The role of causal information for sequence discrimination learning in young children

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Introduction

1.1Background

Humans share a large number of their cognitive skills with other apes, as we are closely related to each other (Tomasello & Herrmann, 2010, p. 3), however in some cases, such cognitive skills are either less evolved or non-existent in other primate species as they do in humans. One such cognitive skill is sequence cognition. Sequence cognition is the capacity to organise, understand and act upon a series of steps in the order in which they were performed, and it is an essential ability in everyday life as it is used in many different ways, for example; language, tool use and foraging, which are traditionally viewed as key skills in human evolution, but which non-human primates also display. Endress et al (2009) suggested that evidence for the precursor to modern language can be seen with monkeys today (p. 750), suggesting that sequence discrimination does exist to some degree in many monkey and primate species. There are past studies supporting the overall hypothesis of this study, that the evolution of cognitive skills, specifically, sequence cognition and discrimination were essential to modern human evolution. One study researching the difference in sensitivity for types of sequences was one conducted by Endress, Carden, Versace and Hauser (2010), which found that chimpanzees were capable of tracking the relative position of items in a sequence after limited exposure to sequences but didn't have sensitivity to relations among items in a sequence. This was supported by the work of Fitch and Hauser (2004) who studied the computational constraints on synthetic processing in non-human primates and showed possible limitations of the synthetical cognitive ability of other primates. Conway and Christiansen's (2001) study is also relevant, as it investigates sequential learning in primates, supporting the previous studies validity. Overall, several studies concluded that non-human primates were capable of discriminating between arbitrarily composed sequences to a limited capacity (Ghirlanda, Lind, & Enguist, 2017). However, it is yet unclear whether this conclusion also applies to a less arbitrary sequence. One aim of the overall study is to determine this, and as such two conditions will be run; causal cue and no causal cue (with the causal cue providing a cue that a specific sequence is the correct one). The "paper towel task" contains a 2-step sequence, and only one out of 4 possibilities will provide a reward. As such, the causal cue will act as a hint to the children to the importance of the sequence itself in gaining reward. The no causal cue will have no such hint, and as such participants will likely take more trials to correctly discriminate between the sequences.

1.2 Hypotheses

The hypotheses of this study are: 1) there is a general correlation between a child's age and their success in performing all types of trials. 2) participants will be more successful in reaching discrimination criteria in the "causal cue" condition rather than the "no causal cue" condition.

