Replacement Experiment Methods

Methods for data collection under ESRC grant ES/M006042/1 - The cognitive requirements of cumulative culture: experiments with typically developing and autistic people

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(a) Participants

The experiment involved 77 participants, ranging in age from 14-16 years old, recruited from mainstream schools in Cornwall and Devon, UK, with written consent from parents/guardians.

Participants worked in groups from the same school. Forty of the participants were typically developing young people (8F, 32M), divided into five groups of eight members each.

The remaining participants had a diagnosis of Autism Spectrum Disorder (ASD; in a small number of cases, formal diagnosis was pending, but was considered highly likely given the views of parents, teachers and doctors and parent-completed Social Aptitudes Scale and Social Communication Questionnaires). Owing to difficulties in recruitment, four ASD groups had eight members but one group had only five members). All participants (TD and ASD) showed an IQ score of ≥90, as determined by the WASI Vocabulary and Block Design tasks. Across groups, ASD and TD participants were matched by IQ.

(b) Pre-experimental group activity and exercises.

On a day prior to the group experiment, each participant completed a series of exercises designed to quantify individual performance in (i) imitation; (ii) construction abilities and (iii) Theory of Mind.

(i) Imitation: The experimenter demonstrated an instrumental action incorporating both functional and non-functional elements, stating "First you can watch me and then you can have a turn." The extent to which the participant copied each action was recorded.
(ii) Construction: To gauge each participant's abilities in manual construction, they were asked to build the tallest possible tower out of spaghetti and plasticine within 5 minutes. The height of the tower was recorded.
(iii) Theory of Mind was quantified using the Frith-Happé triangle animations (see Abell et al. 2000 for details) and a modified version of Happé's (1994) "strange stories" vignettes.

On the day of the main group experiment, participants were informed of the requirements of the pipecleaner tool-making task (see instructions below), but before beginning the task they were invited (in two groups of four) to take part in a 'cup challenge', involving 5 paper cups and an elastic band - onto which were fastened four lengths of string at equidistant points. They were asked to transfer 5 upright cups from one table into a pyramid formation on another table (involving turning each cup upside down – 3 on the bottom row, 2 on the top row). This task did not generate data, but was intended purely as a team exercise to help the participants get to know each other and promote interaction.

(c) Main task

Participants worked in groups to manufacture a tool made from 30 identical, 30cm long pipecleaners, capable of carrying as many marbles as possible. Group members were informed that

the scores (number of marbles carried) would be added up for all the tools produced by the group, and were encouraged to produce the highest possible score for their school.

(d) Replacement experiment design

The experiment began with two group members (P1 and P2) working together to make a pipecleaner tool. The pair were given five minutes to produce their tool, after which then tested their tool by loading as many marbles as they dared into it (using a scoop) and carrying it for 5m across the room to a set of weighing scales.

After the first tool was tested, P2 then worked with a new, naive group member (P3) to make a new tool, while P1 remained as an advisor and was encouraged to watch and give advice to help the pair produce the best tool possible, without touching the pipecleaners. After each subsequent round of building and testing, one participant was replaced with a new group member, while another remained behind in the teaching role. Thus, each group produced seven tools in total.

The scripts of information given (both written and verbally) to the whole group, participants playing in the advisor role and participants engaged in building are provided in the appendix below.

(e) Statistical analyses

ASD/TD differences

Linear models were fitted in R (R Core Team, 2017) to determine the aspects of interactions that differed between ASD and TD groups. To assess ASD/TD differences in continuous response variables (time spent sharing attention), linear mixed-effects models (LMMs) were fitted using the lme4 package (Bates et al., 2013) in R. Group type (ASD or TD) was fitted as a fixed-effect and group ID was fitted as a random effect (random-intercept). Binomial generalized linear mixed-effects models (GLMMs) were fitted using lme4 to investigate differences in responses quantified as counts. In all binomial models, the total number of statements made during an interaction was included as a denominator, such that the group type (i.e. ASD or TD) fixed-effect term in the model represented difference in the proportion of total task talk that featured the response variable of interest. As for the LMMs, group ID was fitted as a random effect. To investigate differences between ASD and TD groups in performance on Theory of Mind (ToM) and imitation tests, cumulative link models (CLMs) were fitted. ToM and imitation tests were scored on an ordered, but non-continuous, scale, such that the difference between a score of zero and one was not necessarily equivalent to the difference between a score of one and two. CLMs do not impose assumptions regarding the nature of a variable's scale and fit multiple polynomials (i.e. linear, quadratic, cubic etc) to determine the best description of the relationship between a predictor and an ordered response. For CLMs, both group type and group ID were fitted as fixed-effects. Model selection was performed using AICc. For each variable, the AICc value of a model including both group type and group ID and the AICc of a simpler model only containing group ID were calculated. Subsequently, the Akaike weights of the two models were calculated to determine strength of support for an ASD/TD difference.

