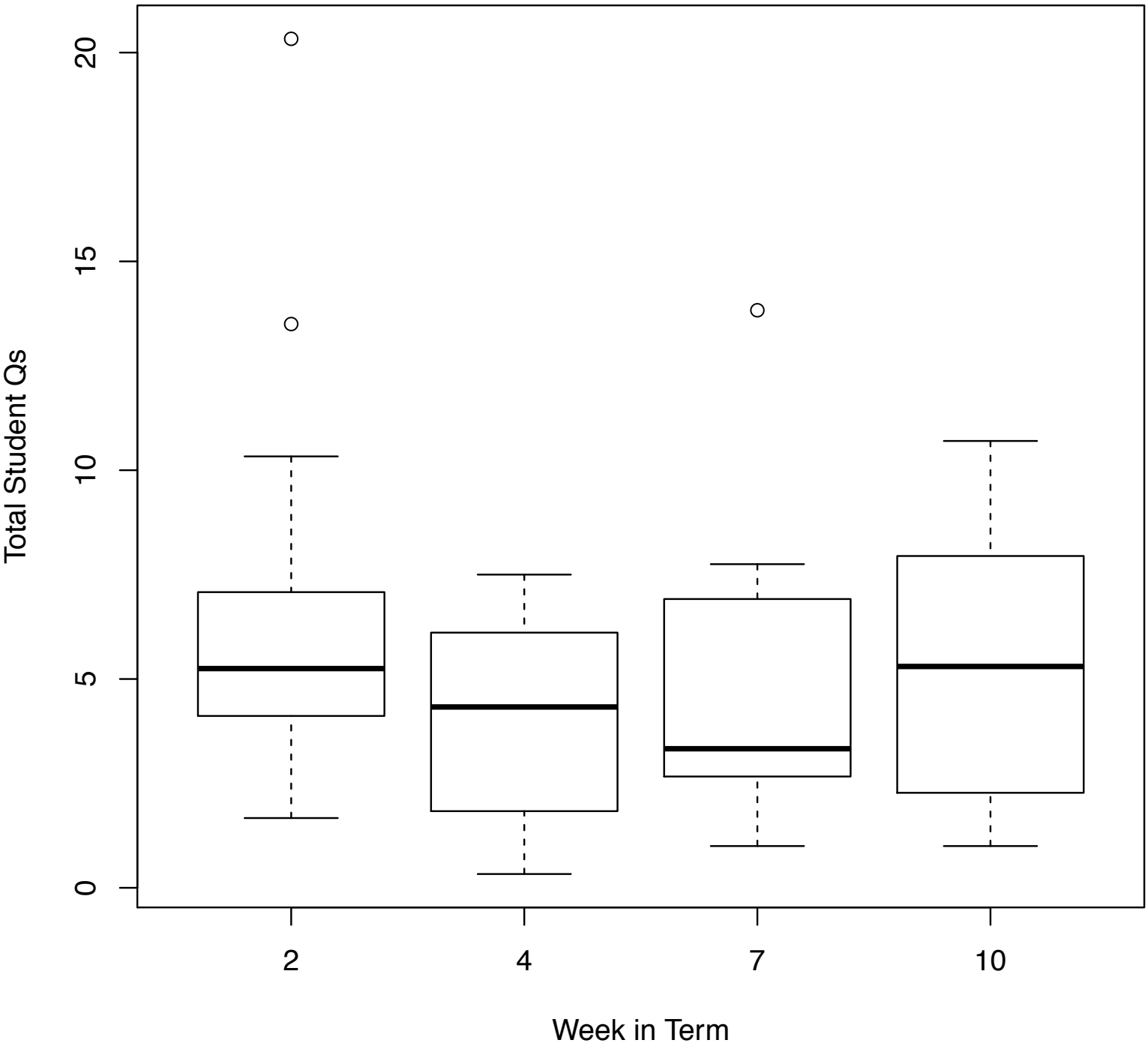

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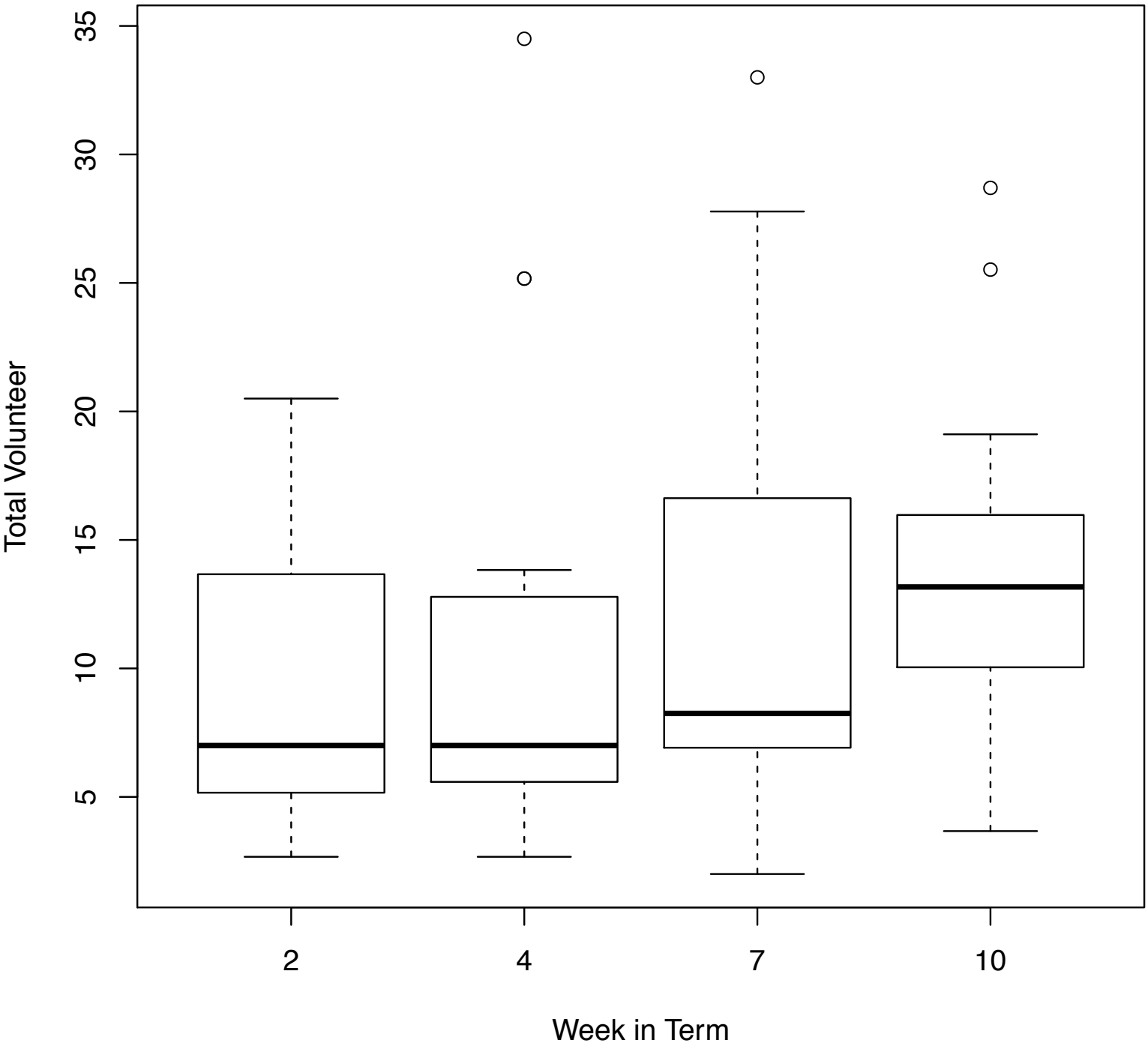
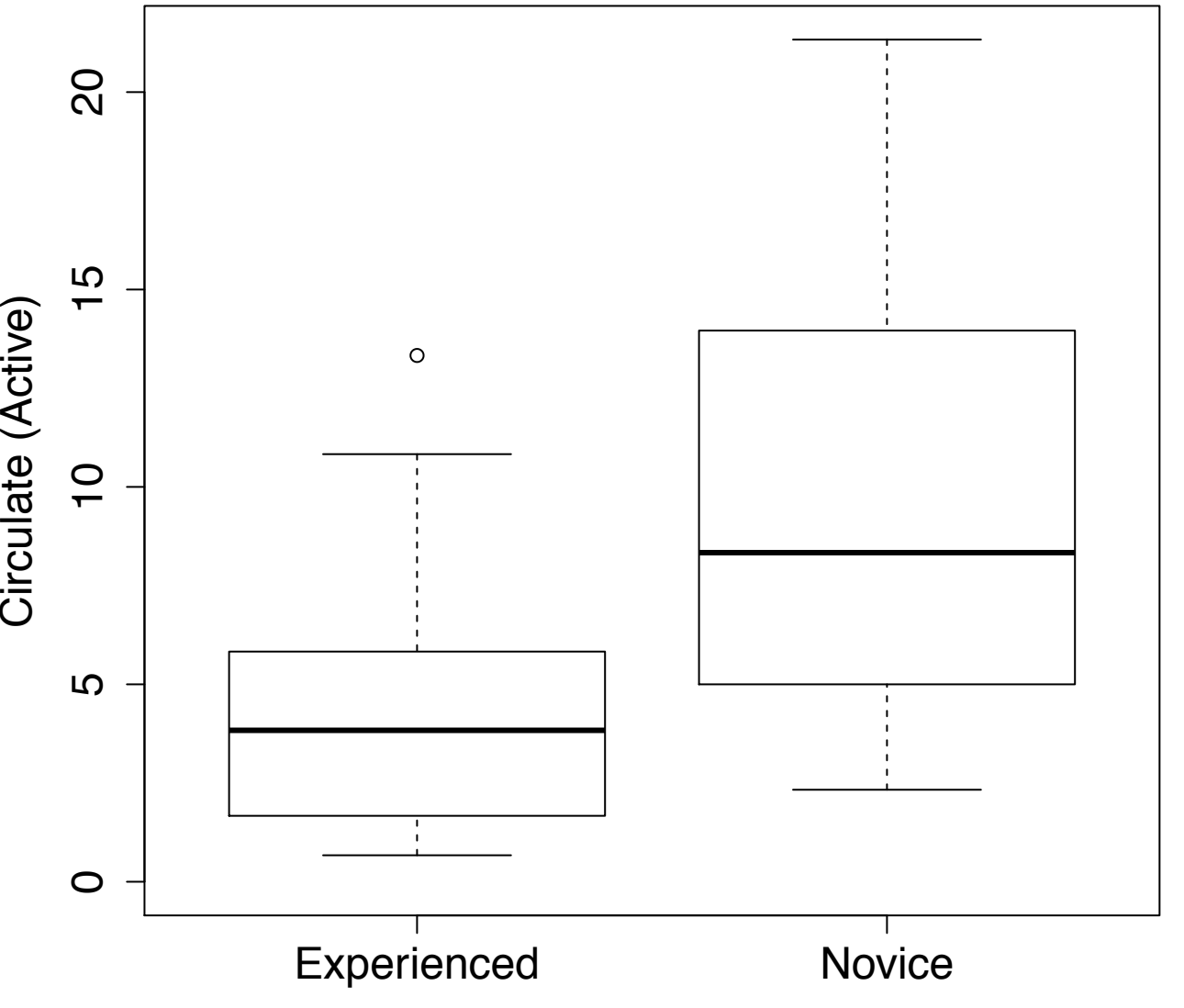
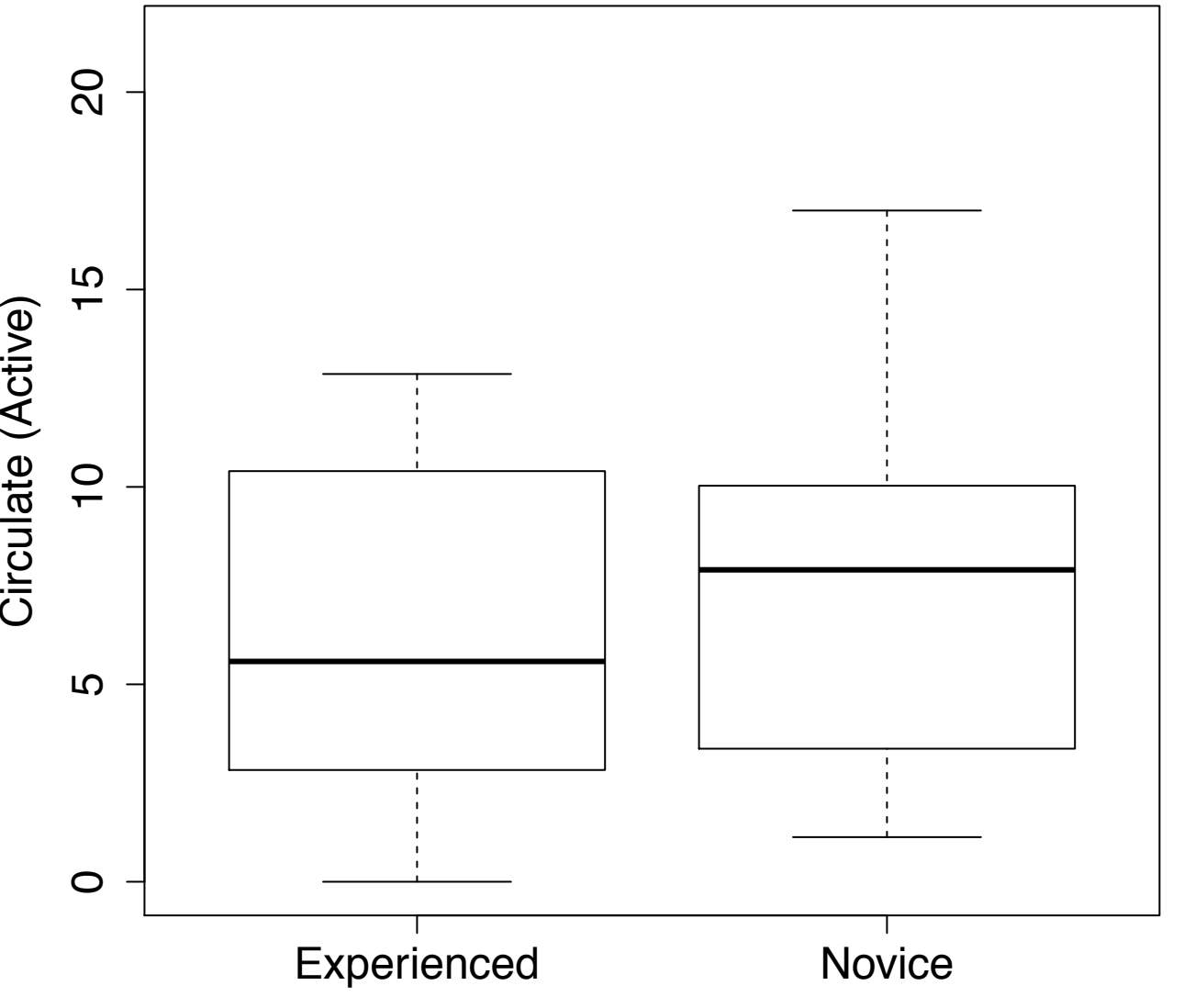


Part II: Boxplots of technique frequency and participation levels by GTA experience level (Early).



Part II: Boxplots of technique frequency and participation levels by GTA experience level (Late).



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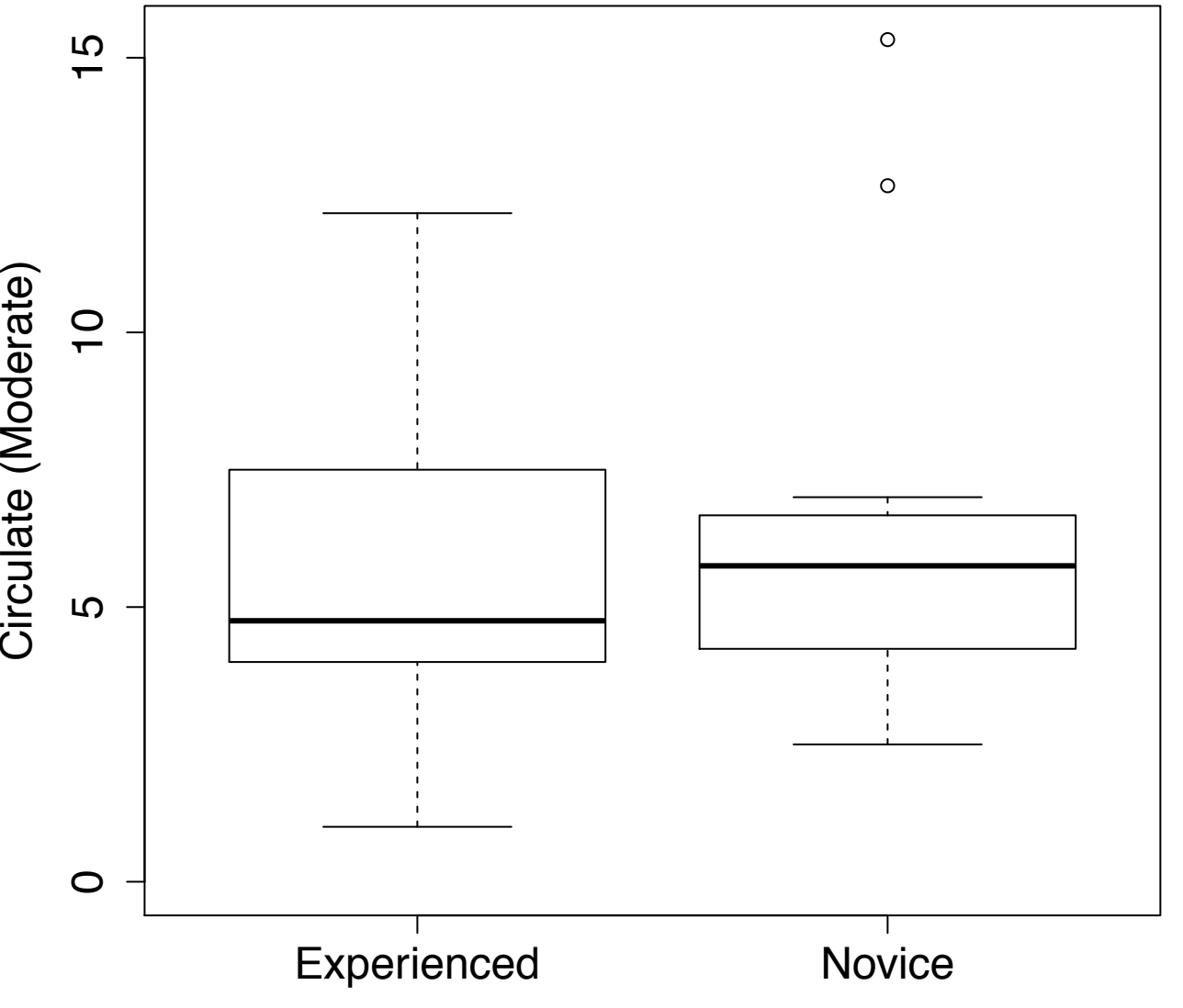