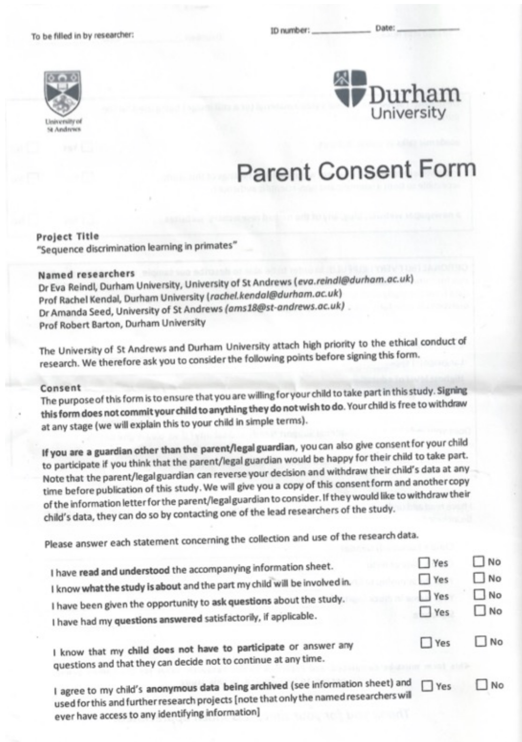
Methods

2.1 Informed Consent

The child study contains a range of children from the age range of 3-11 years old, the children volunteer for the study by approaching the study table in the Bodongo Building located in Edinburgh Zoo. The study will continue until a sufficient sample, reaching 20 children in each age and each condition, overall 320. The parents of the children will be given a consent form and an information sheet (figures 1 & 2 below) in addition to a verbal explanation so informed written consent can be obtained. A time estimation for the length of the study (15 minutes) will also be conveyed. Once the parent gives informed consent the task will be explained to the child, along with the instructions that the child can stop at any time should they decide they no longer want to continue, and so any data gained will no longer be used. Before the beginning of the study, the child will choose a sticker scene from several available options, which will serve as a high reward during the task. Additionally, parents and siblings will be asked to not interfere to maintain the validity of the data. The child's choices will be recorded on a coding sheet, and the child will be given an anonymous number matching the one on the consent form.

A camera will record video of the participant choices, to increase the validity and reliability of the choices marked down in the coding sheets.

figure 1: the front page of the consent form sheet



To be filled in by researcher: ID number: ________ Date: ________

University of St Andrews

Durham University

Parent Consent Form

Project Title
"Sequence discrimination learning in primates"

Named researchers
Dr Eva Reindl, Durham University, University of St Andrews (*eva.reindl@durham.ac.uk*)
Prof Rachel Kendal, Durham University (*rachel.kendal@durham.ac.uk*)
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Prof Robert Barton, Durham University

The University of St Andrews and Durham University attach high priority to the ethical conduct of research. We therefore ask you to consider the following points before signing this form.

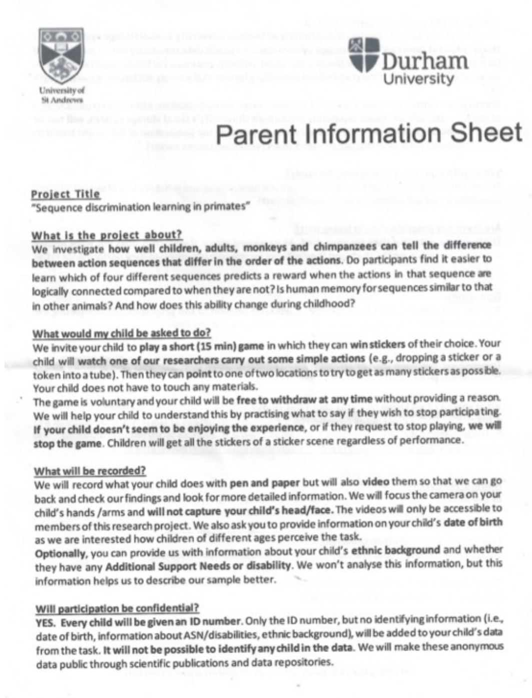
Consent
The purpose of this form is to ensure that you are willing for your child to take part in this study. **Signing this form does not commit your child to anything they do not wish to do.** Your child is free to withdraw at any stage (we will explain this to your child in simple terms).

If you are a guardian other than the parent/legal guardian, you can also give consent for your child to participate if you think that the parent/legal guardian would be happy for their child to take part. Note that the parent/legal guardian can reverse your decision and withdraw their child's data at any time before publication of this study. We will give you a copy of this consent form and another copy of the information letter for the parent/legal guardian to consider. If they would like to withdraw their child's data, they can do so by contacting one of the lead researchers of the study.

Please answer each statement concerning the collection and use of the research data.

I have **read and understood** the accompanying information sheet.	☐ Yes	☐ No
I know **what the study is about** and the part my child will be involved in.	☐ Yes	☐ No
I have been given the opportunity to **ask questions** about the study.	☐ Yes	☐ No
I have had my **questions answered** satisfactorily, if applicable.	☐ Yes	☐ No
I know that my **child does not have to participate** or answer any questions and that they can decide not to continue at any time.	☐ Yes	☐ No
I agree to my child's **anonymous data being archived** (see information sheet) and used for this and further research projects [note that only the named researchers will ever have access to any identifying information]	☐ Yes	☐ No

figure 2: the front page of the information sheet



University of St Andrews

Durham University

Parent Information Sheet

Project Title
"Sequence discrimination learning in primates"

What is the project about?
We investigate **how well children, adults, monkeys and chimpanzees can tell the difference between action sequences that differ in the order of the actions**. Do participants find it easier to learn which of four different sequences predicts a reward when the actions in that sequence are logically connected compared to when they are not? Is human memory for sequences similar to that in other animals? And how does this ability change during childhood?