Score of naïve participant

Task performance was scored as the number of marbles carried by the participant's implement. Scores were most appropriately modelled as over-dispersed count data, so negative binomial GLMMs were fitted to investigate the factors influencing individual performance. Separate models were fitted for factors pertaining to the attributes/statements of the naïve participant, the attributes/statements of the experienced participant and teacher, and characteristics of the overall interaction. A set of candidate models was prepared and a model selection procedure was then

implemented. The set of candidate models were first ranked according to their AICc value. Subsequently, a nesting rule was applied to decide which of the candidate models to retain in the final model set. The final model set contained the best model, according to AICc, and models that had an AICc value within six of the best model and that were also simpler, nested versions of the best model (Richards et al., 2010). The Akaike weights of the retained models were then calculated.

Between-interaction improvement in task performance

The difference between the scores of the teacher and naïve participant was calculated for each interaction. This difference was used as a response term in LMMs containing factors (see Supp. Mat.) related to teaching to assess how information transmission during teaching interactions influenced improvement in performance on the task. Model selection was performed as for the score of naïve participants models.

References

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Happé, F.G., 1994. An advanced test of theory of mind: Understanding of story characters' thoughts and feelings by able autistic, mentally handicapped, and normal children and adults. *Journal of autism and Developmental disorders*, *24*: 129-154.

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Appendix: Scripts of participant instructions

Script for addressing whole groups (of eight children) before Transmission Chain begins:

My name is XXXX and this is XXXX. We are from the University of Exeter and today you are all taking part as a group in some research about making tools. We are very grateful to you all for taking part, and we really hope that you enjoy it, as we promise it is a lot of fun!

So when the research starts we will invite each of you into the classroom next door to have three turns with our task. The task is to work in a pair (so to work together with someone else in the group) to make a simple tool. You will then be able to test how your tool performs and your pair will receive a score. You will then get another turn at the same task with a different member of this group. Finally on your third go you will act as an adviser or helper for another two members of your group who are working together as a pair.

We will add together the scores from each pair to give an overall score for your group. We are visiting lots of different schools and centres and so it would be fantastic if you as a group of eight young people could get the best overall score that you can for your school.

Don't worry if you are not happy with the score of the first tool you make - remember you get a second go, and then finally a third go to help others on your team.

Does anybody have any questions?

We thought it would be nice before the research begins to play a quick game to help us to get to know you all, and for you to get to know any young person that is not usually in your class…

(Proceed by playing the 'Cup Challenge')

Script

First Interaction in Transmission Chain

The task is to make an implement out of pipe cleaners to carry as many marbles as possible. You have 5mins in which to make your implement.

You must work together to make one implement between the two of you.

After you have made your implement, you will each be given one attempt at loading as many marbles as you can in it, or on it, before carrying it by the handle or handles for a distance of 5m. Your score will be the total number of marbles carried, calculated by adding both of your attempts.

When carrying your implement (and the marbles) you cannot have your hands underneath it. You must either hold on to the edges or your implement must have a handle.

After you have received your score, P2 will attempt to make a new pipe cleaner implement with a different member of your group, who is new to the task. P1 will have the chance to give advice for the making of this next implement.

Script

From Second Interaction in Transmission Chain

The task is to make an implement out of pipe cleaners to carry as many marbles as possible. You have 5 mins in which to make your implement.

P2 has already had one turn at this task. You must work together with P2 to make one implement between the two of you.

P1 is also on your team. P1 has already had two turns at this task (one turn if it is the second interaction in the chain). They are here to give advice so that your team can make the best implement possible.

After you have made your implement, both you and P2 will each be given one attempt at loading as many marbles as you can in it, or on it, before carrying it for a distance of 5m. Your score will be the total number of marbles carried, calculated by adding both of your attempts.

When carrying your implement (and the marbles) you cannot have your hands underneath it. You must either hold on to the edges or you must design your implement to have a handle or handles.

After you have received your score, you'll get the chance to make another implement with a different member of your group, who is new to the task. After you have made that implement you will get the chance to give advice to the next two members of your group who will be making an implement.

Script – Advisors

Now another member of the group who has never seen this task before is going to work to build an implement with P2. You are still very much part of the team and your role is to watch what they are doing and to give advice that will help them to make the best pipe-cleaner implement possible. This means that you can help them make their implement by speaking, but you cannot touch the pipe-cleaners. Does that sound okay? Remember, the more marbles they carry with their implement, the better the score for your whole group.

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