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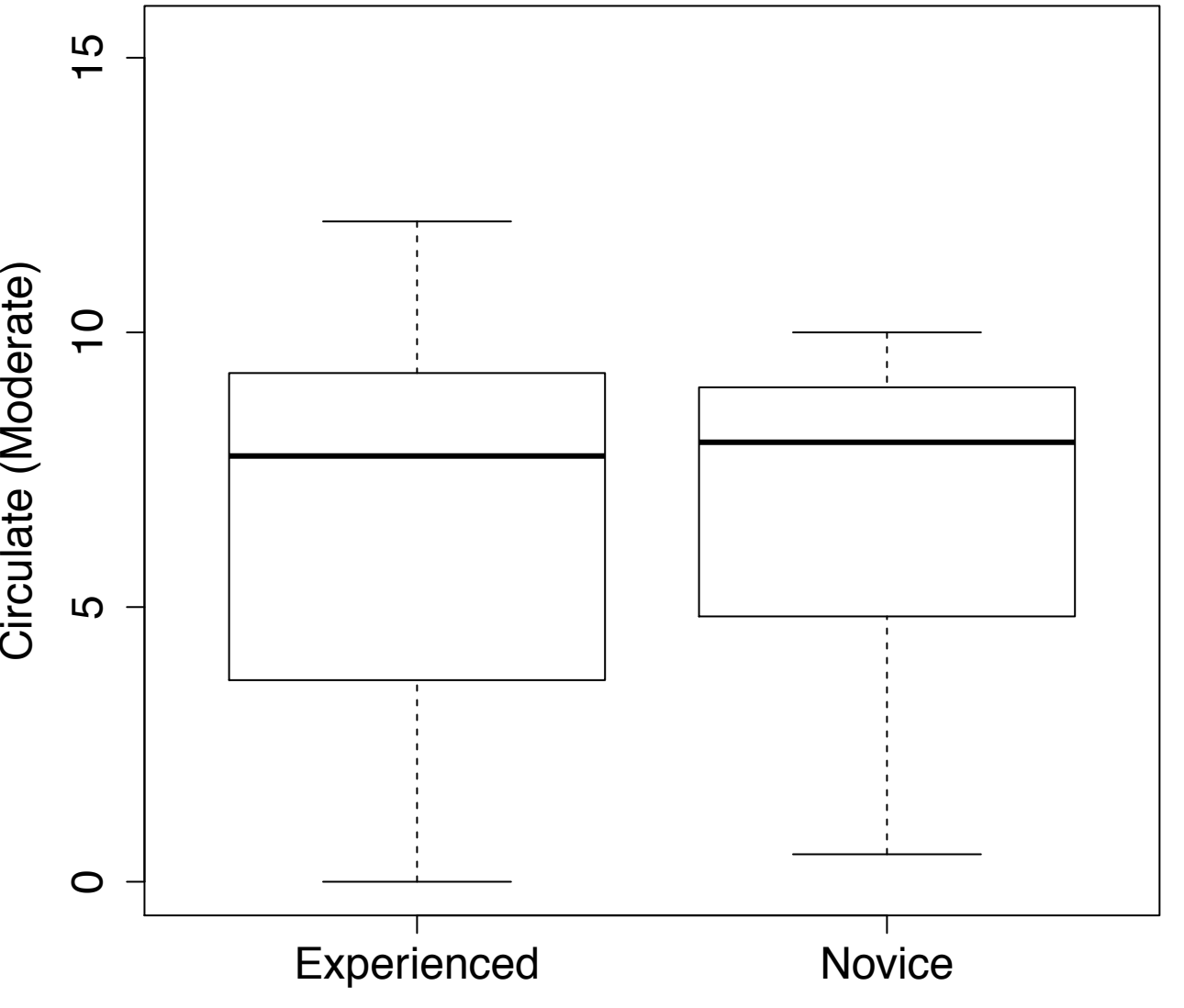

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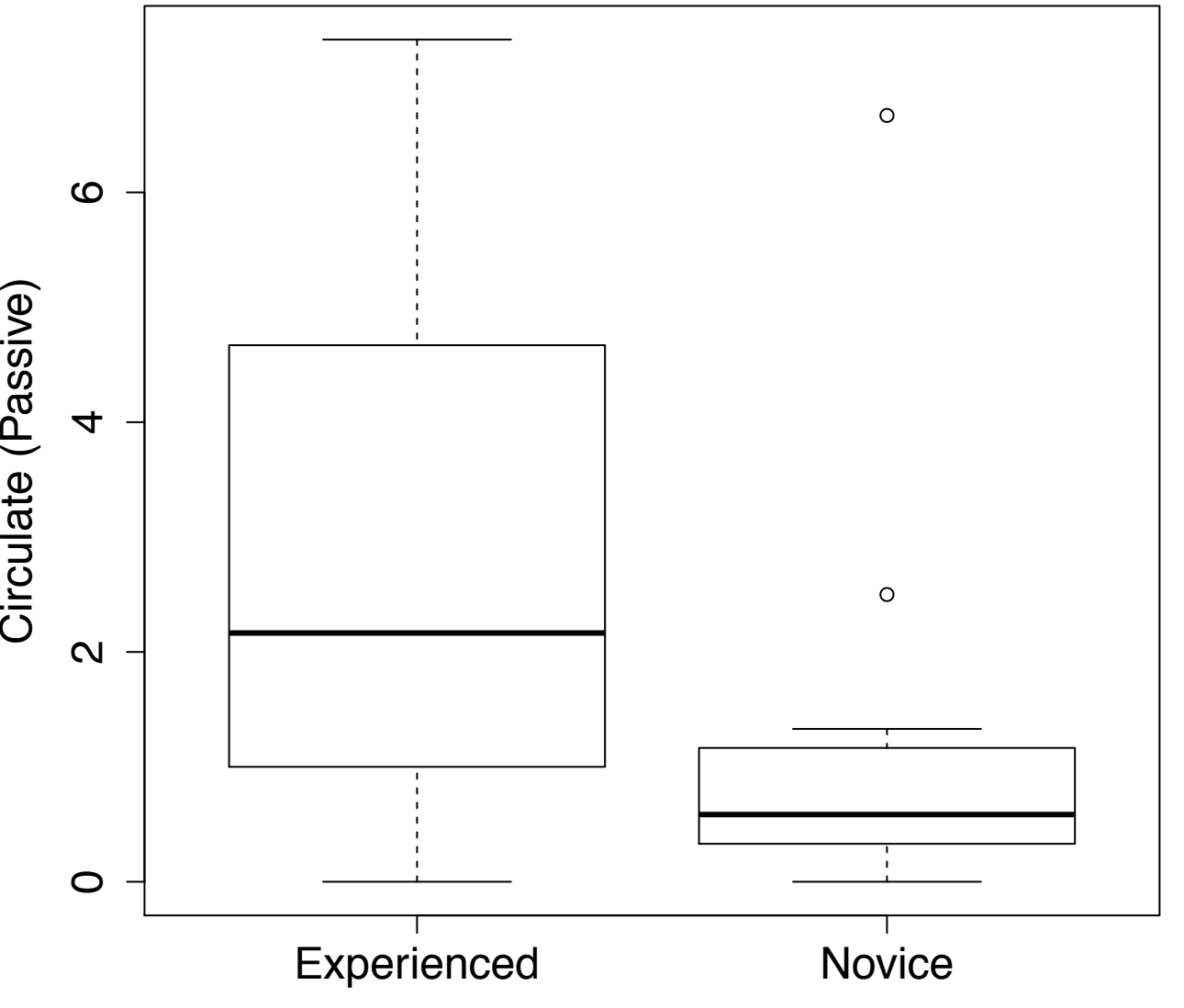

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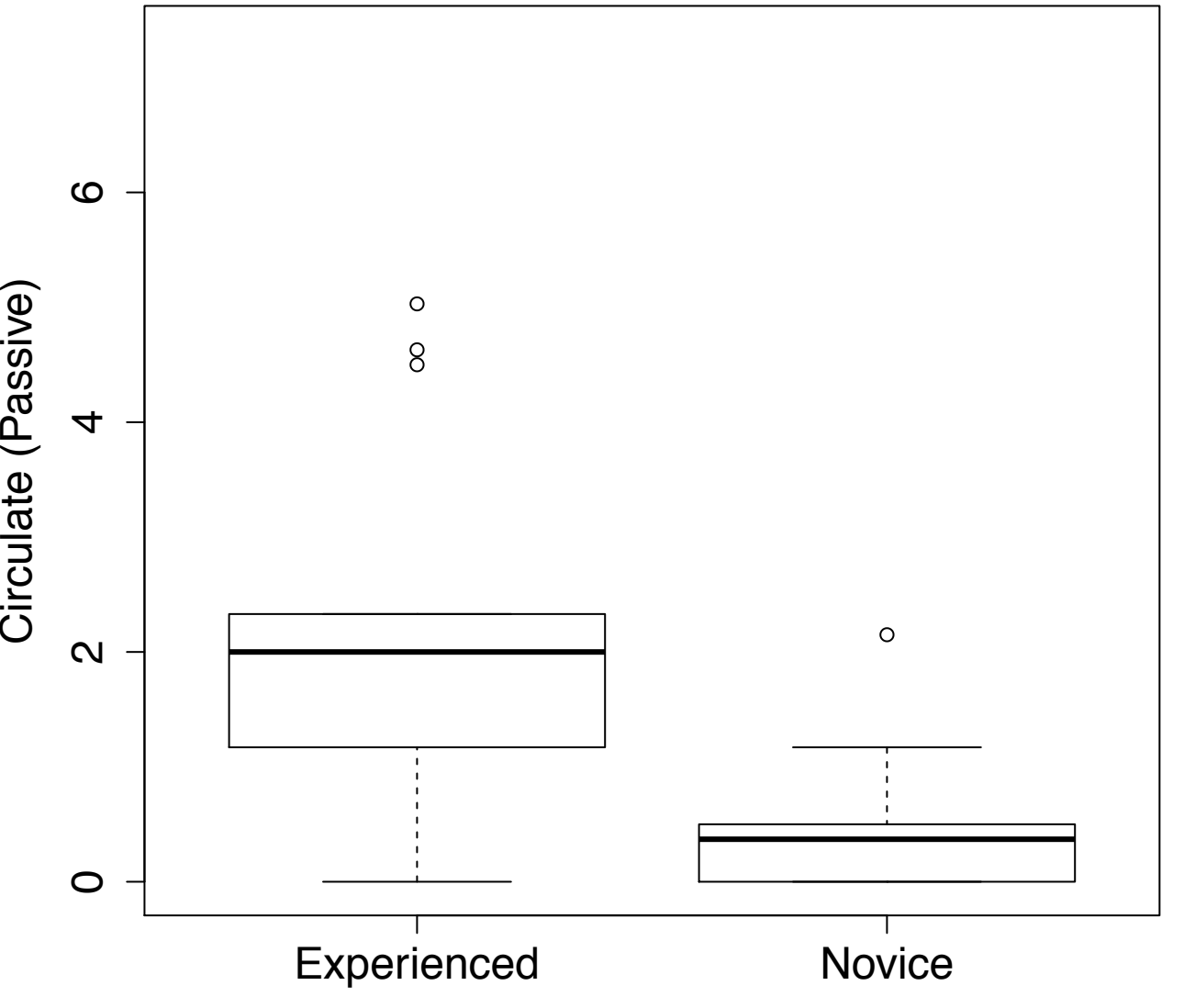

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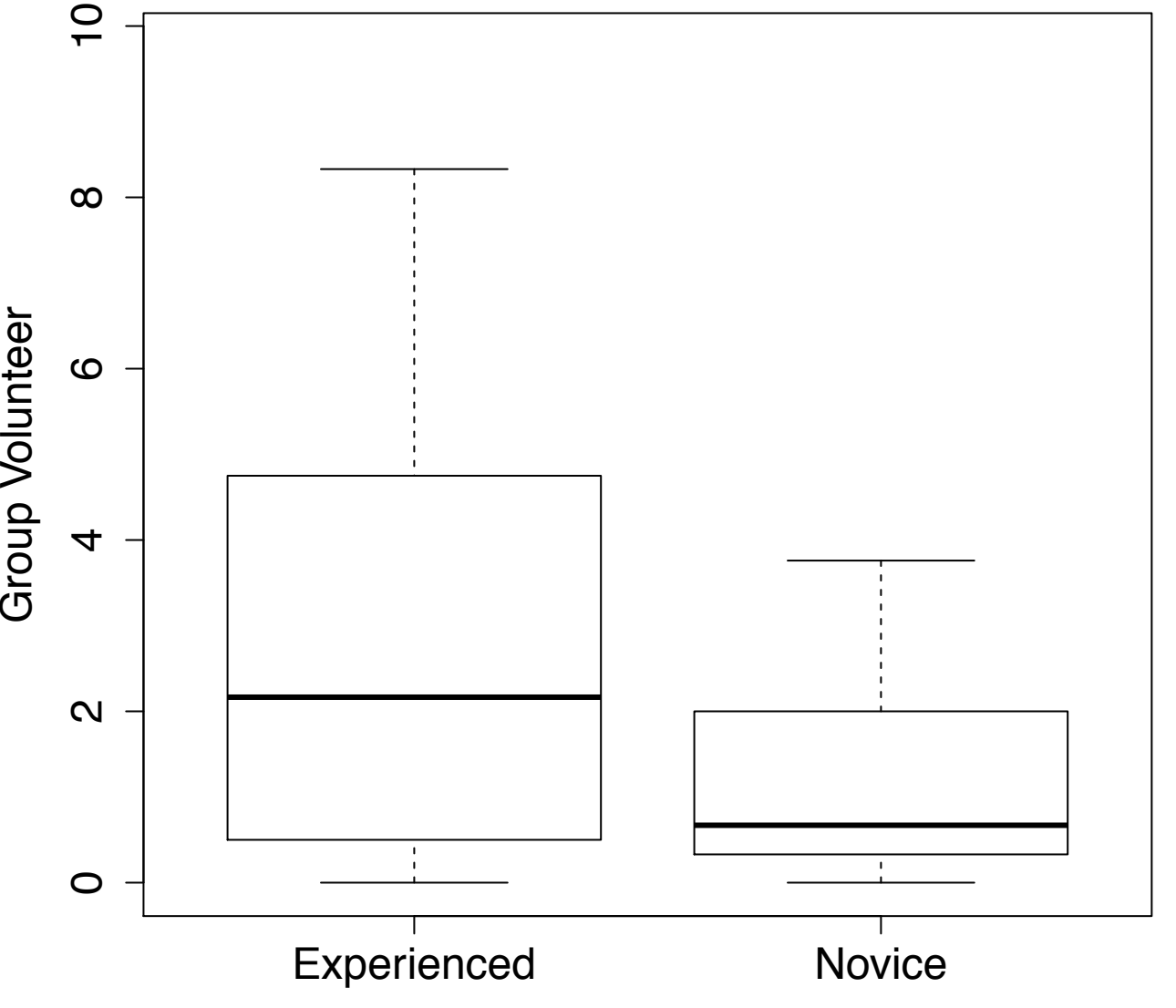

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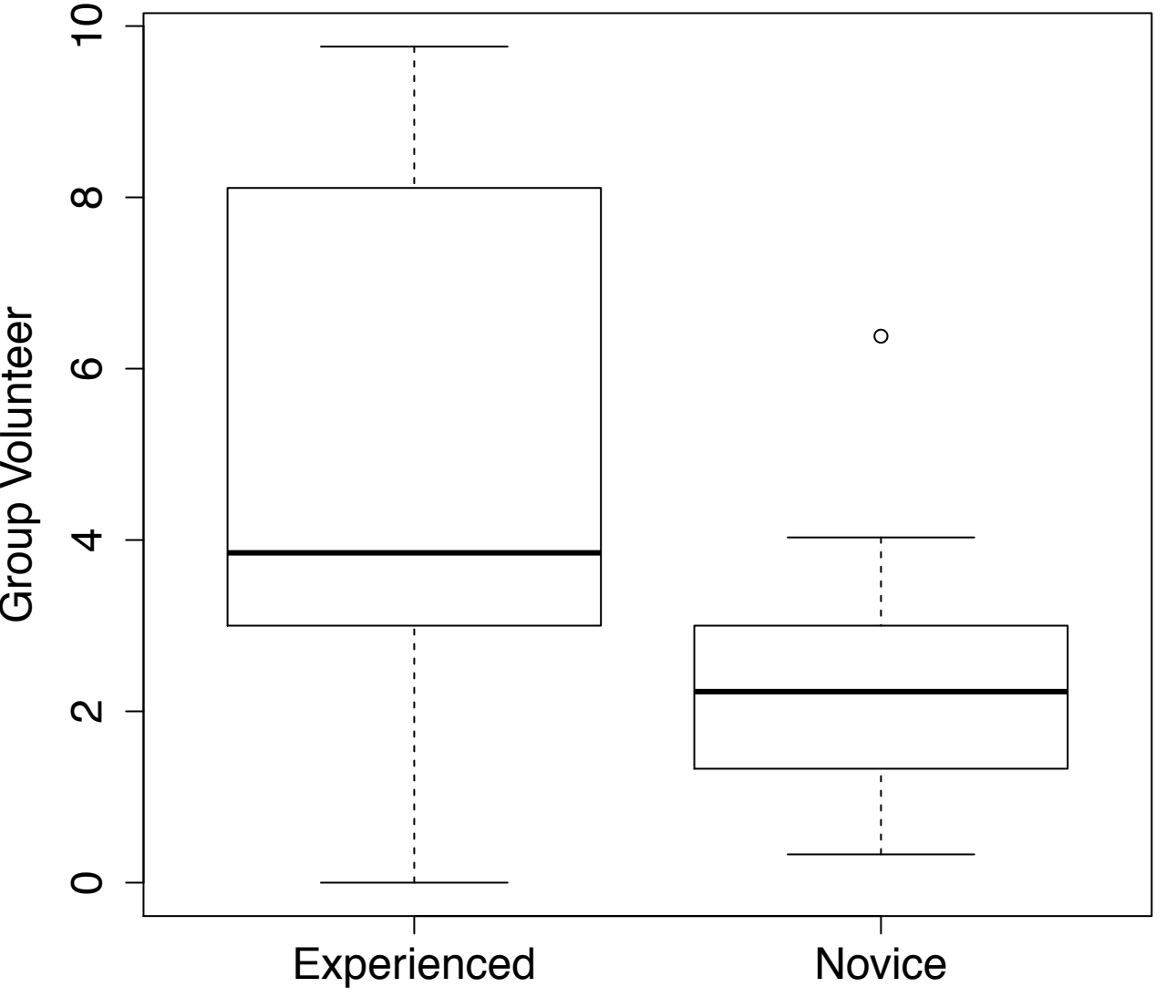
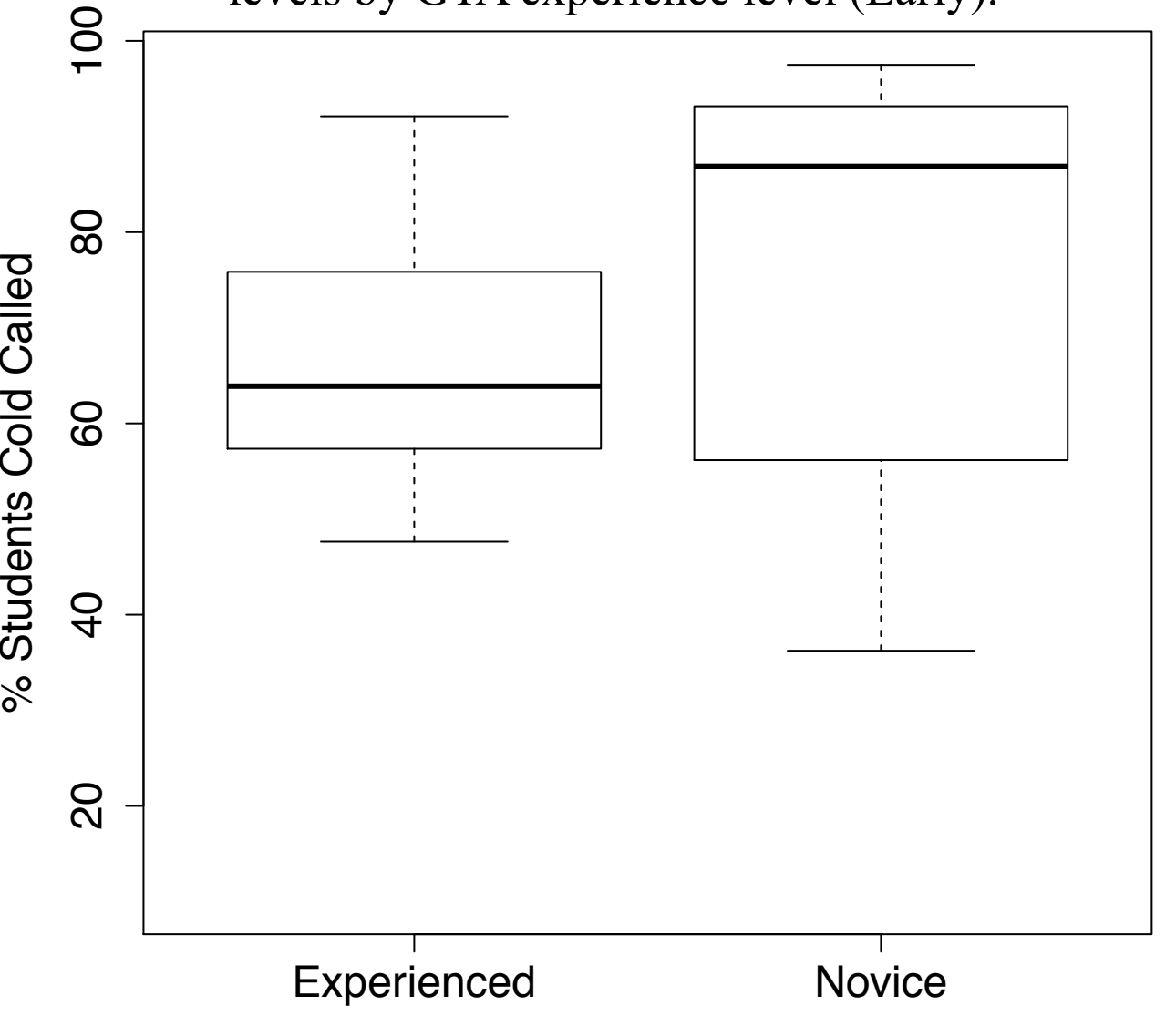


Part II: Boxplots of technique frequency and participation levels by GTA experience level (Early).