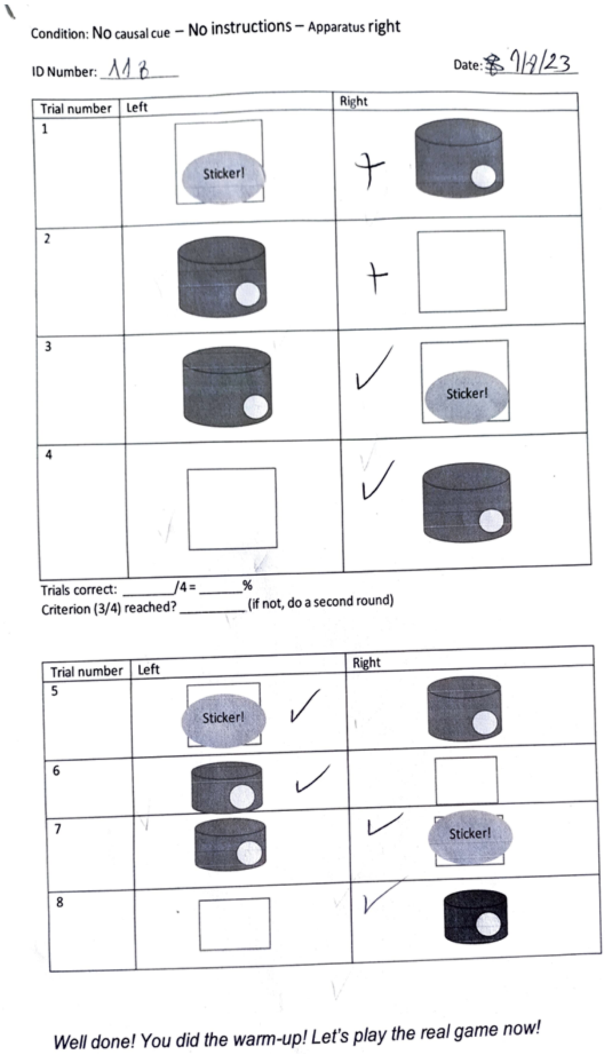
What would my child be asked to do?
We invite your child to **play a short (15 min) game** in which they can **win stickers** of their choice. Your child will **watch one of our researchers carry out some simple actions** (e.g., dropping a sticker or a token into a tube). Then they can **point** to one of two locations to try to get as many stickers as possible. Your child does not have to touch any materials.
The game is voluntary and your child will be **free to withdraw at any time** without providing a reason. We will help your child to understand this by practising what to say if they wish to stop participating. **If your child doesn't seem to be enjoying the experience**, or if they request to stop playing, **we will stop the game**. Children will get all the stickers of a sticker scene regardless of performance.

What will be recorded?
We will record what your child does with **pen and paper** but will also **video** them so that we can go back and check our findings and look for more detailed information. We will focus the camera on your child's hands /arms and **will not capture your child's head/face.** The videos will only be accessible to members of this research project. We also ask you to provide information on your child's **date of birth** as we are interested how children of different ages perceive the task.
Optionally, you can provide us with information about your child's **ethnic background** and whether they have any **Additional Support Needs or disability**. We won't analyse this information, but this information helps us to describe our sample better.

Will participation be confidential?
YES. Every child will be given an ID number. Only the ID number, but no identifying information (i.e., date of birth, information about ASN/disabilities, ethnic background), will be added to your child's data from the task. **It will not be possible to identify any child in the data.** We will make these anonymous data public through scientific publications and data repositories.

