Study Information

1. Title: A replication study on ‘Graded motor responses in the time course of categorizing atypical exemplars’ (Dale et al, 2007)

    1.1. The study replicates *Experiment 1* taken from “Graded motor responses in the time course of categorizing atypical exemplars” by Dick Dale, Caitlin Kehoe and Michael J. Spivey published in the journal ‘Memory & Cognition’ in 2007 (35(1), 15-28). This replication in the form of a browser-based mouse tracking study is entirely based on the information provided in the mentioned paper.

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3. Description
    3.1. **Purpose of the study:** A demonstration that category representations compete during the categorization of atypical animals based on computer mouse trajectories during selection between competing categories.
    3.2. **Description:** Knowledge representation is an important aspect of human cognition. Investigating how we acquire conceptual knowledge and use it to guide categorization in our daily lives has been a major topic in research. Dale, Kehoe, & Spivey (2007) explored the temporal dynamics of decision processes regarding categorization in a mouse tracking study. Following their experimental setup, we will compare the categorization processes of typical and atypical entities and examine the time course of the categorization process by keeping track of the hand, i.e. mouse movement while participants choose a category for a presented exemplar. The underlying intuition is that the uncertainty in categorizing atypical exemplars due to the competition of categories should be evident in the mouse movement trajectories. We will examine whether the results of “Experiment 1” of Dale et al. (2007) can be replicated.

4. Hypotheses
    During the categorization of atypical exemplars (experimental trials) the two category options compete more, i.e. stand in greater conflict than during the

categorization of typical exemplars (control trials). This is represented by mouse trajectories gravitating more towards the competing category (incorrect category) in experimental trials than in control trials.

This intuitive description is operationalized by the following non-directional null-hypothesis:

4.1. **Time-normalized**
H0: The difference between the typical and atypical condition's x-coordinates is significant ($p<.05$) in less than 8 consecutive time steps (of 101).
H1: The difference between the time-normalized typical and atypical condition's x-coordinates is significant ($p<.05$) in at least 8 consecutive time steps (of 101).

4.2. **Space-normalized**
H0: There is no significant effect ($p>=.05$) of trial type on the variance of mouse coordinates within 500ms time bins.
H1: There is a significant effect ($p<.05$) of trial type on the variance of mouse coordinates within 500ms time bins.

Design Plan

5. Study type
Experiment: Data is collected from study participants who are tested on two within-subject conditions. A total of 19 trials contains the exact same stimuli for all participants.

6. Blinding
Participants are not aware that typical, as well as atypical animals are presented to them and that their mouse trajectories are recorded. Additionally, experimenters do not interact with participants at any stage of the study.

7. Study design
We try to follow the experimental design of the original study as closely as possible. As a main difference, we report that our study will be an online study as compared to a laboratory study. We try to diminish possible differences and difficulties by providing precise and thorough written instructions to the participants and by means of our extended exclusion criteria (as described in 18. Data exclusion).
In this experiment we implement a within-subject design with two conditions - control and experimental condition.
There are 3 practice trials and 19 target trials. Each trial stages the name of an animal that needs to be categorized and two possible categories to choose from. In the 19

target trials there are 6 atypical animals (experimental trials) and 13 highly typical ones (control trials) - the animals are typical or atypical in regards to a certain category. There are five different categories: mammal, reptile, bird, fish, insect and amphibia. In the experimental trials the atypical animal is more difficult to categorize since both provided categories share conceptual features with the animal.
For the target trials we will use the lexical stimuli provided by Dale et al. (2007); for the practice trials we will use newly created stimuli.
For each trial, the two possible categories for the animal name are randomly assigned to one of the upper corners of the screen. Participants will see the category names in their assigned positions for 2000 msec. After that a text field with 'Start' will appear at the bottom center which will elicit the appearance of the animal name as soon as participants click it. When the animal name is shown in the bottom center of the screen, participants have to decide which category it belongs to and select the appropriate one with a mouse click in the corresponding corner. Once a choice is made, a new trial starts.
After practice, 19 target trials follow in the same manner. All stimuli are presented in random order and neither in the practice nor in the main trials the participants are provided feedback about whether their category choice was correct.
After the main experiment ends, participants have to answer a questionnaire that corresponds to the content of our exclusion criteria such that we can rule out participants that did not meet the appropriate requirements/conditions to participate.