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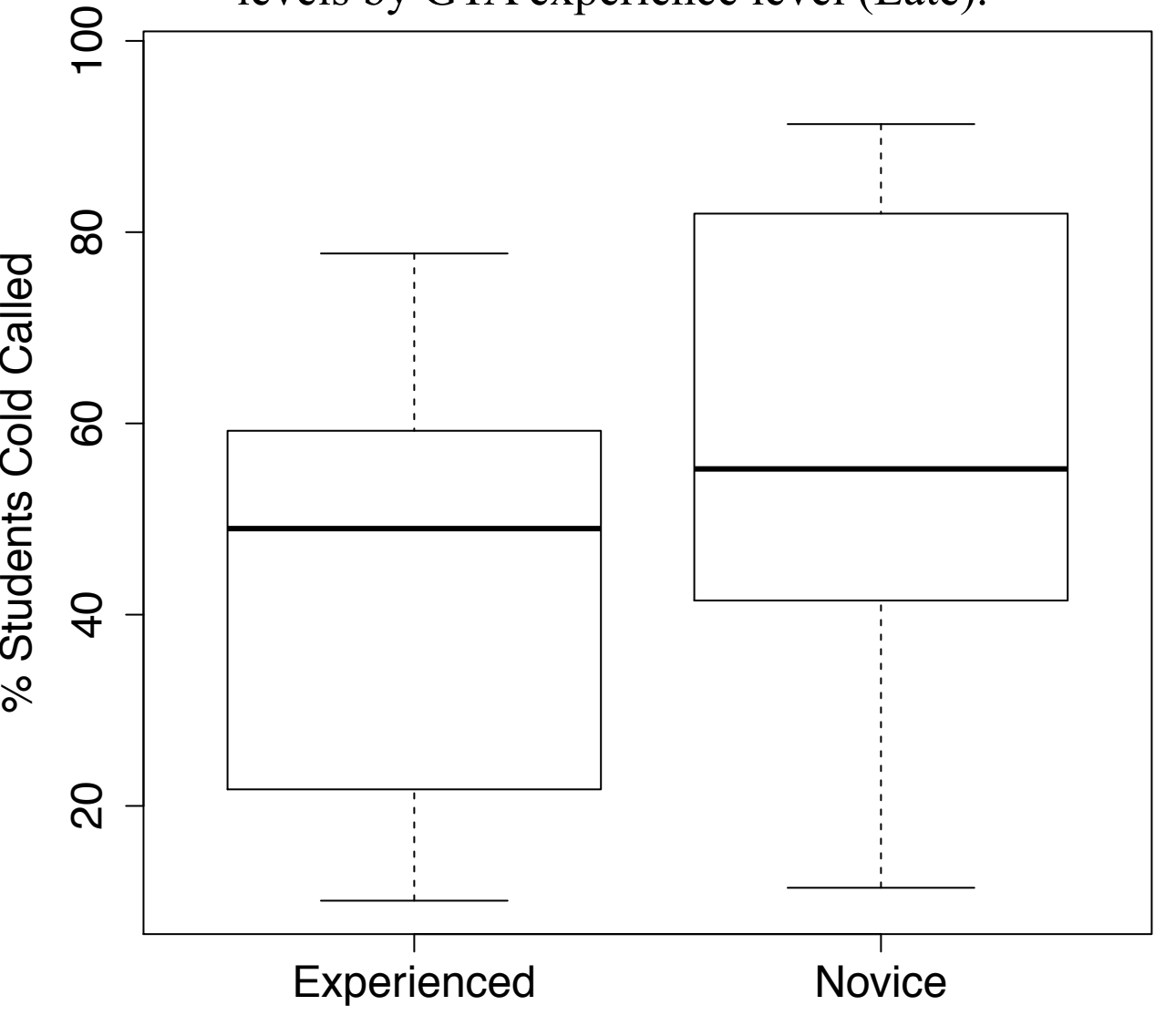

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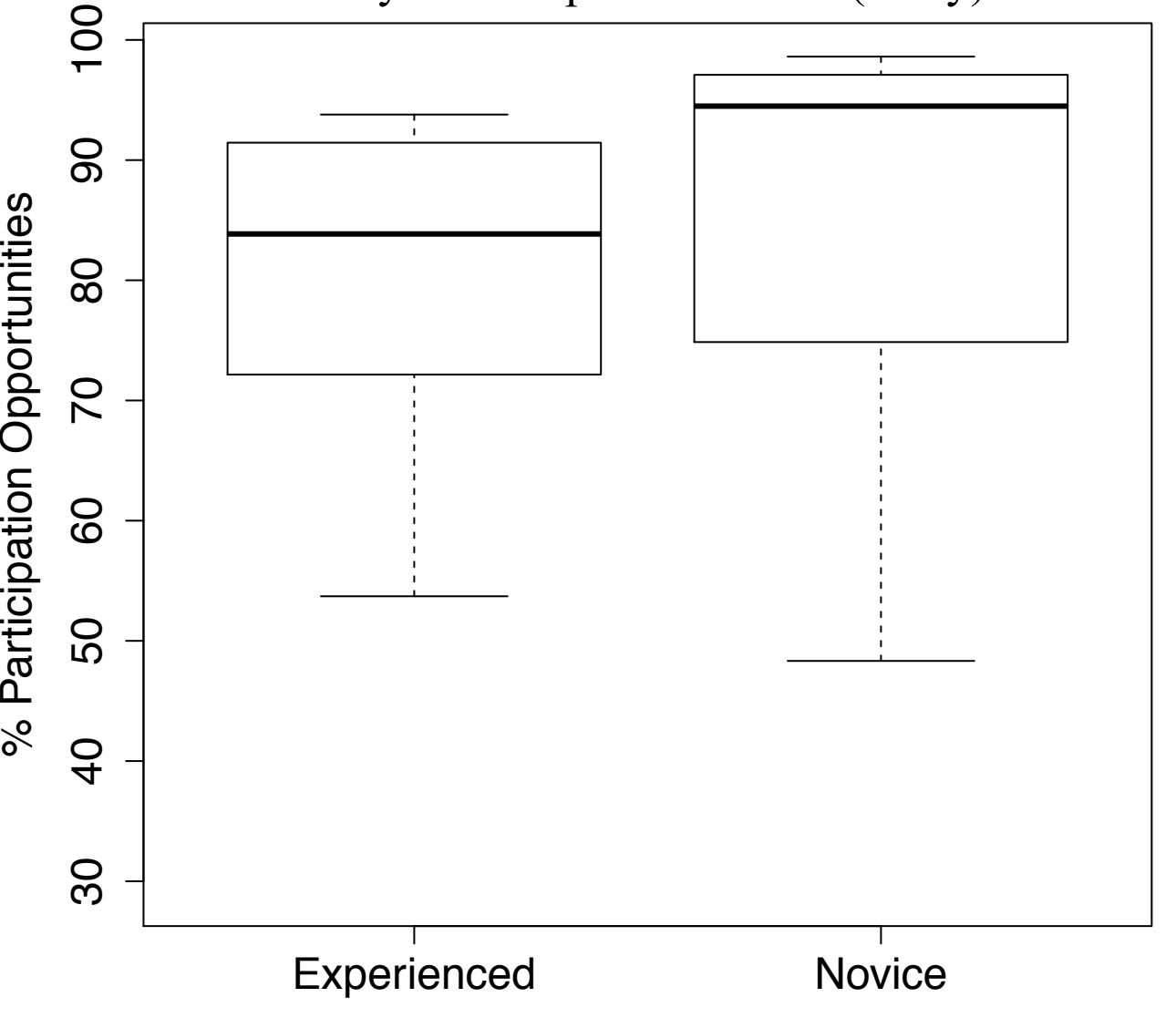

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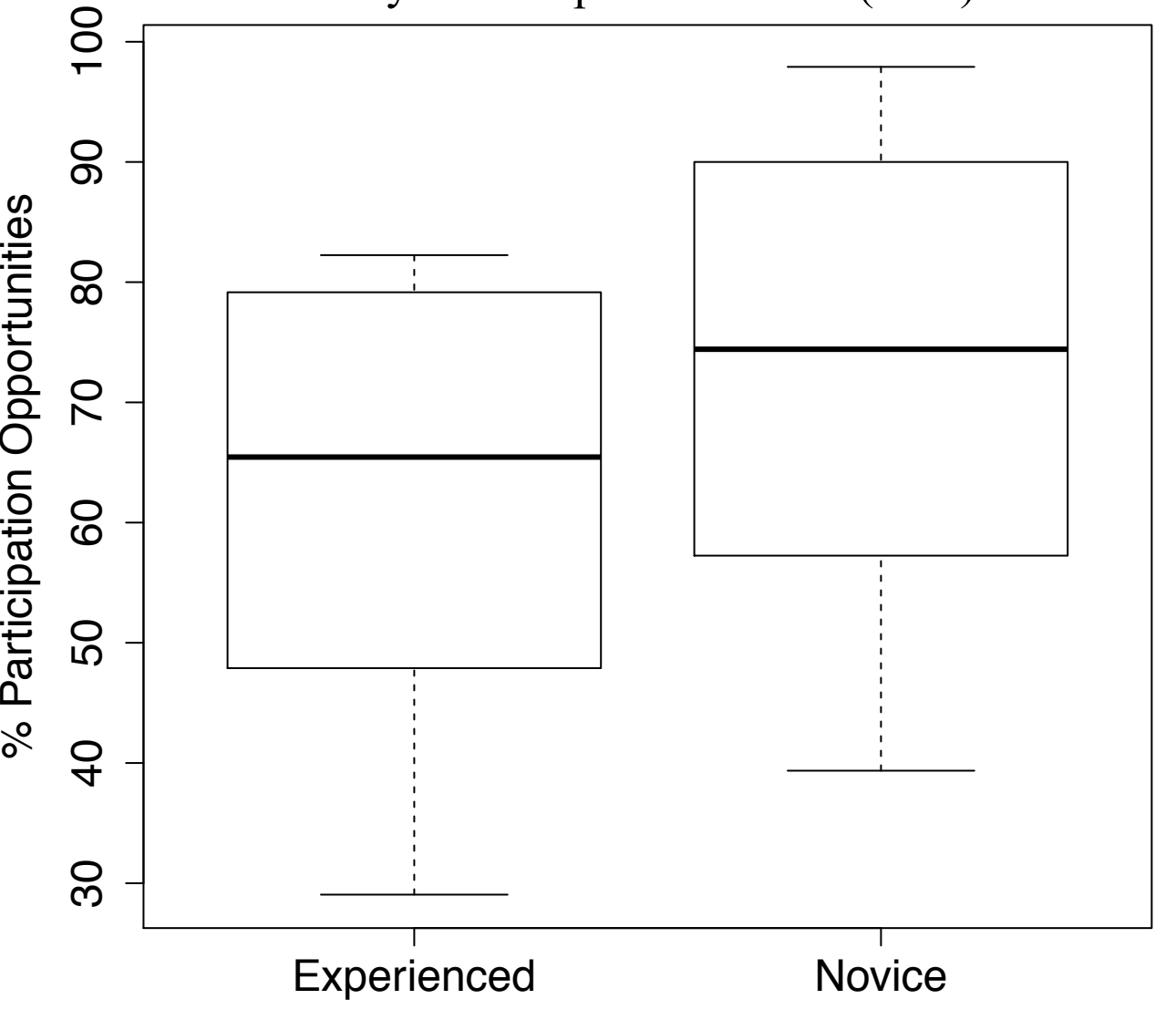

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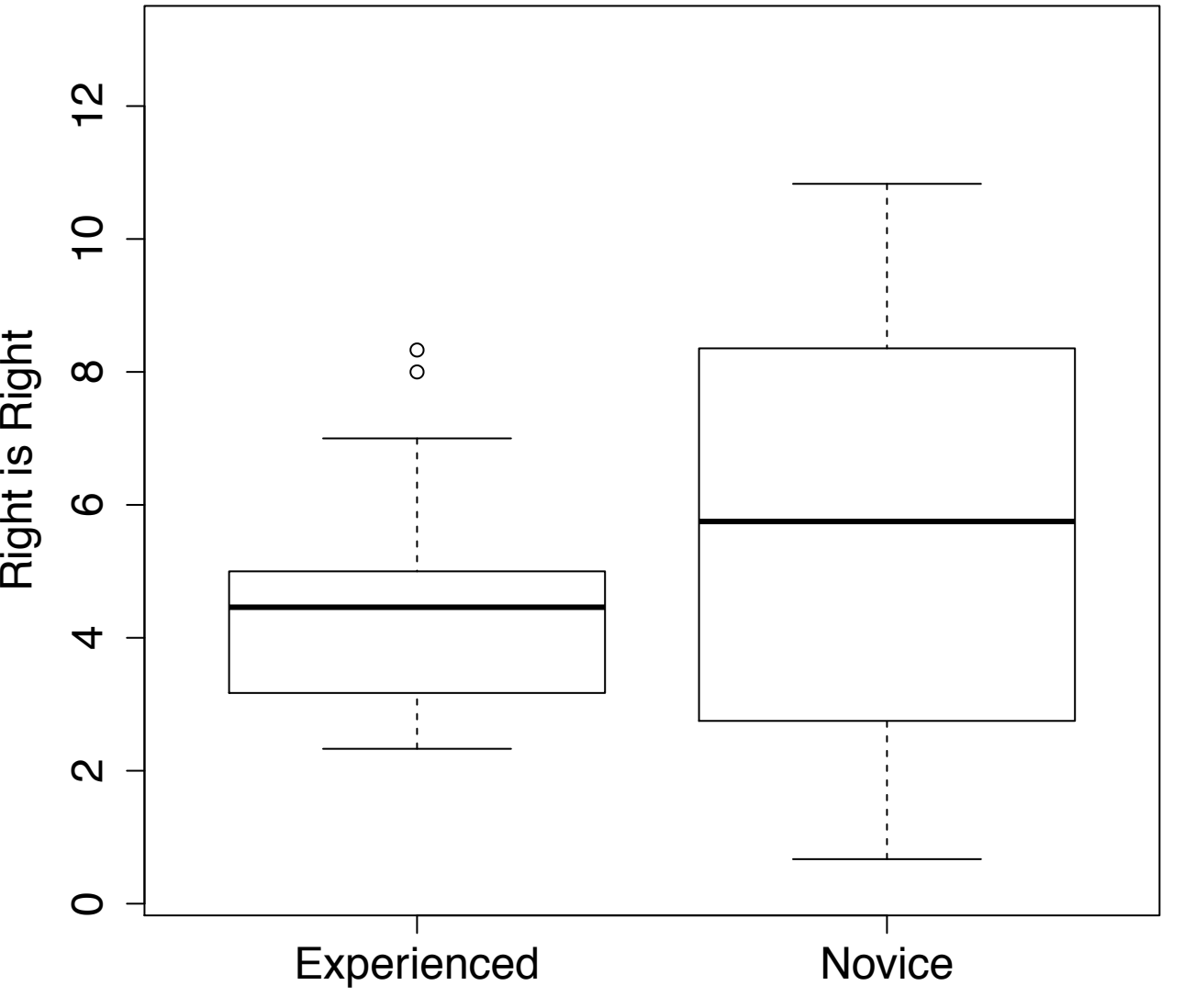

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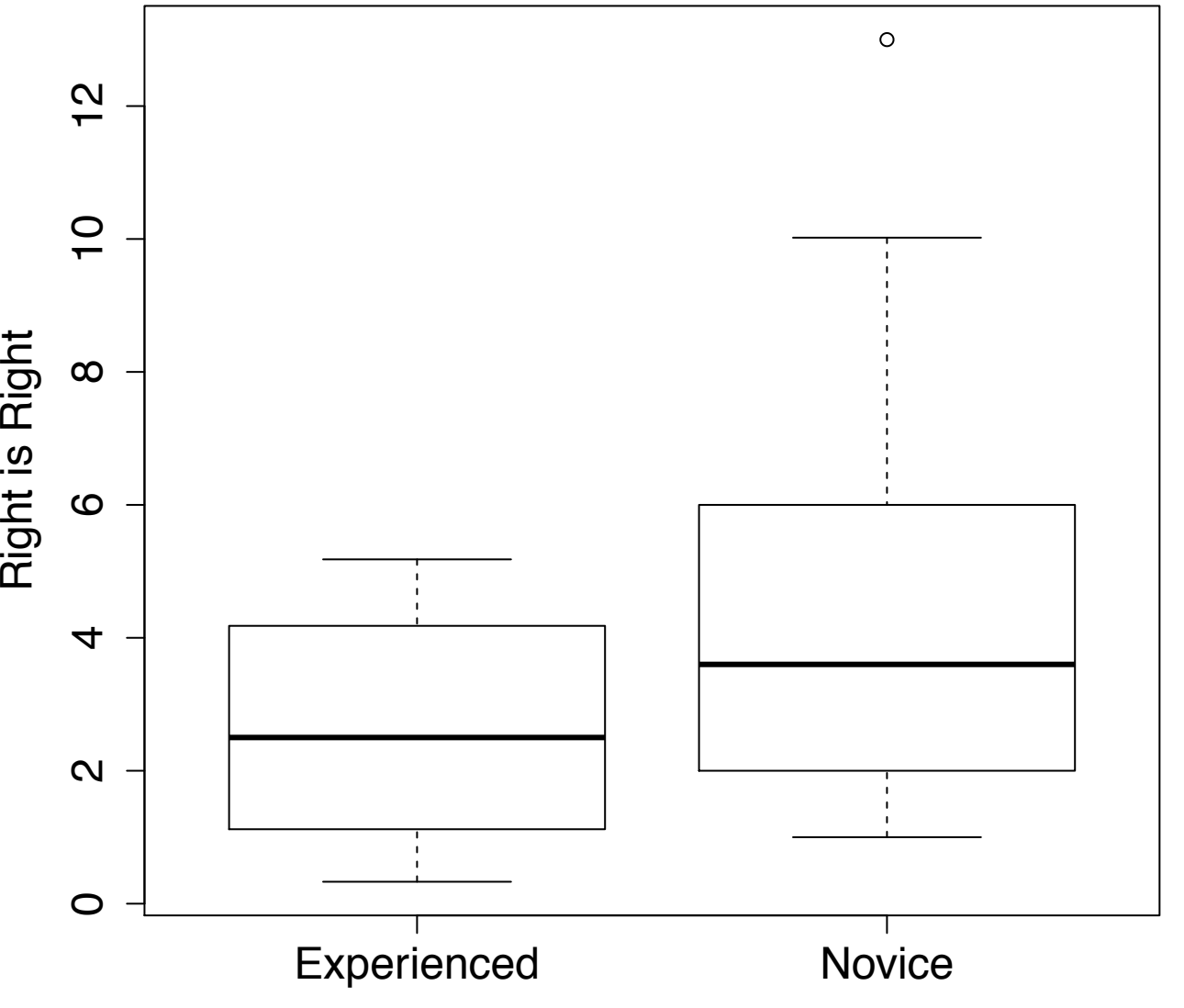