2.2 Opt-out Phase

Children who join the study first go through an opt-out round. The opt-out round contains 4 trials and is designed to test the children for the ability to 'opt out' of an undesired outcome, along with serving the secondary purpose of teaching the child the rules of the study. In the study, this is done to ensure the children are capable of discriminating between the sequences rather than choosing at random. This is also done to maintain fewer variables between the child part of the study and the several non-human primates, as the primates cannot communicate their understanding, unlike the children. Each opt-out round contains t 4 trials, two high-reward ones and two low-reward ones at an alternating pattern and placement, to ensure the children are not simply choosing one side. The child chooses between two boxes; a white one capable of containing the high reward, and a green one containing the low reward (low rewards are plain star stickers). A participant must achieve a 75% success rate to progress to the training phase of the study. If this isn't achieved, a second round of opt-out trials will take place. Once both rounds of opt-out trials were performed, the child progressed to the training phase of the study. All of the child's choices are marked on the coding sheet (figure 3).



Condition: No causal cue – No instructions – Apparatus right

ID Number: 118 Date: 7/9/23

Trial number	Left	Right
1	Sticker!	+
2		+
3		✓ Sticker!
4		✓

Trials correct: ______/4 = ______%

Criterion (3/4) reached? ________ (if not, do a second round)

Trial number	Left	Right
5	Sticker! ✓	
6	✓	
7		✓ Sticker!
8		✓

Well done! You did the warm-up! Let's play the real game now!

figure 3: a coding sheet of a participant showing the marking of the opt-out trials.

2.3 Training Phase

Once a child progresses to the training phase they will be introduced to the apparatus (figures 4 & 5). The Training phase has two possible conditions, no causal cue and causal cue, which are chosen semi-randomly, to approach an even balance in each age group. The no causal cue condition contains another white box, in which the token the child wins for high rewards is placed, rather than in the apparatus, like the causal cue condition. The child goes through six trials, three containing the high reward and three without. Of the trials containing only low rewards, the different sequences are introduced: 1) sleeve then paper towel into apparatus with apparatus already having a paper towel (AA sequence), 2) sleeve then reward with apparatus empty (BA sequence) 3) sleeve then paper towel with apparatus empty (BB). The order of the trials is marked on the coding sheet the researchers follow. The choice is presented to the child in this order: 1) the sequence is performed in front of the child 2) once the child chooses either the tunnel is separated from the apparatus to show the insides of it to the child (causal cue) or the white small box is opened with the contents shown to the child. Each choice the child makes is recorded on the coding sheet.

figure 4: Causal cue training phase apparatus set up, with apparatus to the researcher's left. A green box with low rewards on the right. A plastic shield separates the equipment from the participant, and it has two holes on each side for the child to point to.