8. Randomization
   In this within-subject design there is a random mix of the experimental and control conditions within the experiment of a subject. All participants respectively complete the same number of experimental and control trials are blind in the sense that these are presented in a randomized order.

Sampling Plan

9. Existing data
   On the one hand side, there exists analyzed and interpreted data from the original study, however this data was disregarded entirely for this study and merely the experimental design and the methods of data analysis are based on the original paper.
   On the other hand, there exists data from a pilot study (N=10) which is not included in the final analysis but guided the specification of our statistical models.

10. Data collection procedures
    Participants will be recruited through e-mail and text messenger from the population of students at the University of Osnabrueck, as well as from their close social environment. Participants do not receive payment. There are no exclusion criteria for the selection of

participants before the experiment, however data will be excluded in retrospect according to our exclusion criteria.
We will start recruiting participants at the 20.07.20 and plan to stop collecting data either when we reach 41 eligible participants or at the 29.07.20.

11. Sample size
We aim for a sample size of 41 participants or more because this was the sample size in the original study. We expect that data of quite a few participants will be excluded according to our criteria therefore we will recruit as many participants for this study as possible within the stated time interval and include all eligible data for analysis.

12. Sample size rationale
We try to replicate the sample size of the original study and assume that the data of some participants will have to be disregarded for our final analysis based on the exclusion criteria in 18. Data exclusion.

13. Stopping rule
We will stop as soon as we have collected data from 80 participants.

Variables

14. Manipulated variables
The typicality of an animal in regard to the presented categories will be manipulated as a 2-level factor: The experimental condition comprises *atypical* exemplars while the control condition comprises *typical* exemplars.

15. Measured variables
    15.1. Correctness of the response: Discrete binary variable.
    15.2. X- and Y-coordinates of the computer mouse position sampled at a rate of 42Hz. The coordinates reflect participant's continuous trajectory of mouse movement during categorization.
    15.3. Response time in milliseconds from clicking the button on the bottom until clicking one of the two categories in the top.

Analysis Plan

16. Statistical models

In all our tests the binary variable typicality (either *typical* or *atypical*) acts as a predictor (independent variable) while the x- and y-coordinates together with their respective time points represent the outcomes (dependent variables).
First, the average accuracy in percentage of the typical and atypical conditions will be calculated and compared between the two conditions via a chi-square test. Before the time-normalized and a space-normalized test will be conducted on all correct responses all leftward responses are reflected at the y-axis as thoroughly described in 17. Transformations.

In the time-normalized test the data is normalized to 101 time steps and all start points are normalized to the point (0,0). All 101 x-coordinates are averaged within each condition and are then compared by applying a t-test. Last but not least, we seperate the 101 time steps into three bins (1-33 steps ; 24-67 steps ; 68-101 steps) and apply a 2 (*typical* and *atypical*) x 3 (bins) ANOVA.

In the space-normalized test the start and end point of all trajectories is normalized to (0,0) and (1,1) respectively. This data is separated into four bins according to time (0-500 ms; 500-1000 ms; 1000-1500 ms; 1500-2000 ms) and a 2 (*typical* and *atypical*) x 4 (bins) ANOVA is applied.

17. Transformations

Before the time- and space-normalized tests the absolute values of leftward responses will be reflected at the y-axis so that left- and rightward responses can be pooled for both tests. The corresponding formula is defined as: X * (-1)^(target_loaction == left)

18. Inference criteria

The standard p<.05 criteria will be used in all tests, which are one tailed for testing our direct hypothesis.

19. Data exclusion

(1) Criteria for the exclusion of single trials of a participant (data of a single response):

- Any incorrect responses will be excluded
- The response time exceeds 5.0 seconds

(2) Criteria for the exclusion of all trials of a participant (data of a all responses one participant gave):

- The participant did not use a computer mouse.

- The participant did not use his/her right hand to respond in the test.
  (This will probably exclude some but not all left handed people and will allow for higher comparability of our results with the original laboratory setup.)
- The participant terminated the experiment preliminary.
- The participant did not understand the english animals or categories which means he/she selects a score of two or less in the post-experiment question about comprehension of the english words.

20. Missing data

    If a participant does not complete all 19 target trials that participant's data will be excluded entirely from the final analysis.

Other

21. References

Dale, R., Kehoe, C., & Spivey, M. J. (2007). Graded motor responses in the time course of categorizing atypical exemplars. *Memory & cognition*, *35*(1), 15-28.