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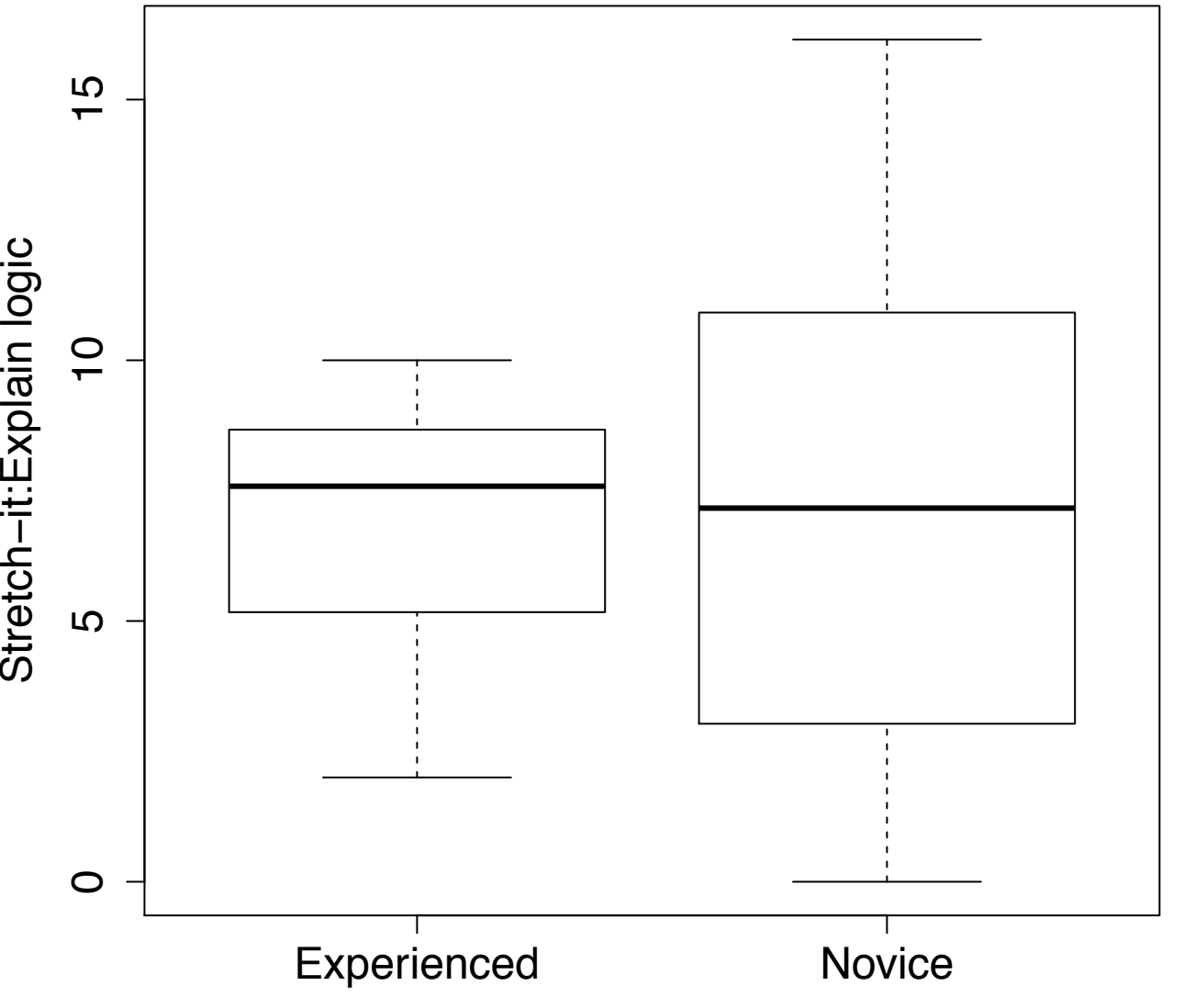

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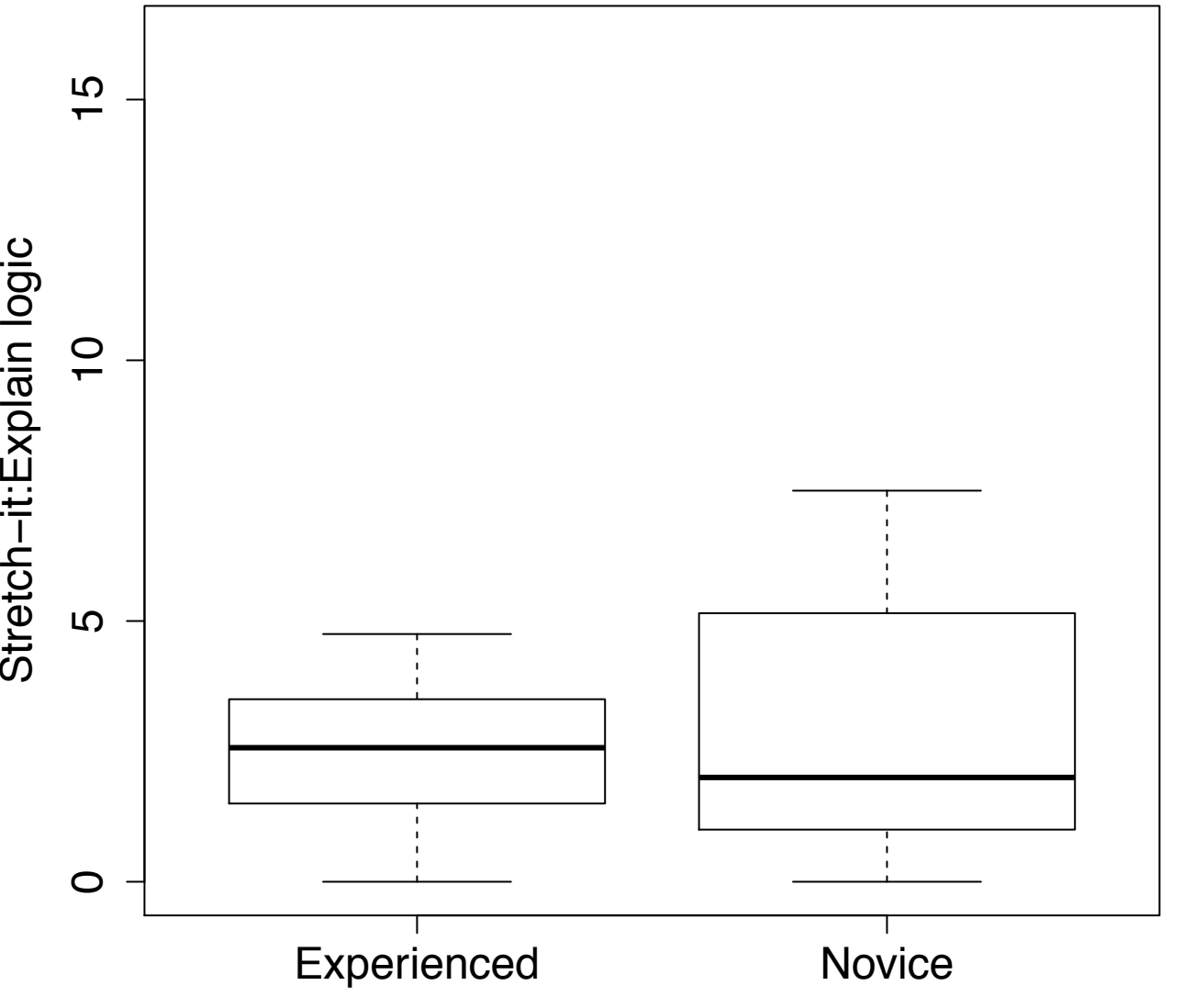

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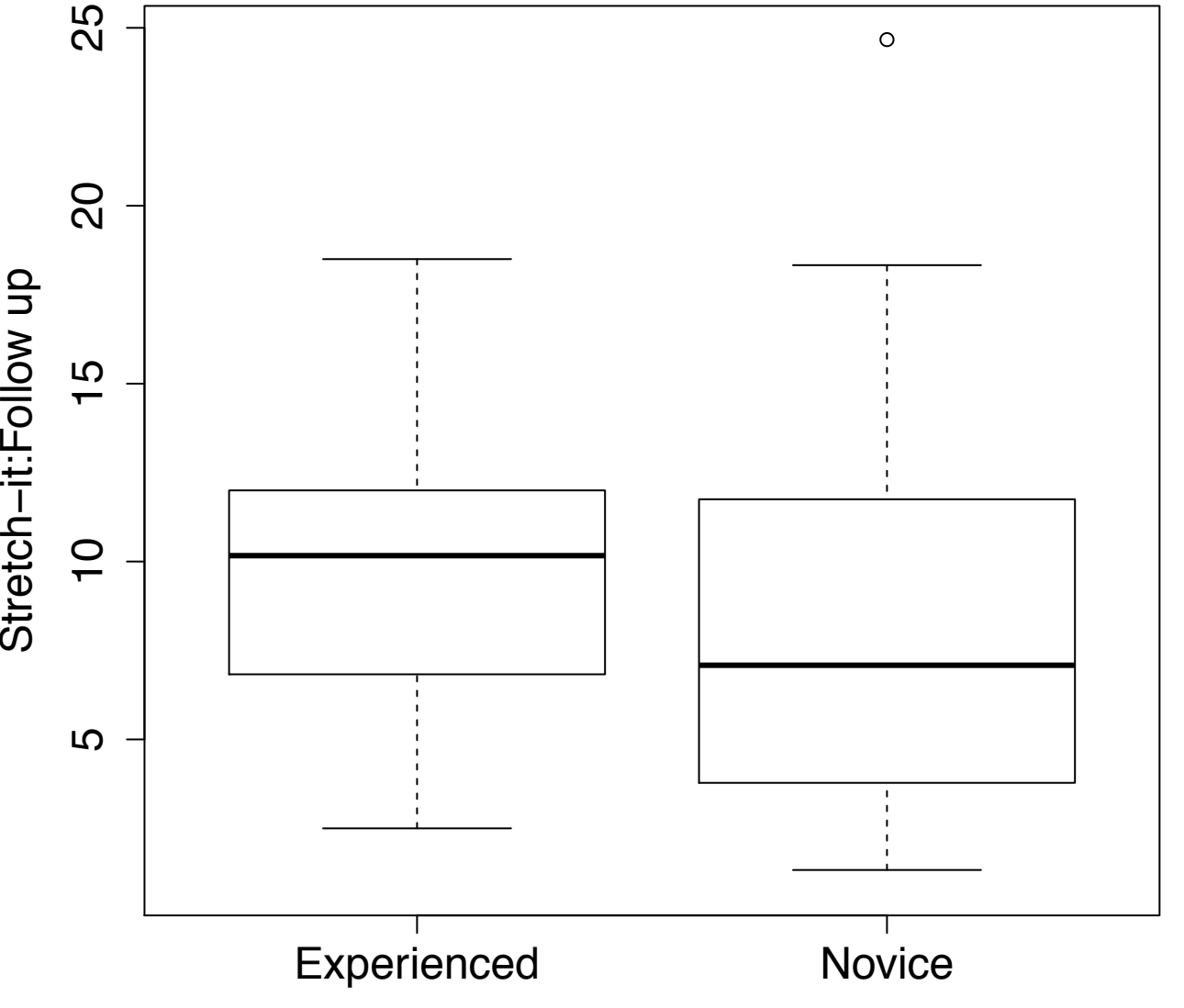

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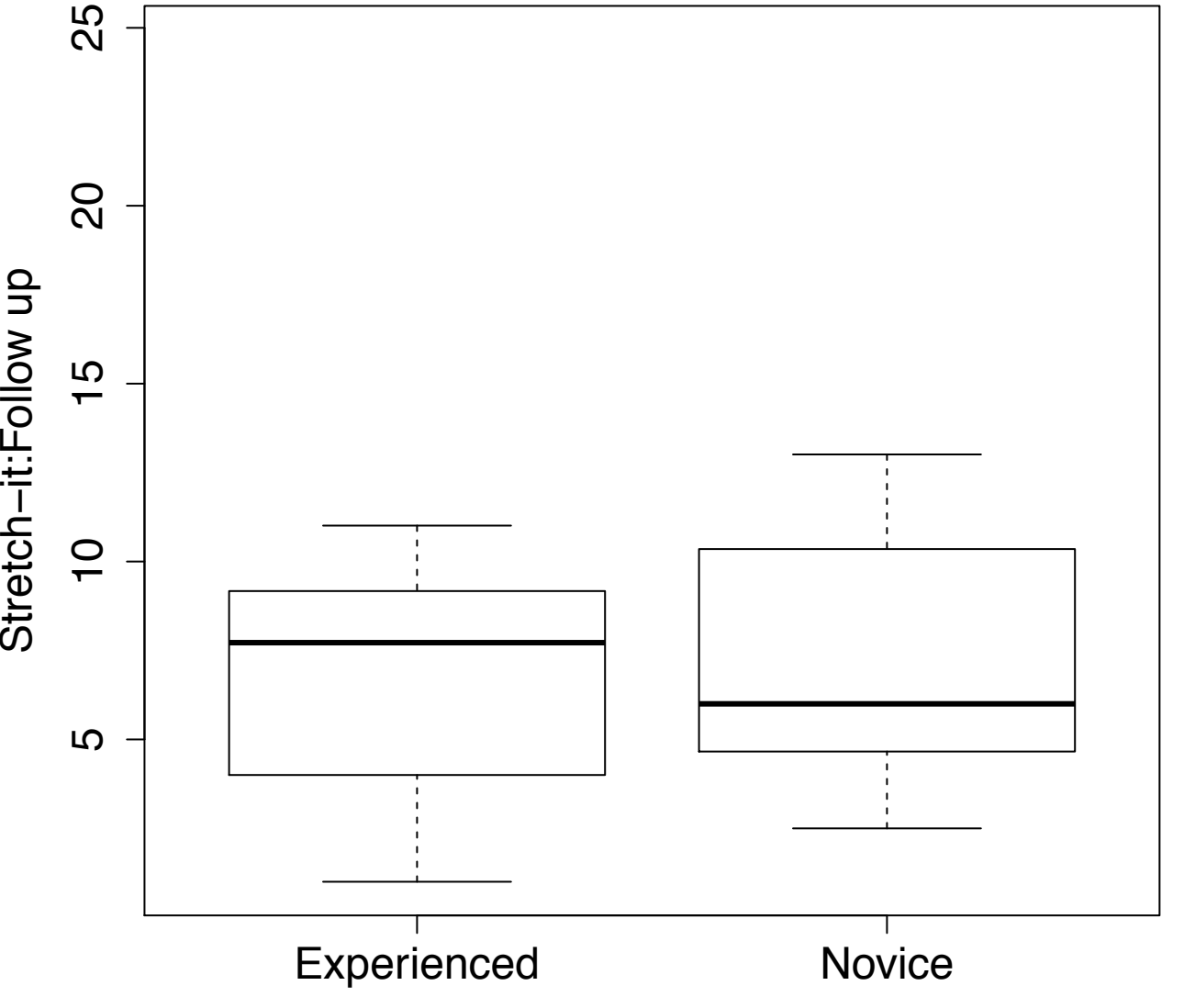

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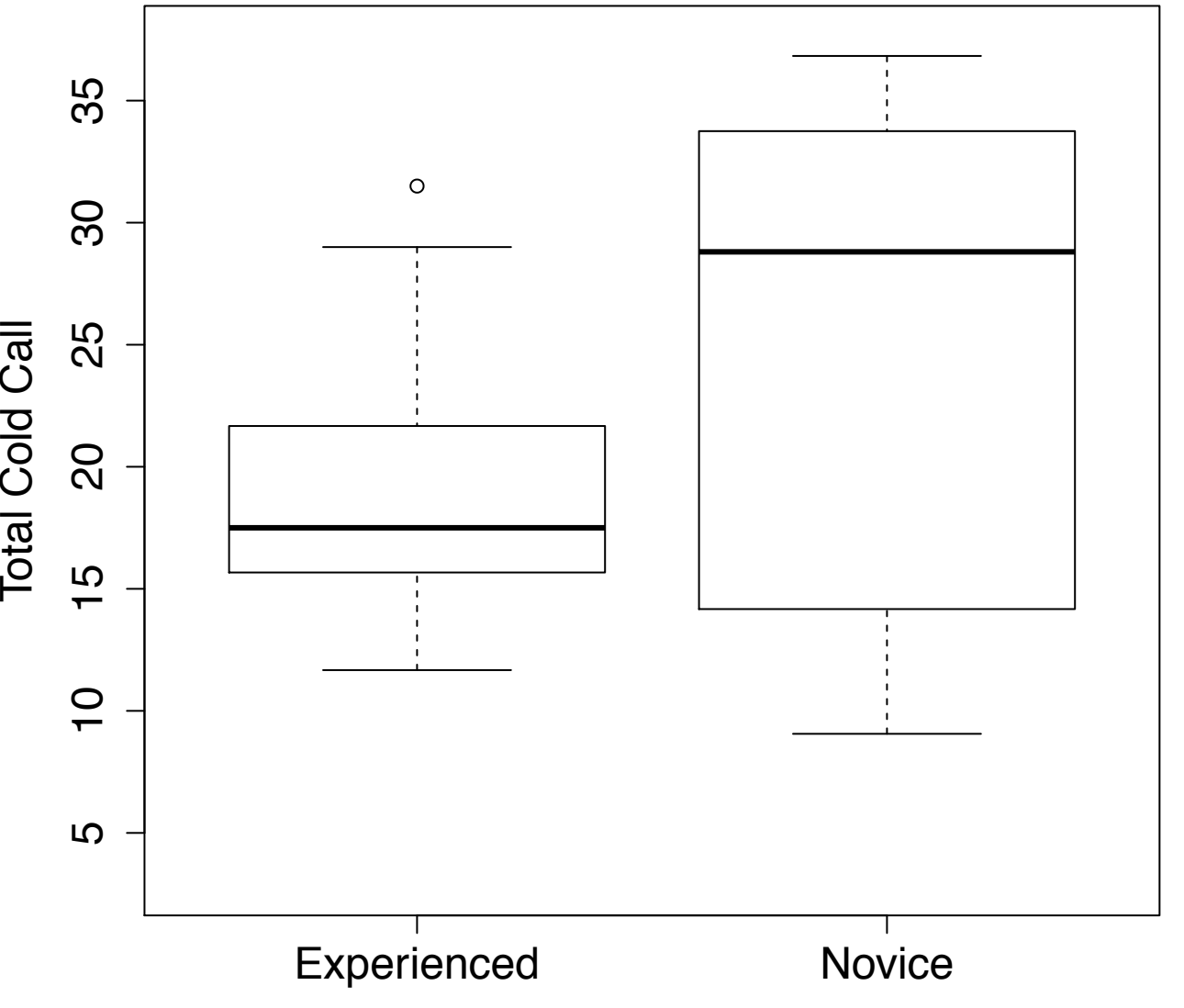

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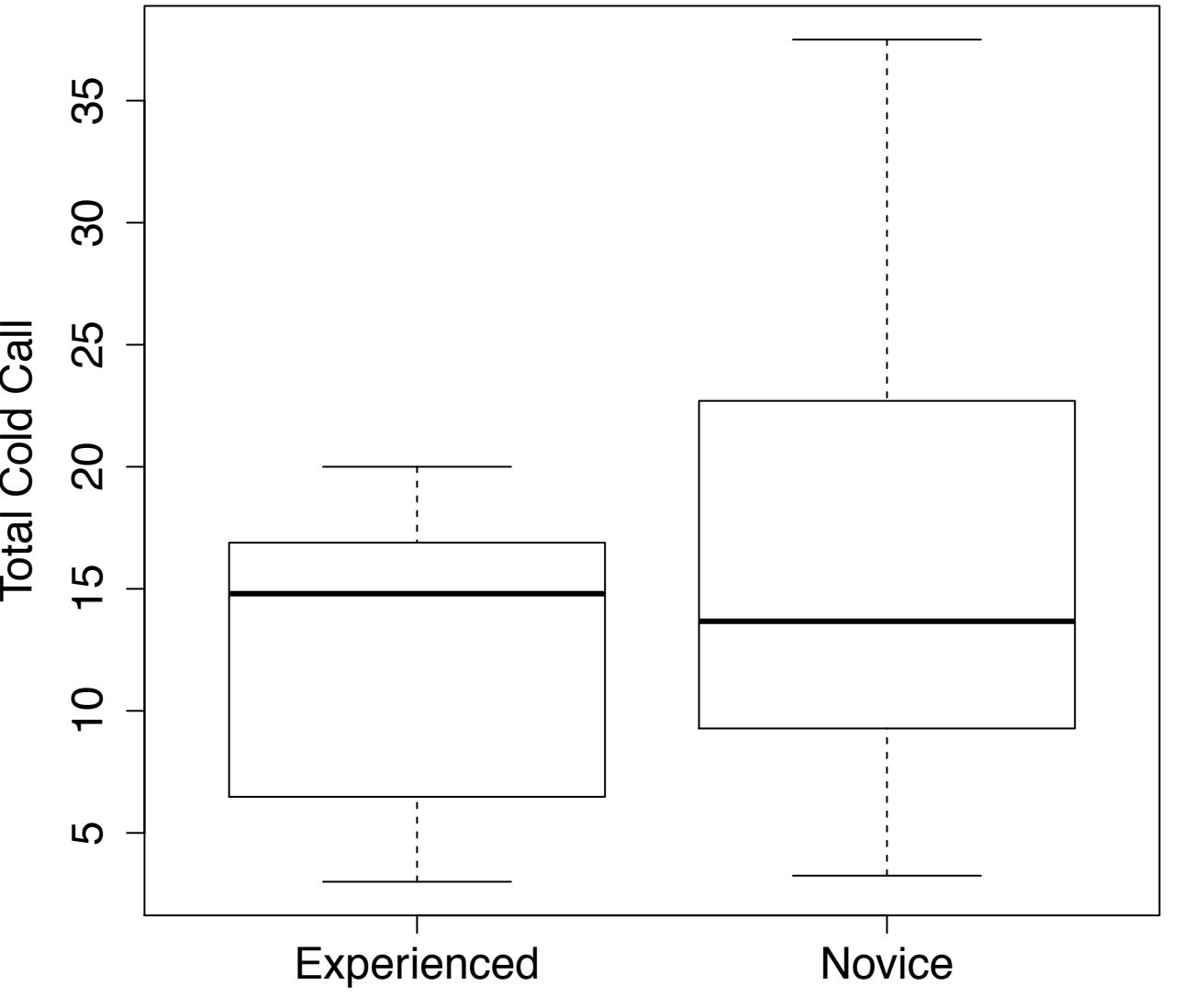