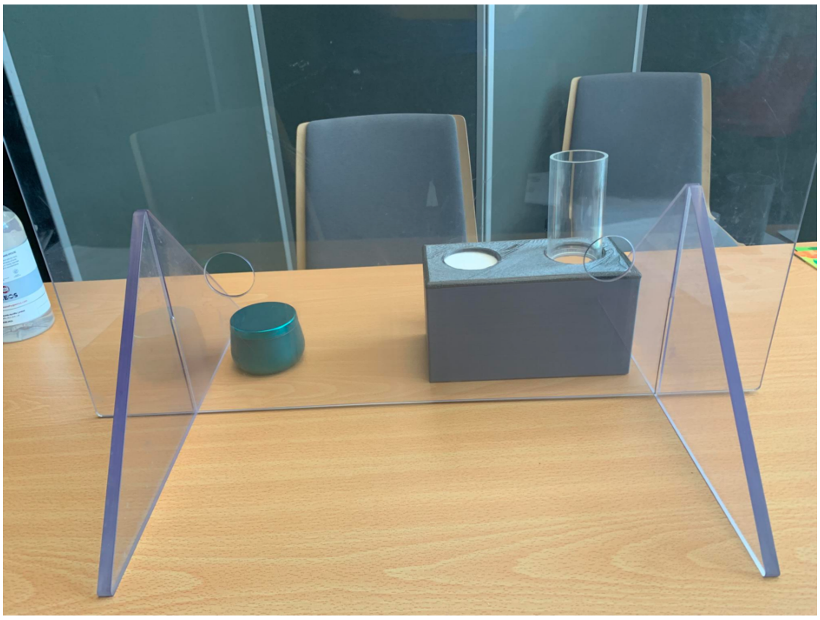


figure 5: No causal cue training phase apparatus set up, with apparatus to the researcher's left. A green box with low rewards on the right. A plastic shield separates the equipment from the participant, and it has two holes on each side for the child to point to.

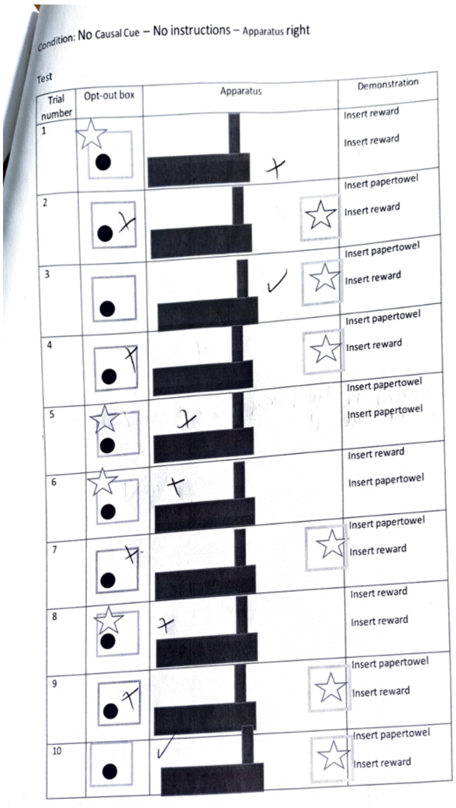
2.4 Testing Phase

During the testing phase, the apparatus's tunnel is replaced by a longer grey tunnel without a sleeve (figures 6 & 7). The test phase also contains two conditions, which mirror the conditions in the training phase. The child goes through 12 trials, six containing the high reward and three without. Of the trials containing only low rewards, the three different sequences are repeated. With 2 repetitions of each low reward sequence.: 1) two paper towels are put into the apparatus (AA sequence), 2) a reward then the paper towel is into the apparatus (BA sequence) 3) two rewards are placed into apparatus (BB). The order of the types of trials is marked on the coding sheet. The choice is presented to the child in this order: 1) the sequence is performed in front of the child 2) once the child chooses either the tunnel is separated from the apparatus to show the insides of it to the child (causal cue) or the small white box is opened with the contents shown to the child (no causal cue). Each choice the child makes is recorded on the coding sheet (figure 8).

figure 6: No causal cue testing phase apparatus set up, with apparatus to the researcher's left. A green box with low rewards on the right. A plastic shield separates the equipment from the participant, and it has two holes on each side for the child to point to.

Figure 7:Causal cue testing phase apparatus set up, with apparatus to the researcher's left. A green box with low rewards on the right. A plastic shield separates the equipment from the participant, and it has two holes on each side for the child to point to.