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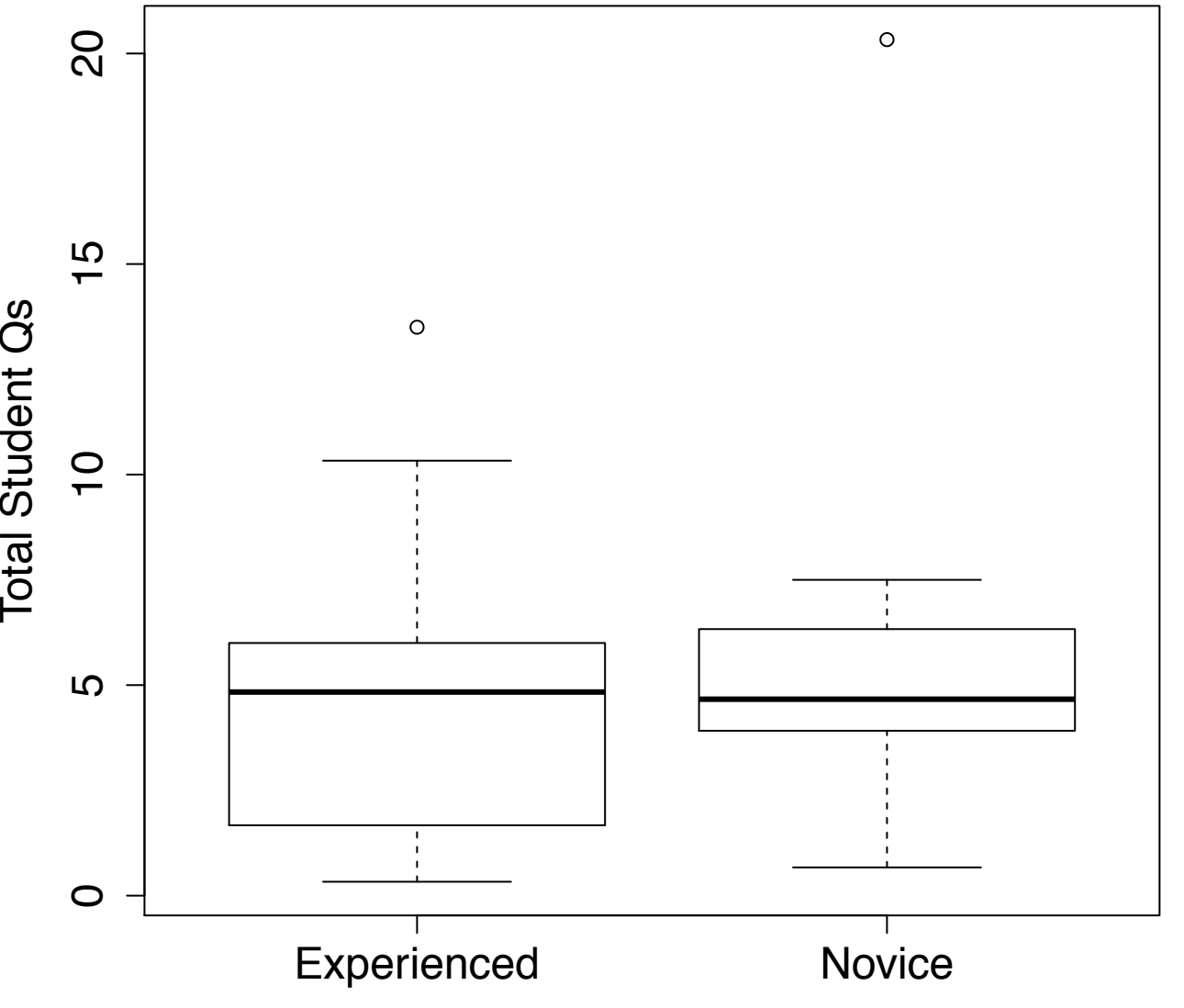

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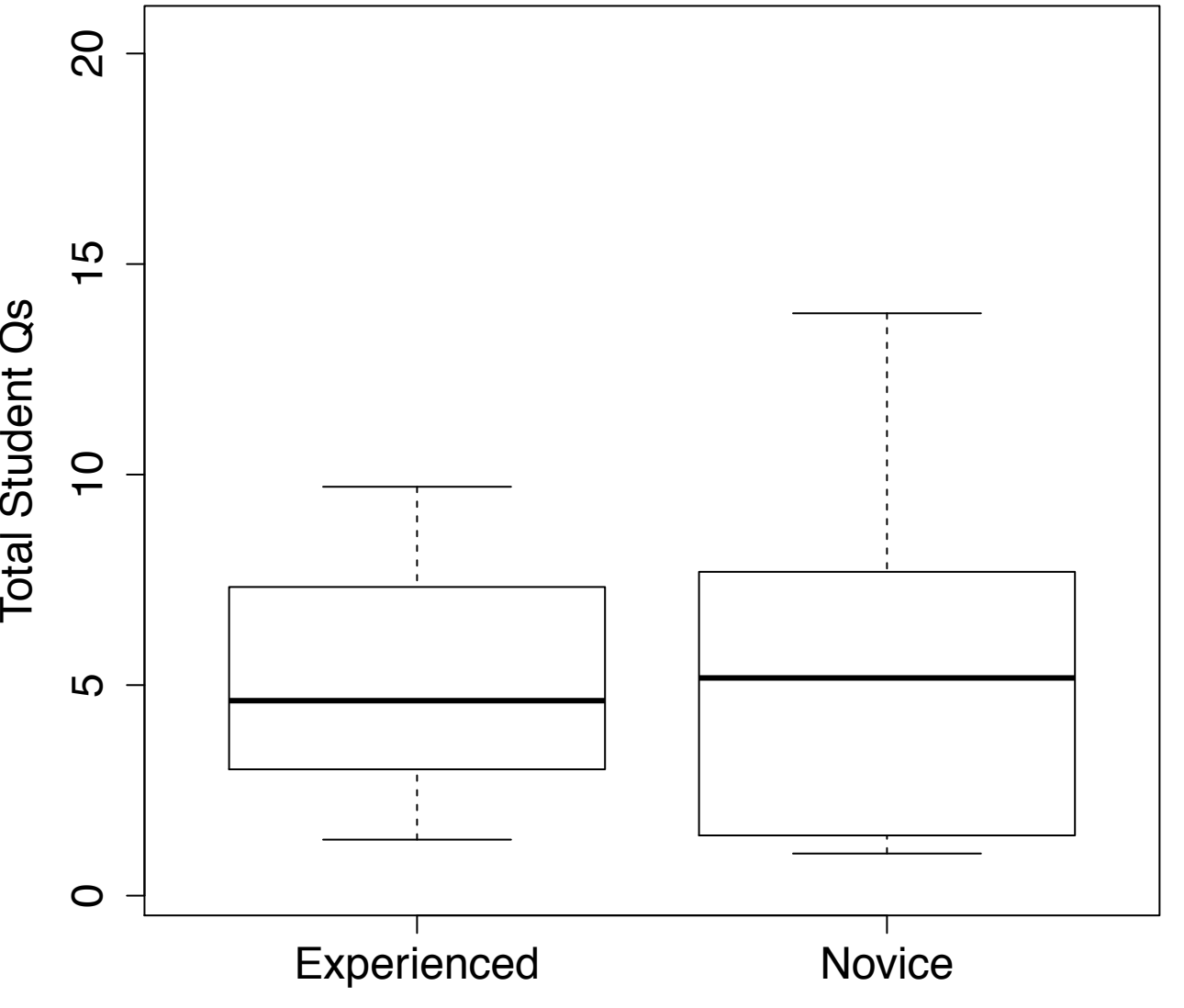

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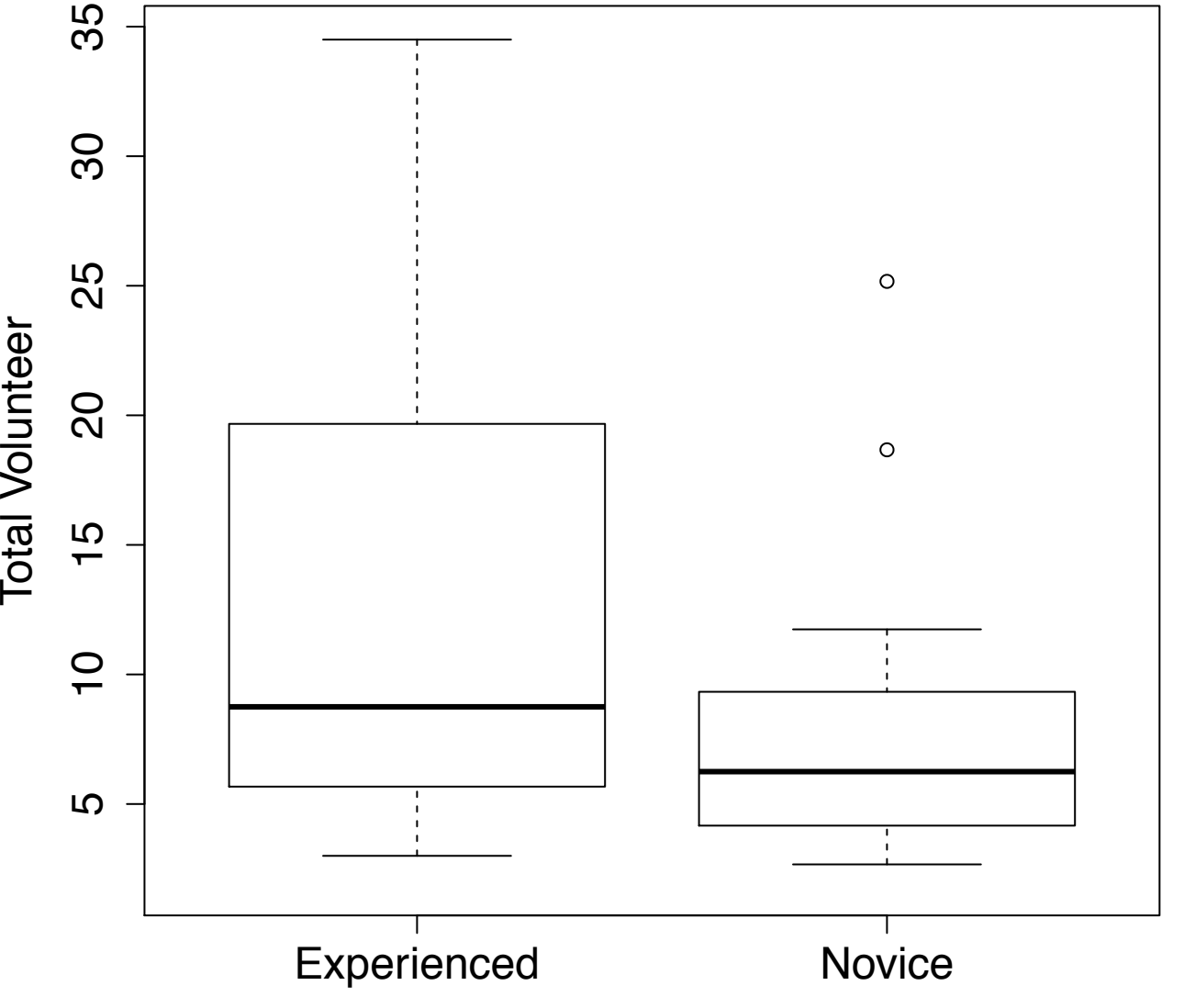

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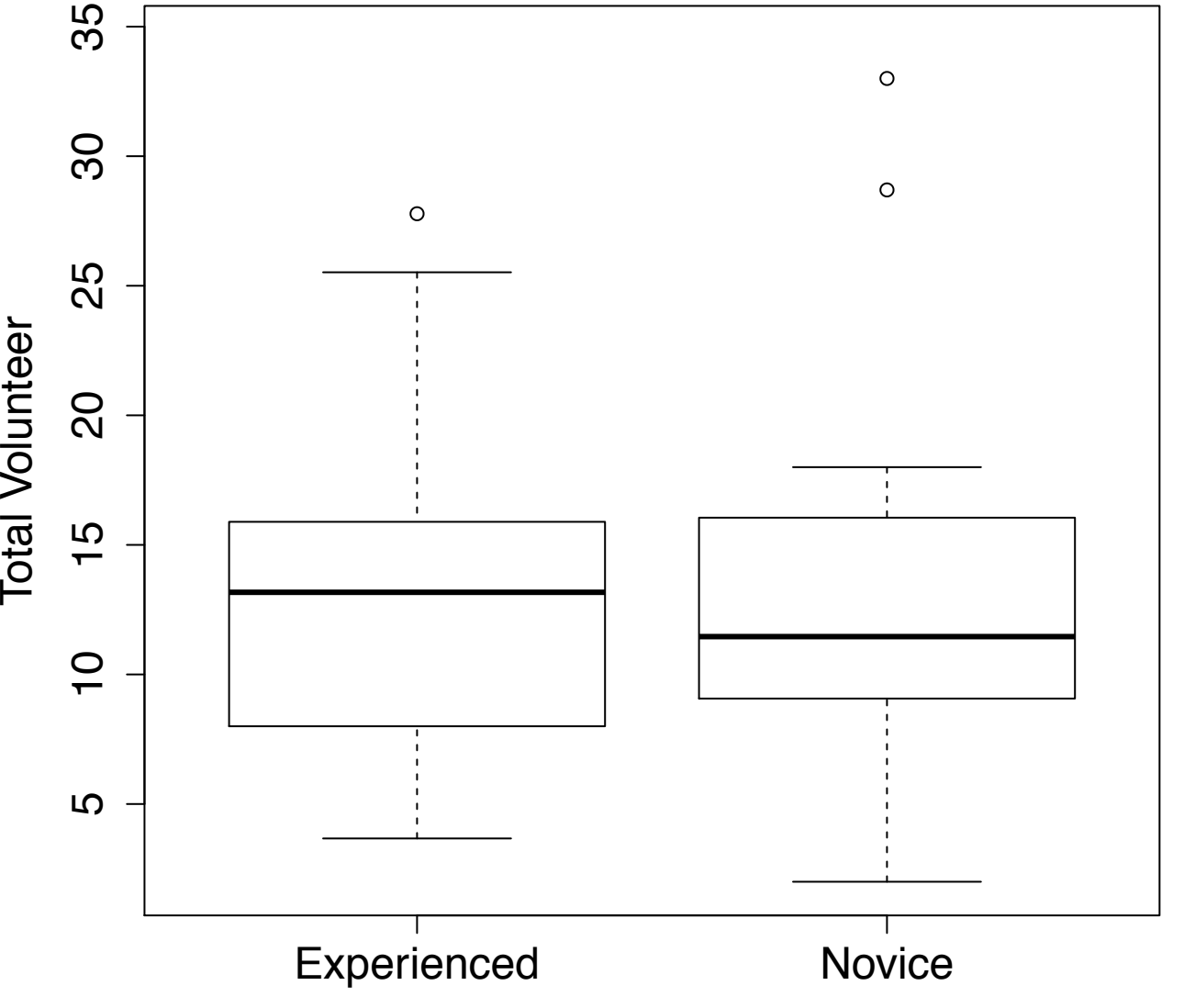
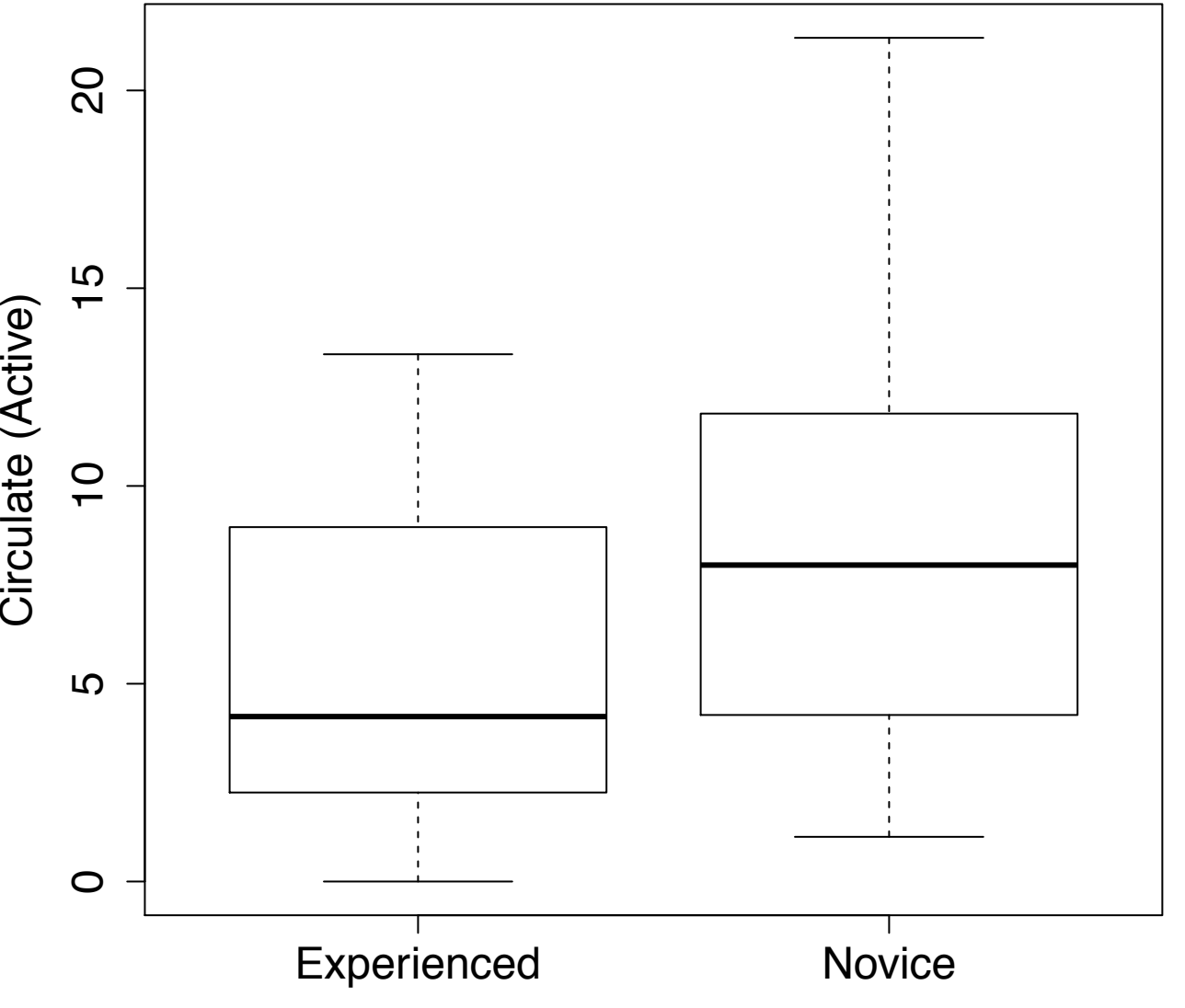


Part III: Boxplots of technique frequency and participation levels by GTA experience level (Overall).



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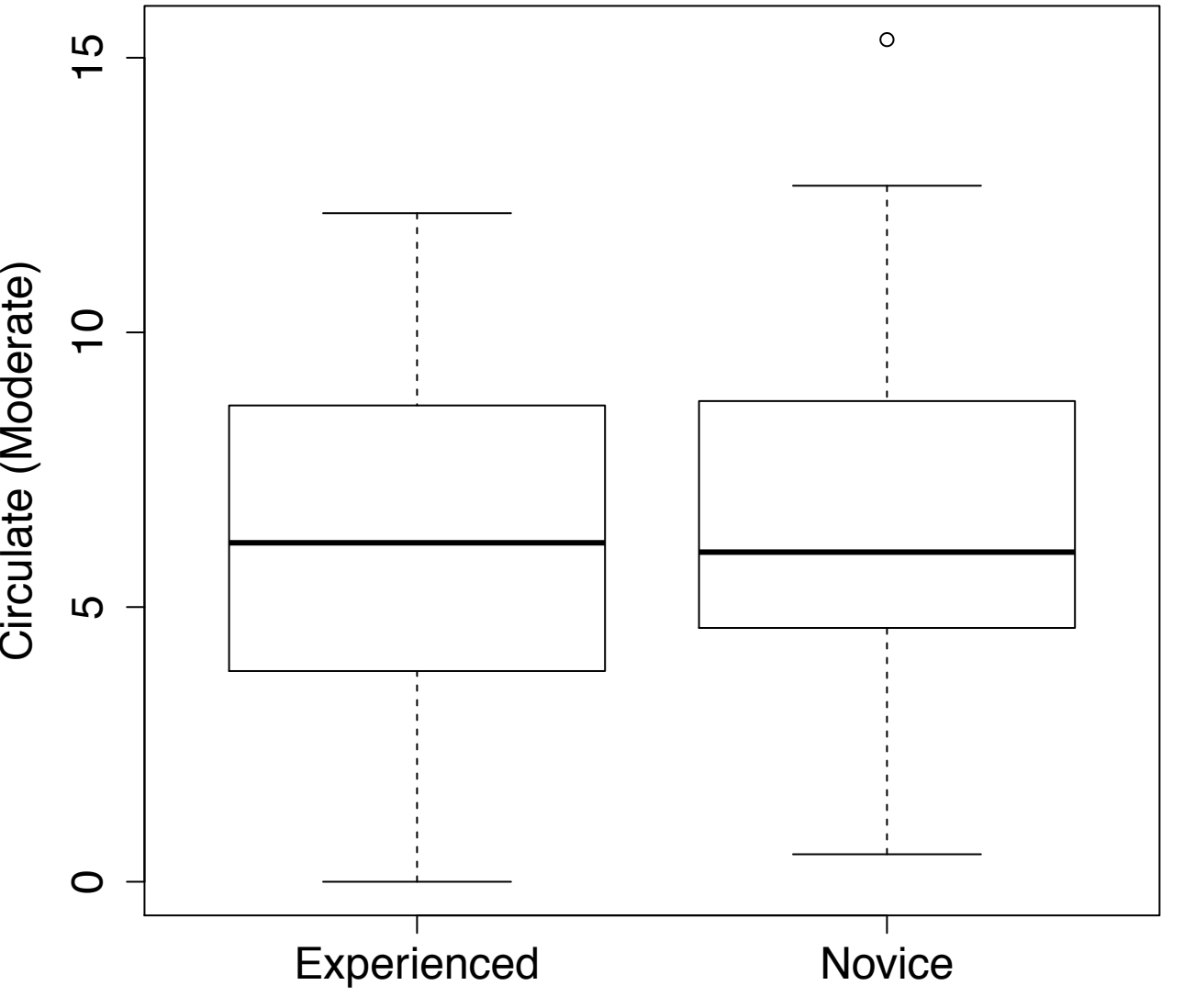

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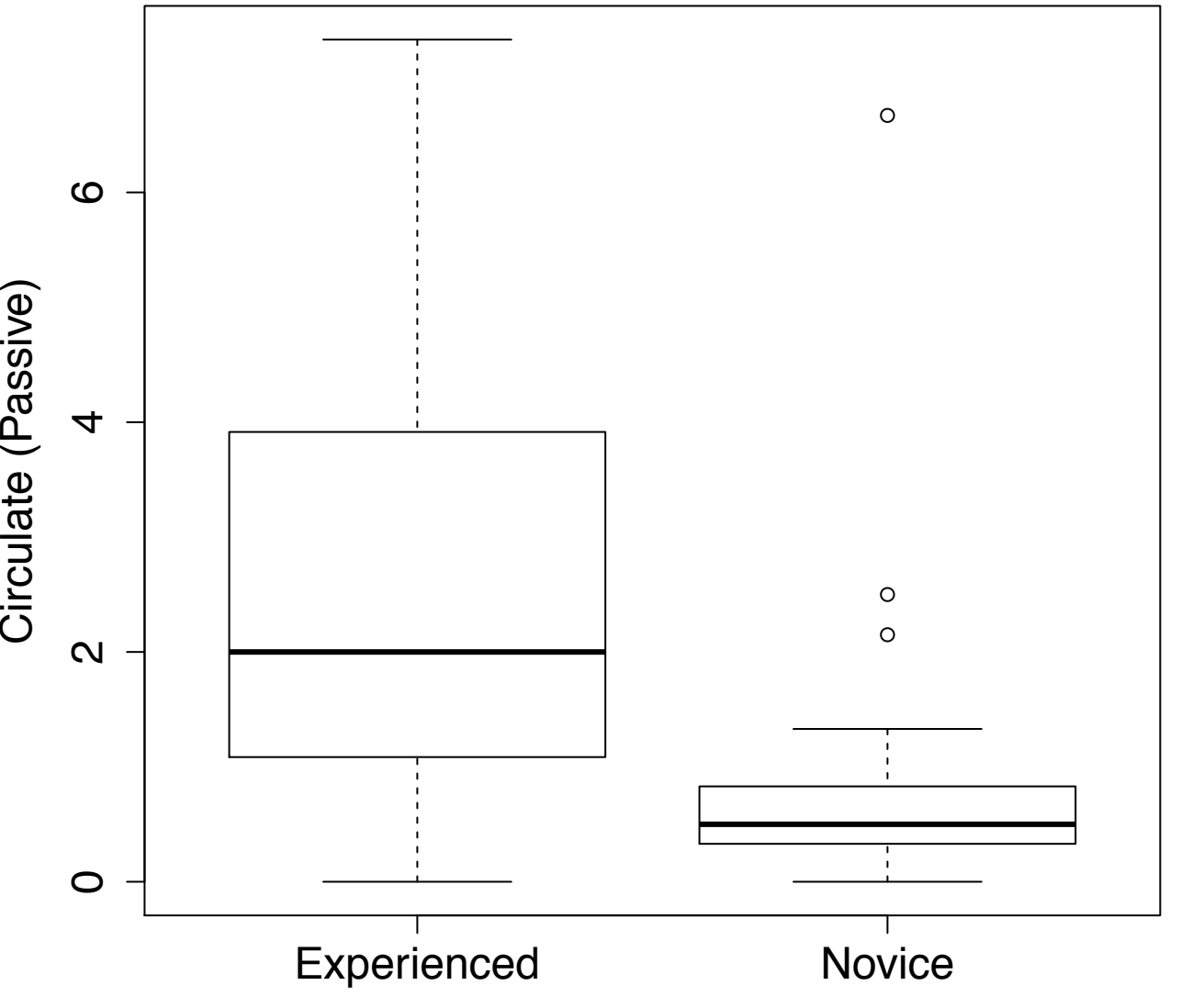

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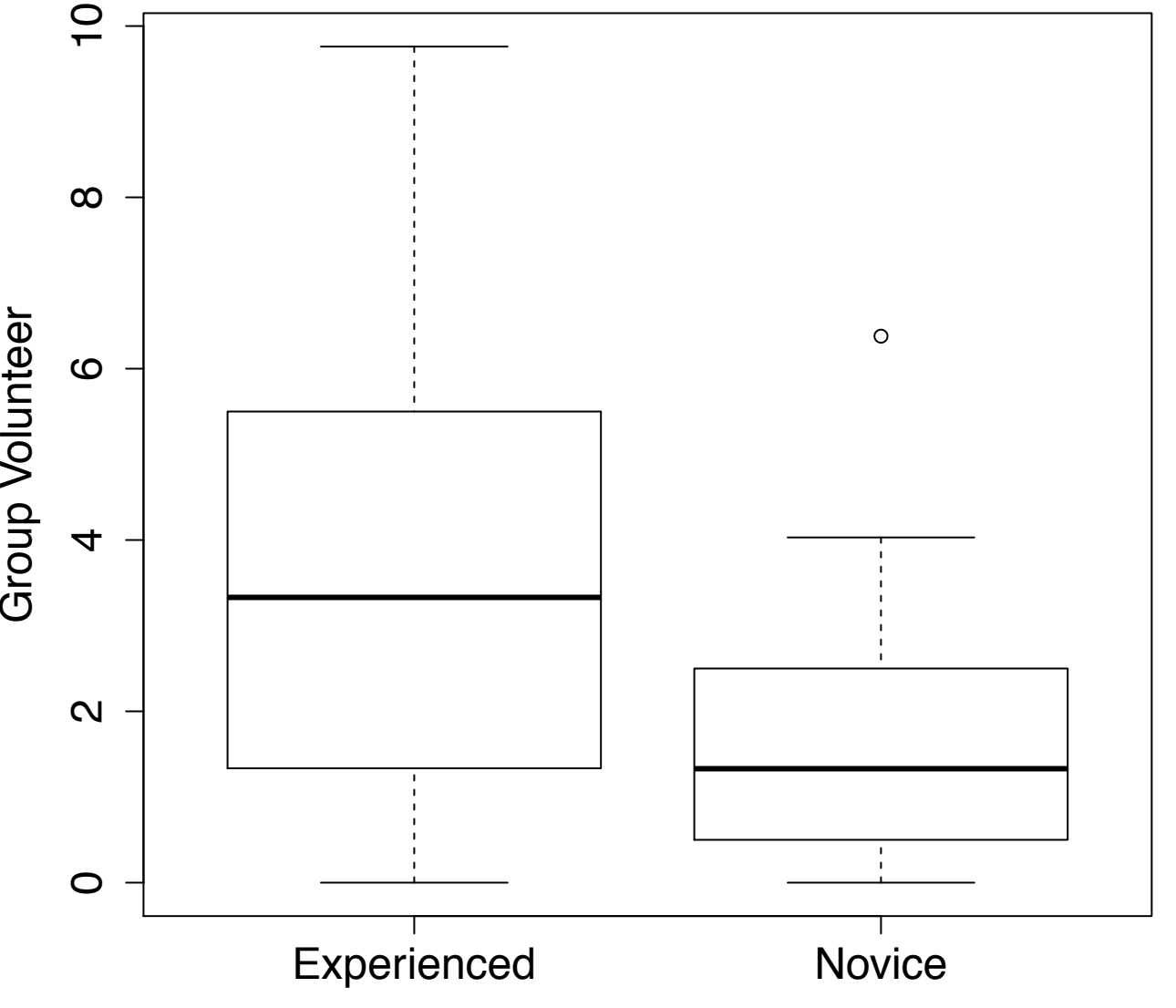

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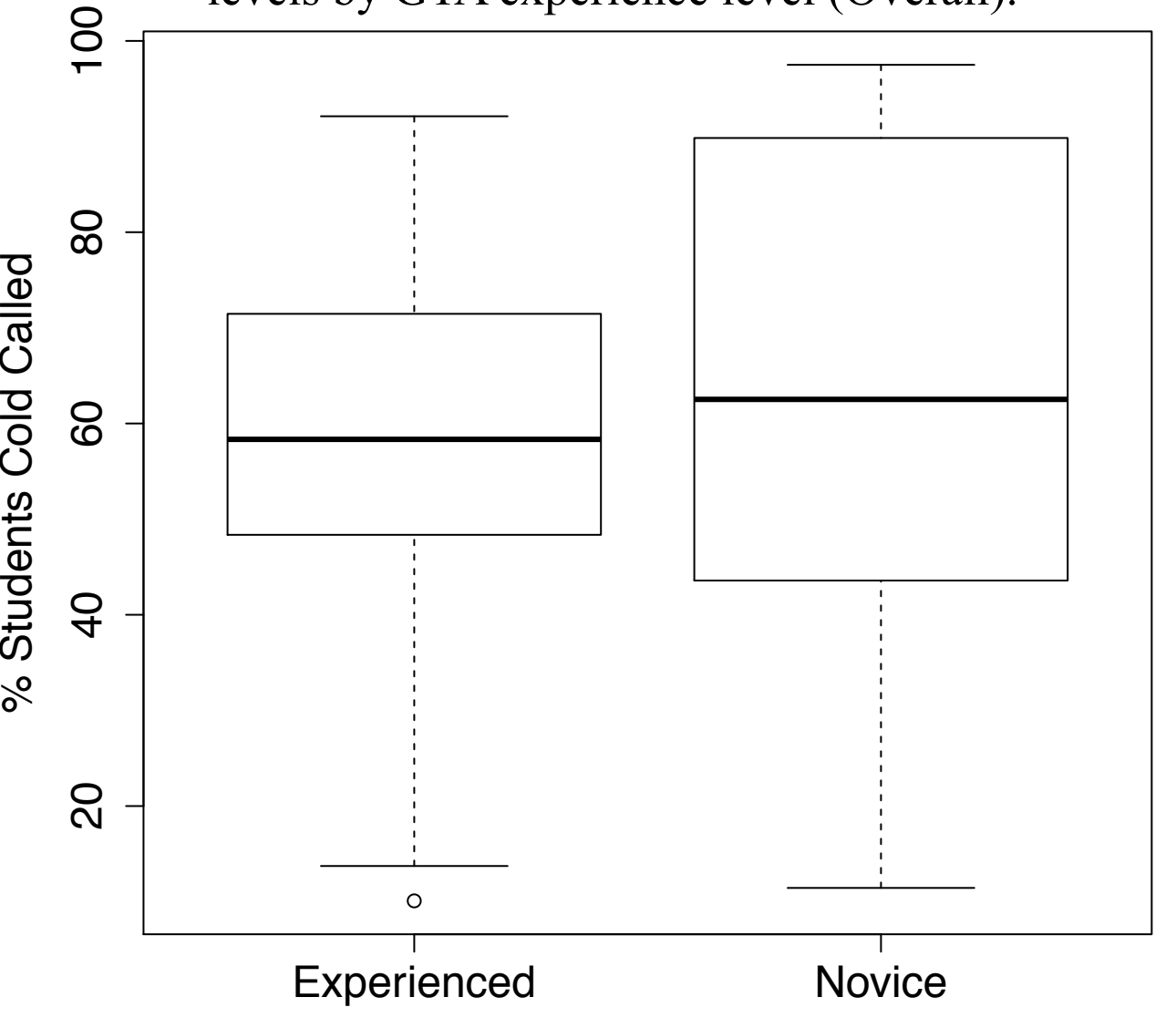

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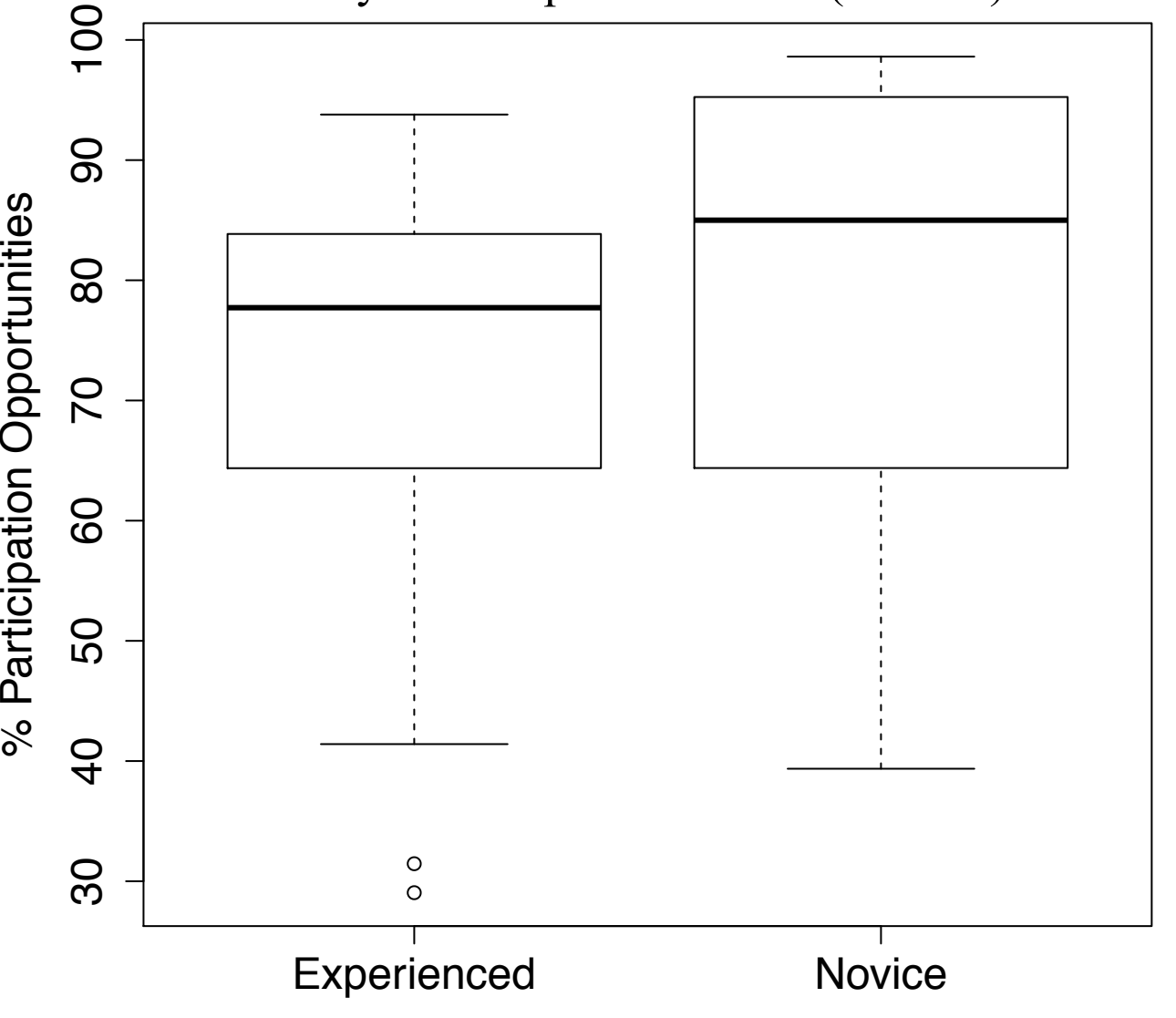

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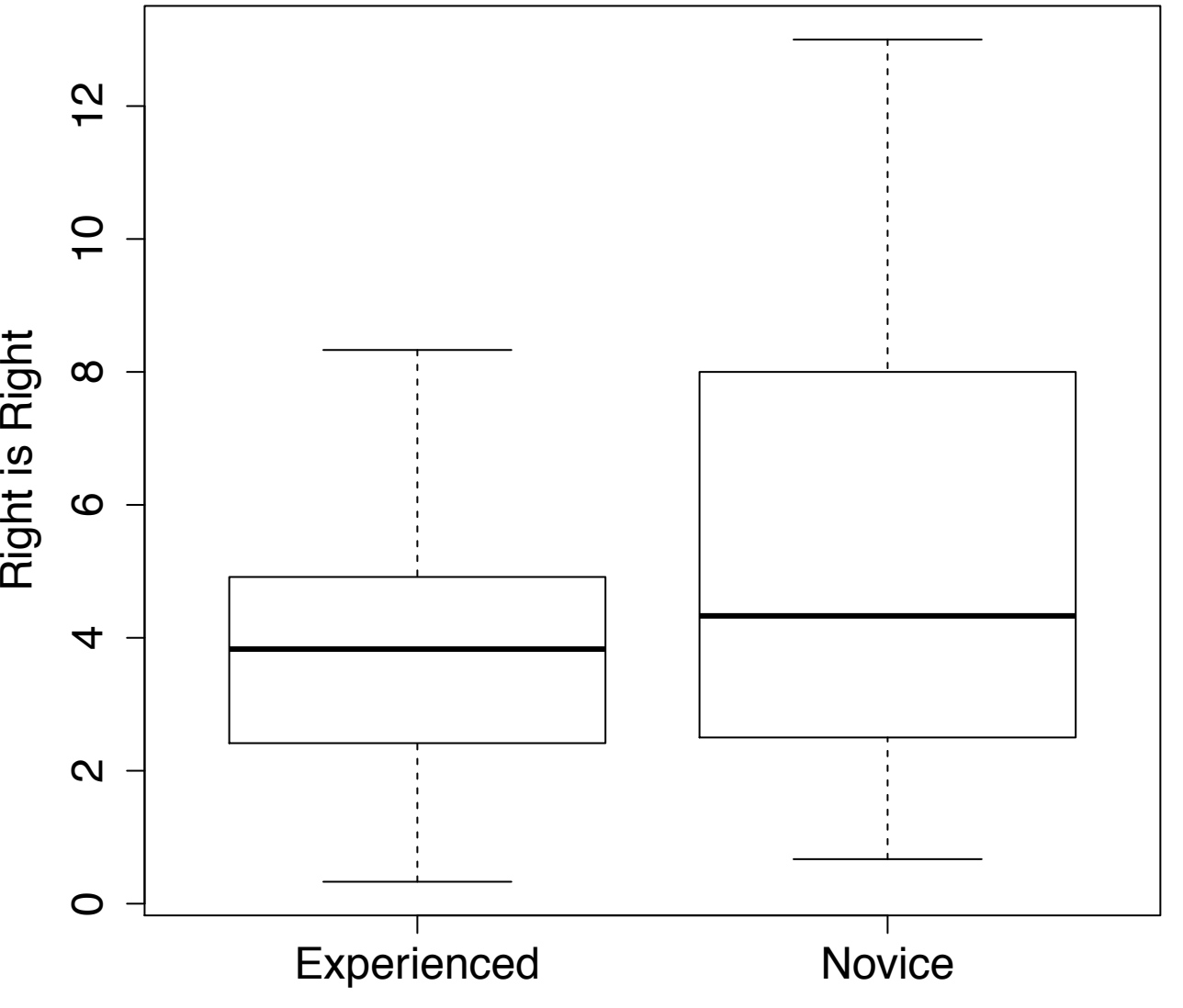