Figure 8: A coding sheet showing the testing phase:



Condition: No Causal Cue – No instructions – Apparatus right

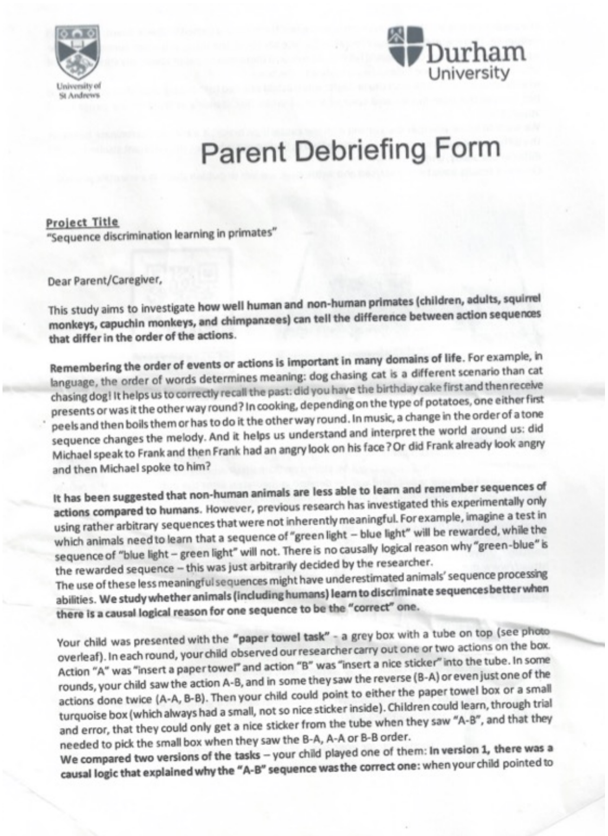
Test

Trial number	Opt-out box	Apparatus	Demonstration
1			Insert reward Insert reward
2			Insert papertowel Insert reward
3			Insert papertowel Insert reward
4			Insert papertowel Insert reward
5			Insert papertowel Insert papertowel
6			Insert reward Insert papertowel
7			Insert papertowel Insert reward
8			Insert reward Insert reward
9			Insert papertowel Insert reward
10			Insert papertowel Insert reward

2,5 Wrap Up

Once the trials are finished the child is asked the question "How did you decide which box to choose?" with the answer being recorded on the coding sheet. If the answer isn't satisfactory a second question "Sometimes there was a sticker in this box (point to apparatus) and sometimes there wasn't. How did you know when to choose this box?" with the second answer also being recorded on the coding sheet. A debrief sheet (Figure 9) is handed to the parent/guardian of the child, the rest of the stickers from the child's sticker scene are given in an envelope, and any questions from the participant or guardian are answered.

Figure 9: The front page of the debrief sheet given to the guardians after the study is concluded.



University of St Andrews

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Parent Debriefing Form

Project Title
"Sequence discrimination learning in primates"

Dear Parent/Caregiver,

This study aims to investigate **how well human and non-human primates (children, adults, squirrel monkeys, capuchin monkeys, and chimpanzees) can tell the difference between action sequences that differ in the order of the actions**.

Remembering the order of events or actions is important in many domains of life. For example, in language, the order of words determines meaning: dog chasing cat is a different scenario than cat chasing dog! It helps us to correctly recall the past: did you have the birthday cake first and then receive presents or was it the other way round? In cooking, depending on the type of potatoes, one either first peels and then boils them or has to do it the other way round. In music, a change in the order of a tone sequence changes the melody. And it helps us understand and interpret the world around us: did Michael speak to Frank and then Frank had an angry look on his face? Or did Frank already look angry and then Michael spoke to him?

It has been suggested that non-human animals are less able to learn and remember sequences of actions compared to humans. However, previous research has investigated this experimentally only using rather arbitrary sequences that were not inherently meaningful. For example, imagine a test in which animals need to learn that a sequence of "green light – blue light" will be rewarded, while the sequence of "blue light – green light" will not. There is no causally logical reason why "green-blue" is the rewarded sequence – this was just arbitrarily decided by the researcher.
The use of these less meaningful sequences might have underestimated animals' sequence processing abilities. **We study whether animals (including humans) learn to discriminate sequences better when there is a causal logical reason for one sequence to be the "correct" one.**