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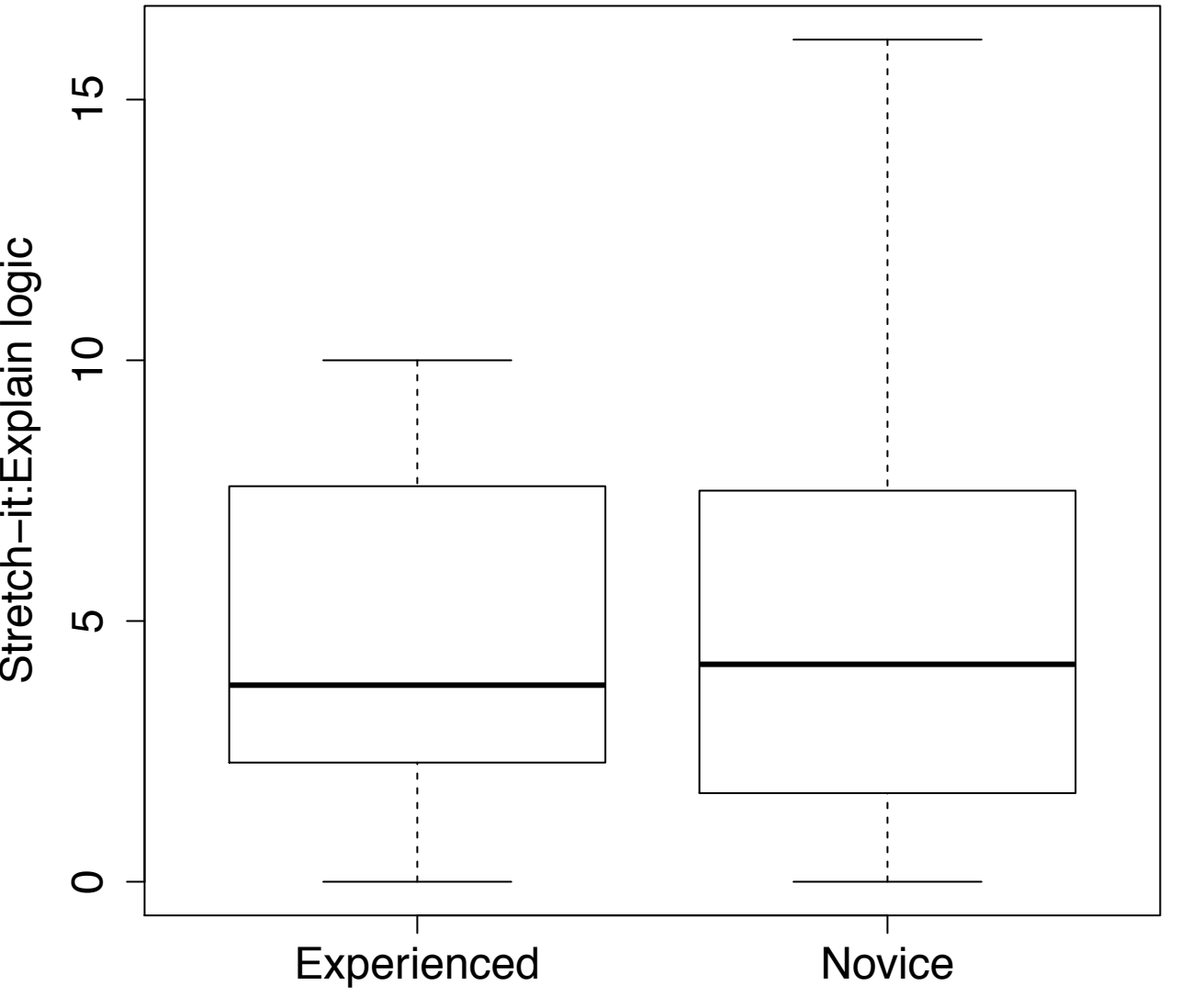

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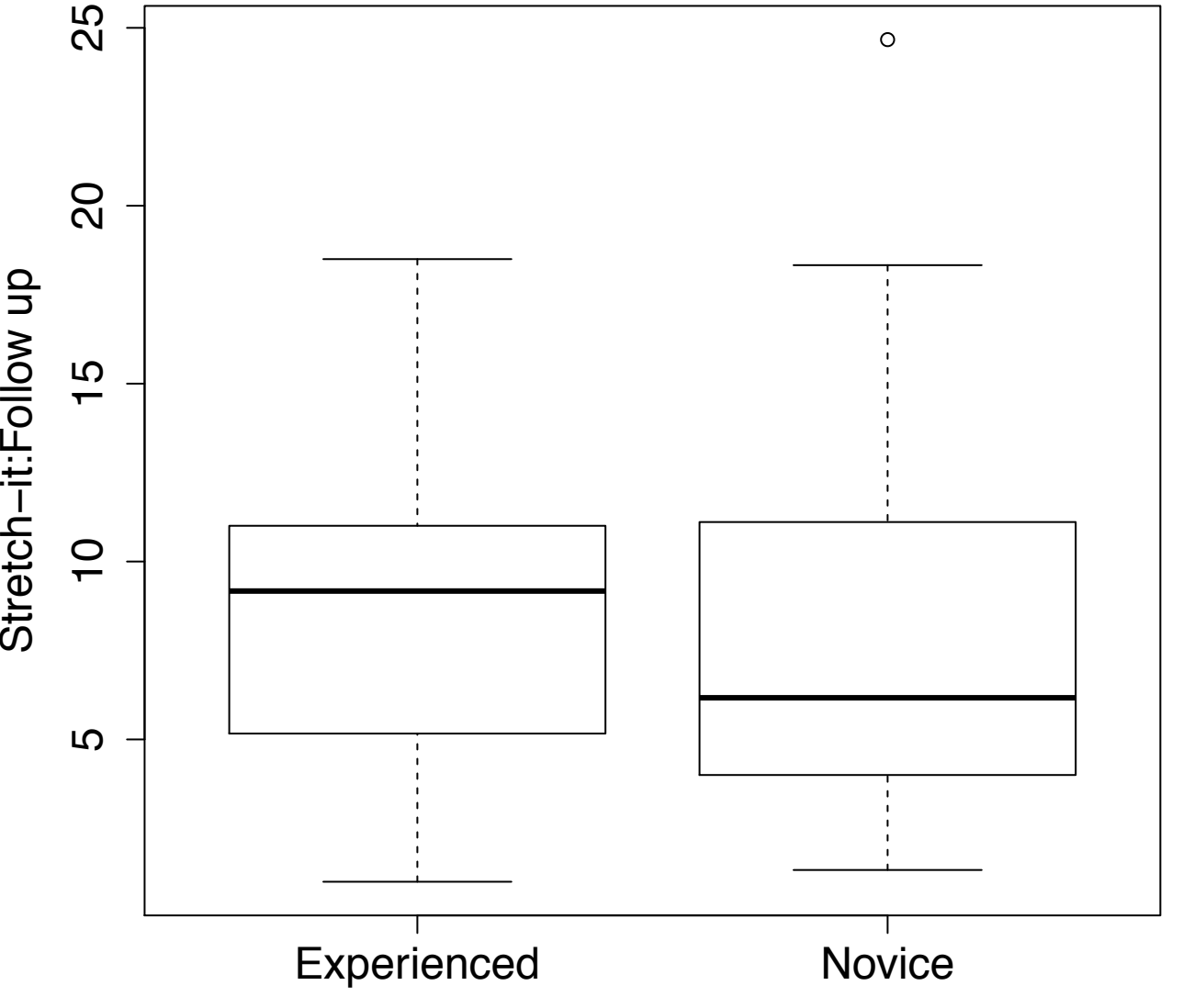

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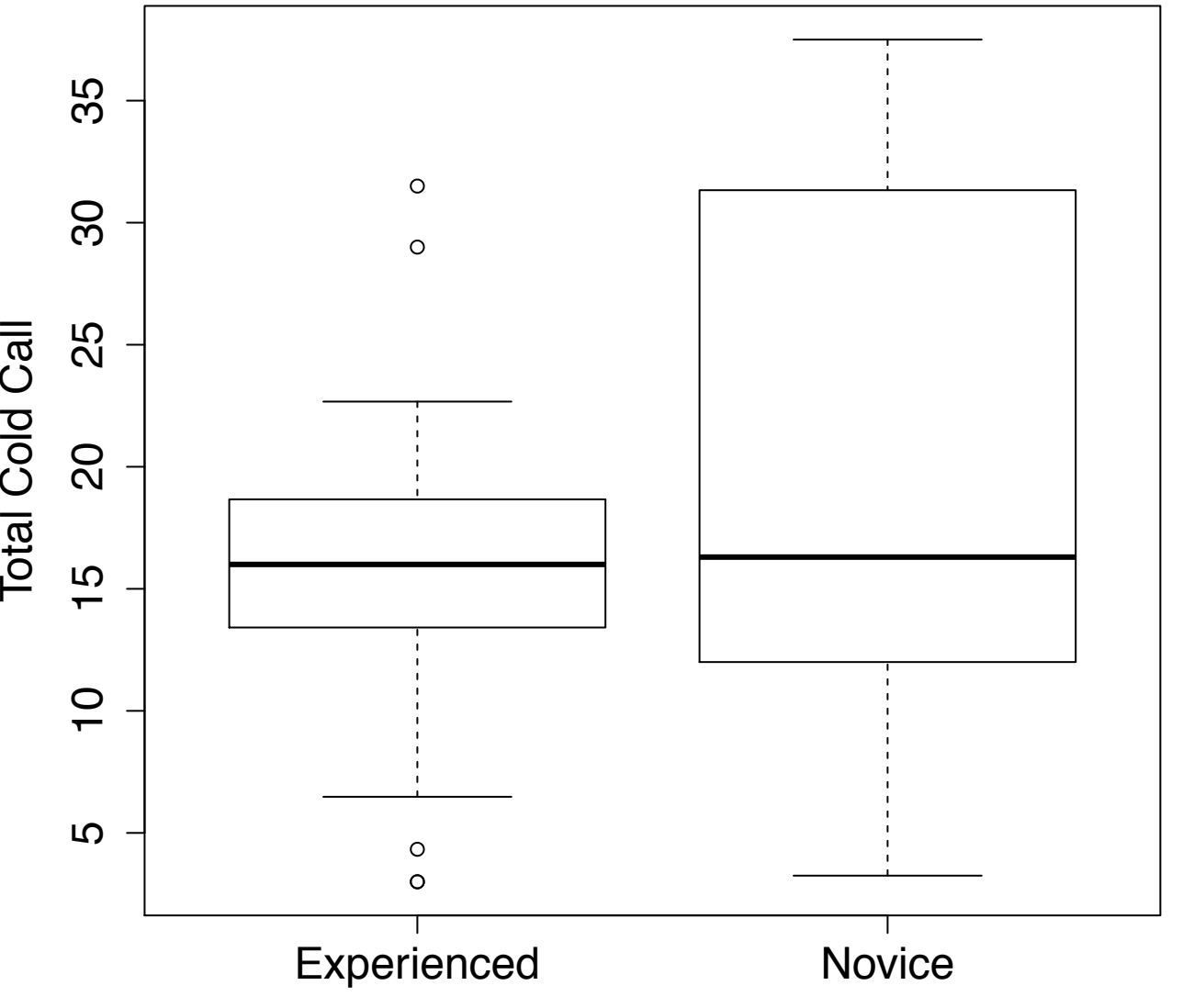

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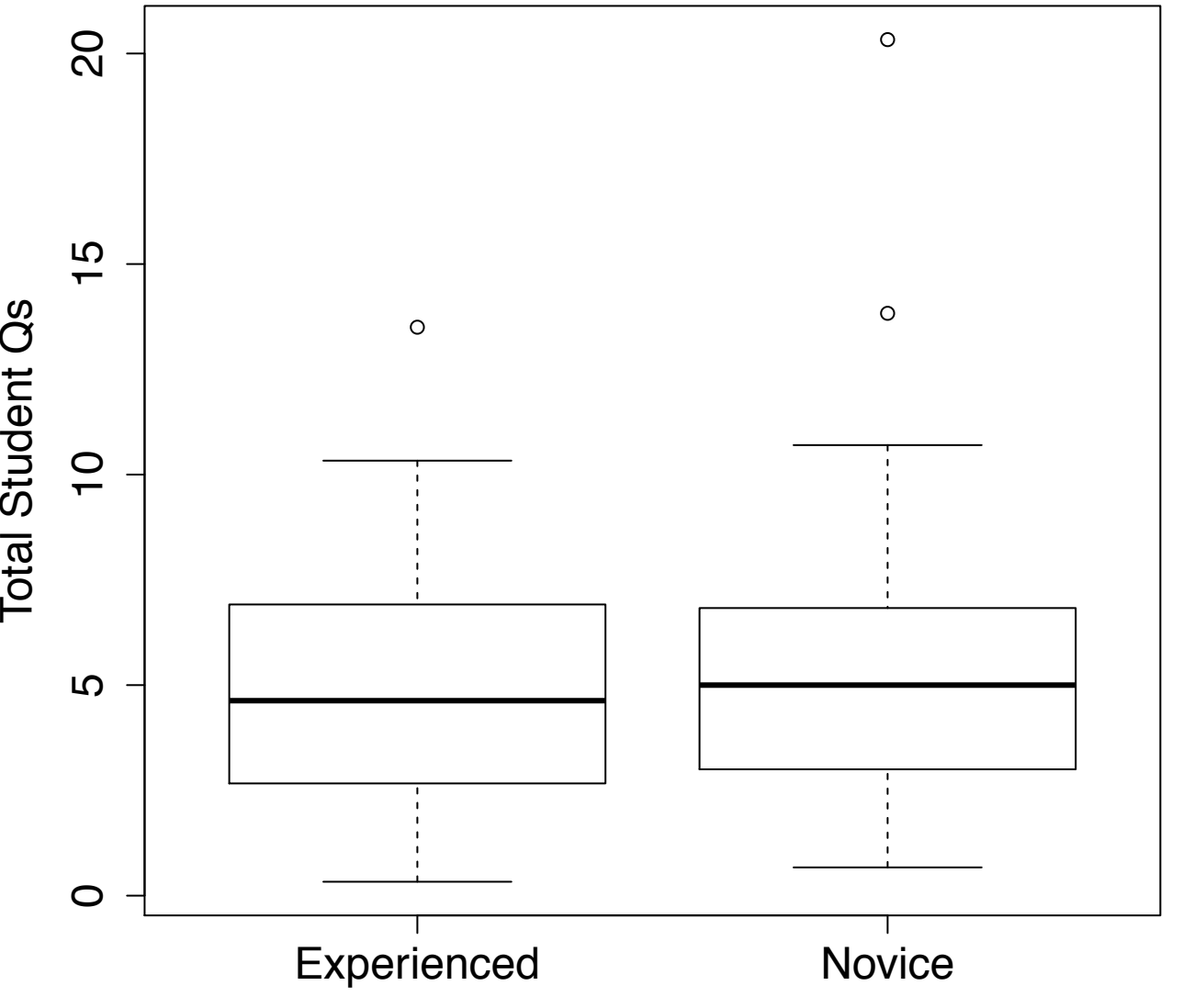

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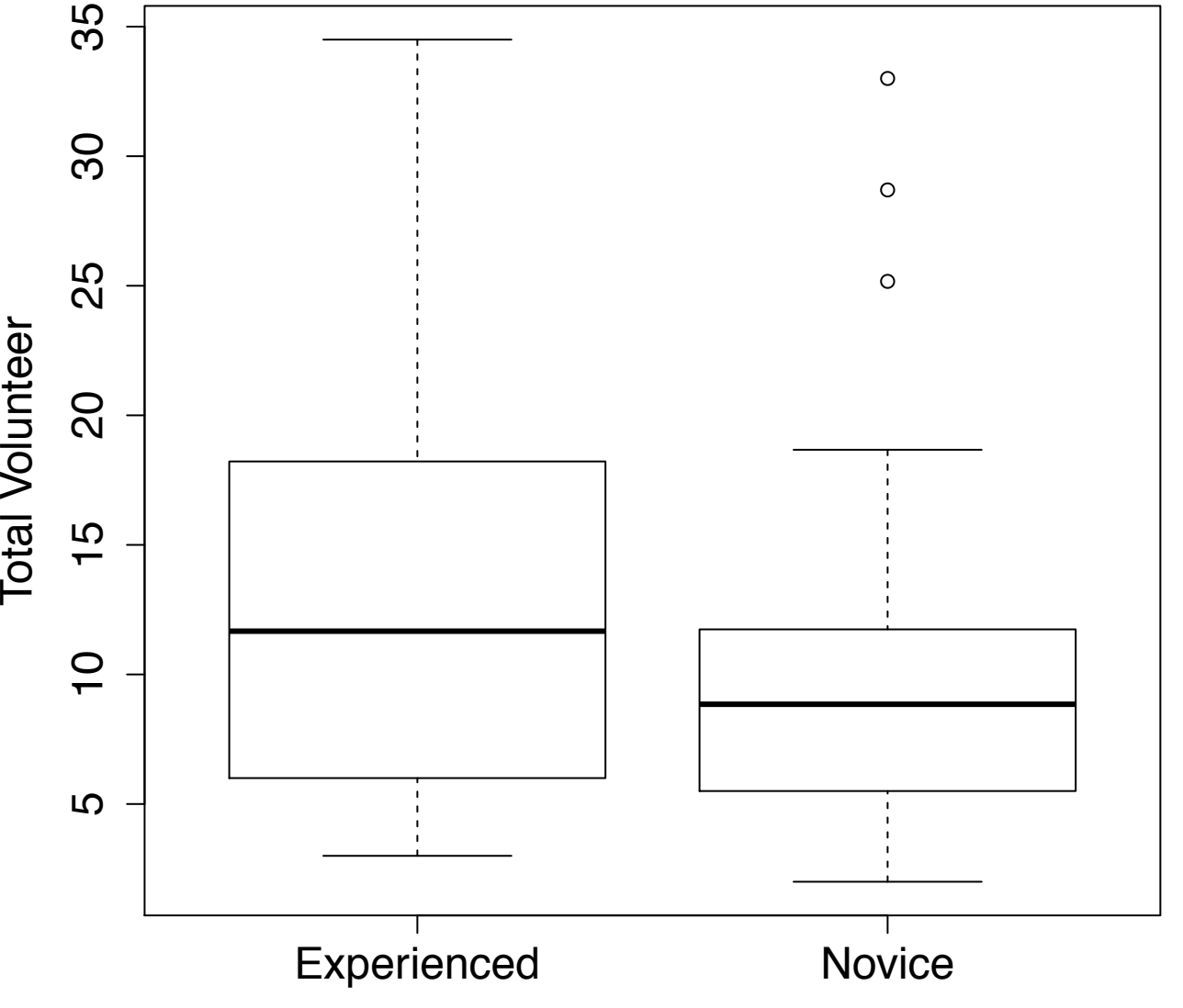