Your child was presented with the **"paper towel task"** - a grey box with a tube on top (see photo overleaf). In each round, your child observed our researcher carry out one or two actions on the box. Action "A" was "insert a paper towel" and action "B" was "insert a nice sticker" into the tube. In some rounds, your child saw the action A-B, and in some they saw the reverse (B-A) or even just one of the actions done twice (A-A, B-B). Then your child could point to either the paper towel box or a small turquoise box (which always had a small, not so nice sticker inside). Children could learn, through trial and error, that they could only get a nice sticker from the tube when they saw "A-B", and that they needed to pick the small box when they saw the B-A, A-A or B-B order.
We compared two versions of the tasks – your child played one of them: **In version 1, there was a causal logic that explained why the "A-B" sequence was the correct one:** when your child pointed to

Results

As data collection was not finished before the write-up of this report, the results were only obtained from 160 children, meaning that the data is incomplete, and is likely biased in a few age groups as a result of the lack of participants at the time of writing this report.

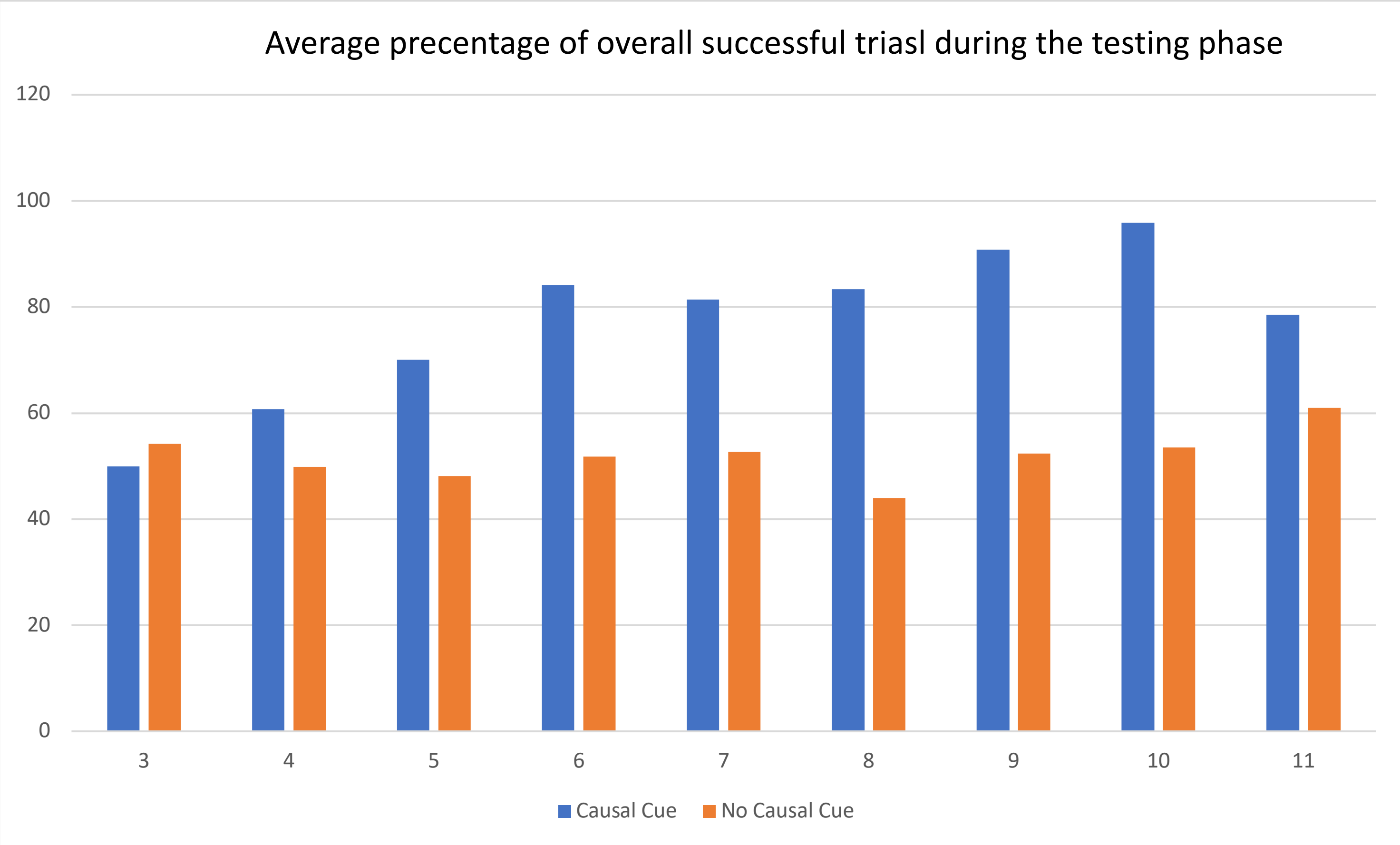
Table 1: Overall average success rates of the Causal cue condition, divided by age groups.

Age	Percentage of overall success in training phase (%)	Percentage of overall success test phase (%)
3	50	50
4	80.7	60.8
5	74.8	70.03
6	74.42	84.14
7	75.54	81.45
8	83.17	83.35
9	69.5	90.8
10	83	95.85
11	71.29	78.54

Table 2: Overall average success rates of the No causal cue condition, divided by age groups.

Age	Percentage of overall success in training phase (%)	Percentage of overall success test phase
3	74.75	54.25
4	83.25	49.9
5	74.9	48.13
6	66.78	51.84
7	61	52.77
8	71.57	44.04
9	72.64	52.32
10	70.81	53.51
11	50	61

Figure 10: Bar graph comparing the overall Average percentage of success between the testing phases of both conditions, across the age groups.



Discussion

3.1 Findings

Images 11 and 10 show the overall average success per condition per age categories, divided between the testing and training phases. As can be seen from Table 2 and Figure 10, there is no clear connection that can be seen between the age of a participant and their success in the no-causal cue paper towel task. This result could very likely simply be a result of the study currently not having enough children in a few of the categories, meaning that a specifically high or low result is not currently representative of the age categories in question. This will be resolved as more children are added to the study, thus changing the averages. However, a trend can be seen in the Causal cue condition, which seems to show an overall increase in success rate with age. Overall the results seem to contradict the suggestion that sequence discrimination is an innate skill, and as such not one that significantly improves age. There is a possibility of the task itself, in the Causal cue condition, being too simple for the older children, leading to a drop. In performance as they overcomplicate the task. However as no age category or condition reached an average of under 40%, as shown by Figure 10 and Tables 1-2, it is clear that across the age groups, there is a clear capacity to discriminate between sequences. However, despite the lack of clear results, one conclusion can be clearly drawn from this study; the no causal cue task is clearly harder for the children to discriminate between than the Causal cue tasks. This can be seen in image 12, which compares the average overall success rate for the testing phase between the conditions. As can be seen, across all the age categories, the children consistently performed better in the Causal cue task. As such, one of the hypotheses of the overall study is proven and will likely continue to be when more participants are added to the study, leading to a change in the overall average.

3.2 Next Steps

The child study will continue to run until each category and condition contains a minimum of 20 children, resulting in over 300 children overall. After the results are obtained, the data can then be analysed to draw definitive conclusions regarding possible improvements in sequence discrimination as age increases. The results of this study will then be checked for accuracy using the video, to minimise human error and increase the reliability of the answers marked in the coding sheets. Once the study either proves or disproves its hypotheses, the child study can then be compared to the other studies within this research, such as the adult study or the chimpanzee study. This will likely contribute to answering the overall question of whether humans are better at sequence discrimination than non-human primates. After this, the study can then be published and will likely be used by other studies in further research on sequence discrimination and the capacity of non-human primates, humans and other animals to discriminate. Additionally, this is one of, if not the first, study to compare casual and no causal (arbitrary) cues, and as will assist further studies researching causal versus no causal cues in sequence discrimination.

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