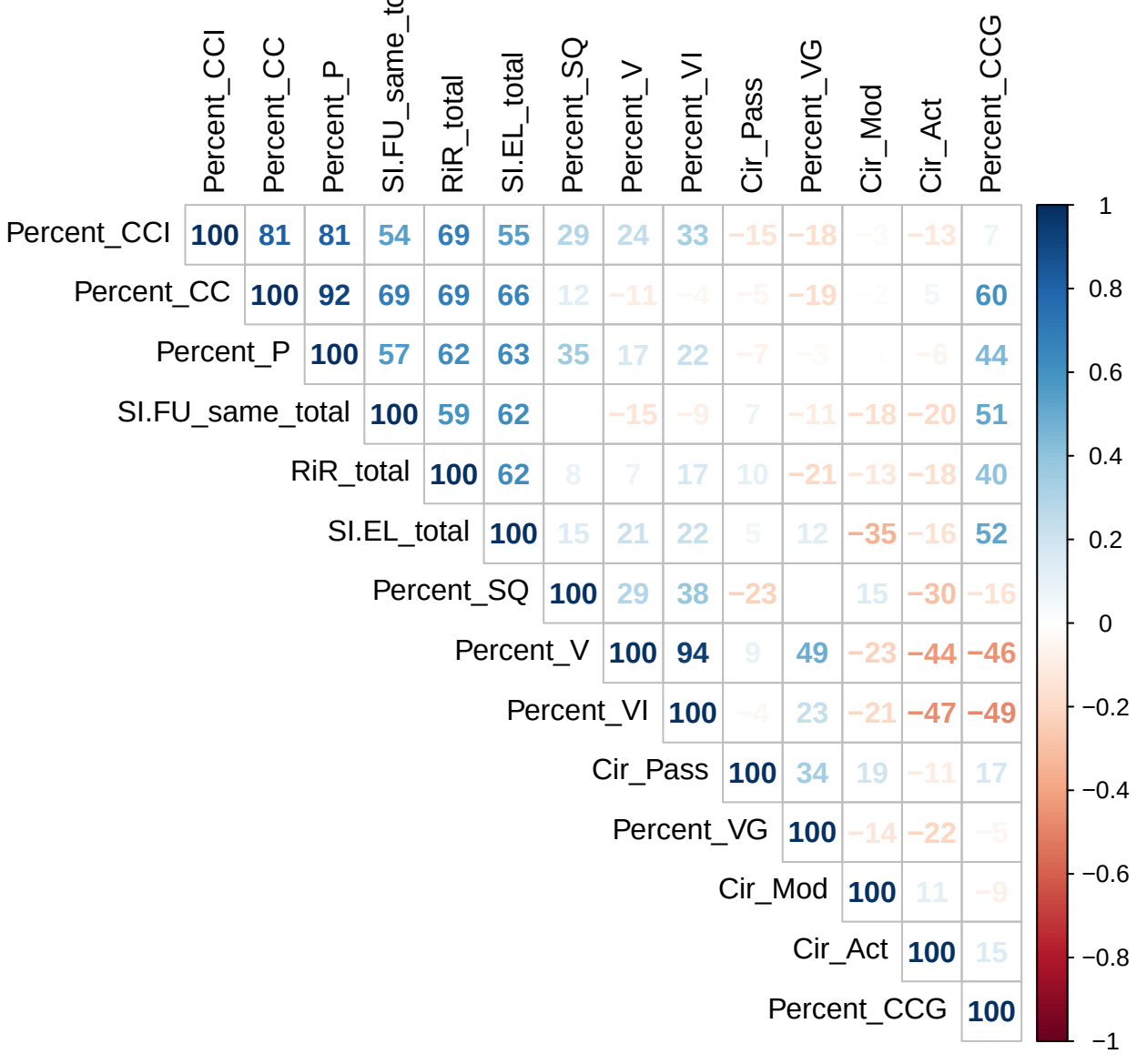
Percent_CCI
Percent_CC
Percent_P
SI.FU_same_to
RiR_total
SI.EL_total
Percent_SQ
Percent_V
Percent_VI
Cir_Pass
Percent_VG
Cir_Mod
Cir_Act
Percent_CCG
Percent_CCI 100 81 81 54 69 55 29 24 33 −15 −18 −3 −13 7
Percent_CC 100 92 69 69 66 12 −11 −4 −5 −19 −2 5 60
Percent_P 100 57 62 63 35 17 22 −7 −3 −6 44
SI.FU_same_total 100 59 62 −15 −9 7 −11 −18 −20 51
RiR_total 100 62 8 7 17 10 −21 −13 −18 40
SI.EL_total 100 15 21 22 5 12 −35 −16 52
Percent_SQ 100 29 38 −23 15 −30 −16
Percent_V 100 94 9 49 −23 −44 −46
Percent_VI 100 −4 23 −21 −47 −49
Cir_Pass 100 34 19 −11 17
Percent_VG 100 −14 −22 −5
Cir_Mod 100 11 −9
Cir_Act 100 15
Percent_CCG 100
1
0.8
0.6
0.4
0.2
0
−0.2
−0.4
−0.6
−0.8
−1

Supplementary Table 1: Discussion topics

Week	Subject
1	Chemistry
2	Redox chemistry
3	ATP production strategies
4	Membranes
5	Cell cycle
6	Common features of living things
7	DNA replication
8	Proteins
9	Central dogma
10	Gene regulation

Supplementary Table 2: Interclass correlation coefficients

	Paired-checked		Paired-independent		
Code	value	Interpretation	value	Interpretation	Description
RiR_Same_GTA	0.94	Excellent	0.94	Excellent	Right-is-Right-Same student-GTA
RiR_Same_ULA	NA	N/A	0.80	Excellent	Right-is-Right-Same student-ULA
RiR_Diff_GTA	0.96	Excellent	0.59	Fair	Right-is-Right-Different student-GTA
RiR_Diff_ULA	NA	N/A	0.00	Poor	Right-is-Right-Different student-ULA
RiR_total_GTA	0.97	Excellent	0.90	Excellent	Right-is-Right-Same or different-GTA
RiR_total_ULA	NA	N/A	1.00	Excellent	Right-is-Right-Same or different-ULA
SI.FU_Same_GTA	0.99	Excellent	0.90	Excellent	Stretch-it-Same student-Follow-up-GTA
SI.FU_Same_ULA	NA	N/A	0.60	Good	Stretch-it-Same student-Follow-up-ULA
SI.FU_Diff_GTA	0.87	Excellent	0.55	Fair	Stretch-it-Different student-Follow-up-GTA
SI.FU_Diff_ULA	NA	N/A	0.00	Poor	Stretch-it-Different student-Follow-up-ULA
SI.EL_Same_GTA	0.96	Excellent	0.89	Excellent	Stretch-it-Same student-Explain logic-GTA
SI.EL_Same_ULA	NA	N/A	1.00	Excellent	Stretch-it-Same student-Explain logic-ULA
SI.EL_total_GTA	0.97	Excellent	0.86	Excellent	Stretch-it-Same or Different-Explain logic-GTA
SI.EL_total_ULA	NA	N/A	1.00	Excellent	Stretch-it-Same or Different-Explain logic-ULA
SI.EL_Diff	0.72	Good	-0.09	Poor	Stretch-it-Different student-Explain logic-GTA
Cir_Pass_GTA	0.94	Excellent	0.89	Excellent	Circulate-Passive-GTA
Cir_Pass_ULA	1.00	Excellent	0.78	Excellent	Circulate-Passive-ULA
Cir_Mod_GTA	0.96	Excellent	0.77	Excellent	Circulate-Moderate-GTA
Cir_Mod_ULA	0.96	Excellent	0.93	Excellent	Circulate-Moderate-ULA
Cir_Act_GTA	0.98	Excellent	0.87	Excellent	Circulate-Active-GTA
Cir_Act_ULA	0.95	Excellent	0.98	Excellent	Circulate-Active-ULA
No_Apology	0.00	Poor	NA	N/A	No apology-GTA
Apology	NA	N/A	NA	N/A	Apology-GTA
Norm_Error	1.00	Excellent	0.00	Poor	Normalize error-GTA
PF.Class_Effort	NA	N/A	NA	N/A	Positive feedback-Whole class-Effort-GTA
PF.Class_Imp	NA	N/A	NA	N/A	Positive feedback-Whole class-Improvement-GTA
PF.Class_Know_GTA	0.66	Good	0.54	Fair	Positive feedback-Whole class-Knowledge-GTA
PF.Class_Know_ULA	NA	N/A	NA	N/A	Positive feedback-Whole class-Knowledge-ULA
PF.Indiv_Effort	1.00	Excellent	-0.03	Poor	Positive feedback-Indiv-Effort-GTA
PF.Indiv_Imp	1.00	Excellent	NA	N/A	Positive feedback-Indiv-Improvement-GTA
PF.Indiv_Know_GTA	0.99	Excellent	0.47	Fair	Positive feedback-Indiv-Knowledge-GTA
PF.Indiv_Know_ULA	NA	N/A	NA	N/A	Positive feedback-Indiv-Knowledge-ULA
NF.Class_Effort	NA	N/A	-0.08	Poor	Negative feedback-Whole class-Effort-GTA
NF.Class_Imp	NA	N/A	NA	N/A	Negative feedback-Whole class-Improvement-GTA
NF.Class_Know	NA	N/A	NA	N/A	Negative feedback-Whole class-Knowledge-GTA
NF.Indiv_Effort	NA	N/A	0.00	Poor	Negative feedback-Indiv-Effort-GTA
NF.Indiv_Imp	NA	N/A	NA	N/A	Negative feedback-Indiv-Improvement-GTA
NF.Indiv_Know	NA	N/A	NA	N/A	Negative feedback-Indiv-Knowledge-GTA
Part.Indiv.V_GTA	0.97	Excellent	0.89	Excellent	Participation -Indiv-Volunteer-GTA
Part.Indiv.V_ULA	NA	N/A	NA	N/A	Participation -Indiv-Volunteer-ULA
Part.Indiv.CC_all_GTA	1.00	Excellent	0.86	Excellent	Participation -Indiv-Cold call-GTA
Part.Indiv.CC_all_ULA	NA	N/A	NA	N/A	Participation -Indiv-Cold call-ULA
Part.Indiv.CC_nonresp	0.77	Excellent	0.92	Excellent	Participation -Indiv-Cold call (no response)-GTA
Part.Indiv.Q_GTA	0.99	Excellent	0.94	Excellent	Participation -Indiv-Student question-GTA
Part.Indiv.Q_ULA	NA	N/A	NA	N/A	Participation -Indiv-Student question-ULA
Part.Group.V_GTA	0.62	Good	0.67	Good	Participation -Group-Volunteer-GTA
Part.Group.V_ULA	NA	N/A	NA	N/A	Participation -Group-Volunteer-ULA
Part.Group.CC_all_GTA	0.99	Excellent	0.84	Excellent	Participation -Group-Cold call-GTA
Part.Group.CC_all_ULA	NA	N/A	NA	N/A	Participation -Group-Cold call-ULA
Part.Group.CC_nonresp	0.00	Poor	0.18	Poor	Participation -Group-Cold call (no response)-GTA
Diff_Stu.Indiv_V_GTA	0.96	Excellent	0.81	Excellent	# different students-Indiv-Volunteer-GTA
Diff_Stu.Indiv_V_ULA	NA	N/A	NA	N/A	# different students-Indiv-Volunteer-ULA
Diff_Stu.Indiv_CC_all_GTA	0.98	Excellent	0.91	Excellent	# different students-Indiv-Cold call-GTA
Diff_Stu.Indiv_CC_all_ULA	NA	N/A	NA	N/A	# different students-Indiv-Cold call-ULA

Supplementary Table 2: Interclass correlation coefficients

	Paired-checked		Paired-independent		
Code	**value**	**Interpretation**	**value**	**Interpretation**	**Description**
Diff_Stu.Indiv_CC_nonresp	0.44	Fair	0.83	Excellent	# different students-Indiv-Cold call (no response)-GTA
Diff_Stu.G_V_GTA	0.77	Excellent	0.72	Good	# different students-Group-Volunteer-GTA
Diff_Stu.G_V_ULA	NA	N/A	NA	N/A	# different students-Group-Volunteer-ULA
Diff_Stu.G_CC_all_GTA	0.98	Excellent	0.86	Excellent	# different students-Group-Cold call-GTA
Diff_Stu.G_CC_all_ULA	NA	N/A	NA	N/A	# different students-Group-Cold call-ULA
Diff_Stu.G_CC_nonresp	0.00	Poor	0.46	Fair	# different students-Group-Cold call (no response)-GTA
Total_V_GTA	0.89	Excellent	0.95	Excellent	Total participation-Volunteer-GTA
Total_V_ULA	NA	N/A	NA	N/A	Total participation-Volunteer-ULA
Total_CC_all_GTA	1.00	Excellent	0.98	Excellent	Total participation-Cold call-GTA
Total_CC_all_ULA	NA	N/A	NA	N/A	Total participation-Cold call-ULA
Total_CC_nonres	0.76	Excellent	0.79	Excellent	Total participation-Cold call (no response)-GTA
Total_Q_GTA	0.99	Excellent	0.94	Excellent	Total participation- Student question-to GTA
Total_Q_ULA	NA	N/A	NA	N/A	Total participation- Student question-to ULA
Total_Diff_V_GTA	0.95	Excellent	0.84	Excellent	# different students-Volunteer (Indiv + Group)-GTA
Total_Diff_V_ULA	NA	N/A	NA	N/A	# different students-Volunteer (Indiv + Group)-ULA
Total_Diff_CC_all_GTA	0.96	Excellent	0.98	Excellent	# different students-Cold call (Indiv + Group)-GTA
Total_Diff_CC_all_ULA	NA	N/A	NA	N/A	# different students-Cold call (Indiv + Group)-ULA
Total_Diff_CC_nonresp	0.43	Fair	0.84	Excellent	# different students-Cold call (no response, Indiv + Group)-GTA
Total_Diff_Q_GTA	0.95	Excellent	0.84	Excellent	# different students-Student question-to GTA
Total_Diff_Q_ULA	NA	N/A	NA	N/A	# different students-Student question-to GTA
Total_Diff_P_opp_GTA	0.96	Excellent	0.93	Excellent	# different students volunteered, asked question, or were cold called-GTA
Total_Diff_P_opp_ULA	NA	N/A	NA	N/A	# different students volunteered, asked question, or were cold called-ULA
Total_Diff_P_actual_GTA	0.96	Excellent	0.93	Excellent	# different students volunteered, asked question, or answered a cold call-GTA
Total_Diff_P_actual_ULA	NA	N/A	NA	N/A	# different students volunteered, asked a question, or answered a cold call-ULA
Num_students	0.99	Excellent	0.96	Excellent	# students during observation
Percent_CC_opp_GTA	0.97	Excellent	0.98	Excellent	% of students who were cold called-GTA
Percent_CC_act_GTA	0.95	Excellent	0.98	Excellent	% of students who answered a cold call-GTA
Percent_Part_opp_GTA	0.96	Excellent	0.93	Excellent	% of students who volunteered, asked a question, or were cold called-GTA
Percent_Part_act_GTA	0.96	Excellent	0.92	Excellent	% of students who volunteered, asked a question, or answered a cold call-GTA
Percent_CC_act_ULA	NA	N/A	NA	N/A	% of students who answered a cold call-ULA
Percent_Part_act_ULA	NA	N/A	NA	N/A	% of students who volunteered, asked a question, or answered a cold call-ULA
Percent_CC_act_total	0.95	Excellent	0.98	Excellent	% of students who answered a cold call (GTA or ULA)
Percent_Part_act_total	0.96	Excellent	0.92	Excellent	% of students who volunteered, asked a question, or answered a cold call (GTA or ULA)
Total_CC_all_total	1.00	Excellent	0.98	Excellent	Total participation-Cold call (GTA or ULA)

Totals
Excellent
Good
Fair
Poor
N/A
>0.9

Totals
Excellent
Good
Fair
Poor
N/A
>0.9

Supplementary Table 3: Student demographics

	Fall 2013 (in class)	**Fall 2014** (in class)	**Fall 2015** (in class)	**Fall 2014** (in model)
First Gen. (%)	35.33	39.86	43.12	40.65
Female (%)	67.03	67.31	68.17	68.32
URM (%)	22.93	26.64	28.71	26.4
Transfer (%)	19.0	17.26	17.31	16.79
Repeater (%)	2.95	3.43	3.33	3.38
GPA (mean ± SD)	2.87 ± 0.67	2.84 ± 0.68	2.91 ± 0.67	2.87 ± 0.63
# students	1016	991	923	947

Supplementary Table 4: Target technique five-number summaries

	By GTA						
	Right is Right	Stretch-it: Follow-up (same student)	Stretch-it: Follow-up (diff student)	Stretch-it: Explain Logic	Circulate (moderate)	Circulate (active)	Cold Call
Min	1.07	3.04	0.89	0.76	2.53	1.18	7.41
Q1	2.80	5.75	1.48	3.59	4.48	5.84	13.21
Median	3.48	8.27	2.11	5.05	6.80	6.63	16.98
Q3	6.54	11.00	3.04	6.82	7.96	9.02	24.94
Max	8.80	14.22	4.80	11.12	9.77	13.35	30.06

	By Classroom						
	Right is Right	Stretch-it: Follow-up (same student)	Stretch-it: Follow-up (diff student)	Stretch-it: Explain Logic	Circulate (moderate)	Circulate (active)	Cold Call
Min	0.38	1.62	0.25	0.00	2.25	0.83	3.12
Q1	2.40	5.76	1.25	3.00	4.12	3.75	11.99
Median	3.81	7.38	1.88	5.39	5.17	7.53	18.22
Q3	6.33	10.84	3.00	7.33	8.30	9.79	24.25
Max	12.10	19.35	6.83	14.21	12.35	16.81	36.27

Supplementary Table 5: Descriptive statistics of participation

	By GTA							
	% Part. (all)	% Cold Call	% Volunteer	% Student Qs	% Volunteer (Group)	% Volunteer (Indiv.)	% Cold Call (Group)	% Cold Call (Indiv.)
Min	46.29	29.00	14.39	5.29	2.67	10.34	4.63	15.30
Q1	64.23	49.92	23.02	13.64	6.85	18.98	13.82	33.88
Median	79.49	58.59	30.16	17.41	9.62	22.81	25.06	41.22
Q3	84.98	74.67	38.27	19.00	14.03	32.32	34.37	58.05
Max	94.17	89.32	52.91	23.64	22.43	51.84	57.95	69.13

	By classroom							
	% Part. (all)	% Cold Call	% Volunteer	% Student Qs	% Volunteer (Group)	% Volunteer (Indiv.)	% Cold Call (Group)	% Cold Call (Indiv.)
Min	28.59	13.56	6.13	2.90	1.70	4.88	1.85	8.79
Q1	70.02	45.72	21.68	10.13	4.64	17.30	13.71	29.68
Median	79.47	62.50	27.97	14.99	9.94	22.04	22.75	43.79
Q3	85.12	74.91	40.56	20.75	14.74	33.33	38.34	58.34
Max	100.00	99.64	67.77	37.45	22.63	67.77	79.20	82.32

Supplementary Table 6: Longitudinal changes in classroom practices

Classroom Practice	Cliff's *d*	95% CI	magnitude	p-value
Circulate (passive)	-0.23	[-0.57, 0.19]	-	0.298
Circulate (moderate)	0.55	[0.11, 0.81]	large	0.010
Circulate (active)	-0.12	[-0.45, 0.23]	-	0.576
Right is Right	-0.42	[-0.72, 0.02]	-	0.054
Stretch it: Explain Logic	-0.64	[-0.87, -0.17]	large	0.003
Stretch it: Follow-up (same)	0.05	[-0.37, 0.45]	-	0.819
Stretch it: Follow-up (diff)	0.28	[-0.17, 0.63]	-	0.206
Individual Volunteer	0.41	[-0.09, 0.75]	-	0.056
Group Volunteer	0.52	[0.09, 0.78]	large	0.017
Total Volunteer	0.45	[-0.02, 0.76]	-	0.038
Individual Cold Call	-0.41	[-0.71, 0.01]	-	0.056
Group Cold Call	-0.13	[-0.47, 0.24]	-	0.547
Total Cold Call	-0.52	[-0.78, -0.11]	large	0.016
Student Questions	-0.13	[-0.5, 0.28]	-	0.561
% Cold Call	-0.59	[-0.83, -0.16]	large	0.005
% Participation	-0.56	[-0.81, -0.14]	large	0.008