Design for Conceptual Replication of Experiment 1 by Wühr and Seegelke(2018)

Background

ATOM ("A theory of magnitude") is a theory proposed by Walsh(2003), which basically states that there exist relations between the cortical representations of "time, space and quantity". If there were such relations, this might also have implications on experimental research investigating stimulus-response tendencies comprising different numerical, temporal or spatial properties.

Many studies have investigated different aspects and proposals of this theory in terms of Stimulus-response (S-R) compatibility, where S-R compatibility refers to how “natural” it is for a certain required response (or action) to follow a given stimulus type. Typically, such compatibility effects are investigated by comparing reaction times for a required action or response in experimental tasks with a specifically defined Stimulus-Response mapping that is varied within the experiment. For example Dehaene et al.(1990) found compatibility effects between numerical size and horizontal response location, which Dehaene et al.(1993) later coined as “Spatial-Numerical Association of Response Codes” (SNARC) effect. The SNARC effect is interpreted as a spatial mapping of numbers to horizontal locations.

In 2013, Ren et al. have furthermore analogously investigated the relationship between physical stimulus size and horizontal response location. Their results show similar compatibility effects of stimulus size and horizontal response location, but only for right hand responses. In 2018, Wühr and Seegelke attempted a conceptual replication and extension of this study. They claim that their results indicate the existence of a general magnitude code, as proposed in ATOM in that we might intrinsically associate small objects with the left side and large objects with the right. We will here aim to assess these findings via a conceptual replication of the first experiment from Wühr and Seegelke(2018).

In the experiment, subjects are presented with "small" or "large" stimulus objects and are required to judge their size as "small" or "large". The keys for subjects to communicate these judgements are mapped to either left- or right-handed responses and these mappings are switched once within the experiment. Wühr and Seegelke(2018) found, that participants were faster to respond to a large stimulus object with a key that is on the right of the keyboard (e.g. "Backspace", pressed with the right hand), than with a key that is on the left of the keyboard (e.g. "Tabulator", pressed with the right hand). For small stimulus objects, they found that reaction times were numerically faster for left-hand responses than for right-hand responses.

For each of the two stimulus types ("small" vs. "large") used in the experiment, example stimulus objects are shown in *Figure 1* below.

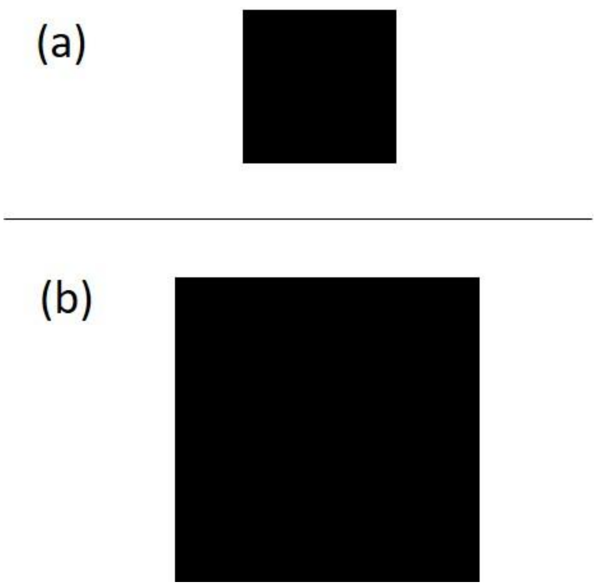

Figure 1: Physical stimulus size - spatial response location - compatibility*: - Is this object small or large?*
(a) small square stimulus, (b) large square stimulus

For participants to judge whether the stimulus is a small or large object, ATOM would propose that subjects need to mentally activate an internal representation of size and the corresponding spatial response mapping in order to generate an action as response according to their judgement about stimulus size, and that these representations are linked. Ren et al. (2011), and Wühr and Seegelke (2018) showed that stimulus size and horizontal response location indeed exhibit compatibility effects, which can be regarded as evidence for this sub-aspect of ATOM. They found that the horizontal response mapping (key press with either left or right hand) to judgements about stimuli of different size influences response behavior and matters for success and swiftness of judgements of 'small' or 'large' stimulus objects.

Hypotheses

We are here concerned with some specific predictions from previous experimental research by Wühr and Seegelke(2018), namely that small stimuli are associated with left responses, whereas large stimuli are associated with right responses in right-handed people. This stimulus size - response location compatibility effect is claimed to extend proposals of ATOM. We seek to replicate similar stimulus size - response location compatibility effects as those reported by Wühr and Seegelke(2018), i.e. to find out whether different stimulus - response mapping conditions have an effect on participant's response time to a specific type of stimulus (in this case: small or large stimuli). Furthermore, in extension of the original experiment, we aim to investigate, whether we can find compatibility effects (either in similar or opposite direction) for left-handed people. In particular, we are going to address the following **research hypotheses**, which we will separately test for right- and left-handed people:

1. Response times for right-hand responses are faster to the larger stimulus than to the smaller stimulus.

2. Response times for left-hand responses are faster to the smaller stimulus than to the larger stimulus.
3. The stimulus size – response location compatibility effect is larger for right-hand responses than for left-hand responses. This means, the difference in response times for right-hand responses to be faster to the larger stimulus than to the smaller stimulus is larger than the difference in response times for left-hand responses to be faster to the smaller stimulus than to the larger stimulus.

Hypotheses 1.-3. will be tested for left- and right-handed participants separately. Additionally, we will test the following hypotheses for left-handed people:

4. Response times for left-hand responses are faster to the larger stimulus than to the smaller stimulus.
5. Response times for right-hand responses are faster to the smaller stimulus than to the larger stimulus.
6. The stimulus size – response location compatibility effect is larger for left-hand responses than for right-hand responses. This means, the difference in response times for left-hand responses to be faster to the larger stimulus than to the smaller stimulus is larger than the difference in response times for right-hand responses to be faster to the smaller stimulus than to the larger stimulus.

Design

Participants. Participants are recruited via [whatever media we will use to spread the link to the experiment]. By following the link to the experiment, participants declared to have normal or corrected-to-normal visual acuity and should be naive with respect to the purpose of the study. Participation is voluntary and not rewarded with material things or money but the experimenters' deep gratitude.

Materials. In each trial, a visual stimulus object is presented in the center of the screen with gray background. A stimulus object in the experimental block is a simple black square, which is either small (about 3*3 cm, depending on the size of the screen) or large (edges twice as long as those of the small stimulus, i.e. about 6*6 cm, depending on the size of the screen). We used information about the stimulus objects (i.e. information about how they are to be displayed concerning their form, size and position on the display) as provided by Wühr and Seegelke (2018), however we cannot guarantee an exact same formatting of stimuli for each participant in terms of equal edge lengths, but only in terms of relations between edge lengths, since the size of the displayed stimulus will be relative to the screen on which it is presented. The 2 different types of stimulus objects are used for training trials and main trials in both experimental blocks. Pictures of these stimulus objects are shown above (Figure 1). A stimulus object in the intermediate block is either a simple black circle or a simple black triangle (shown in Figure 2, below), both of small to intermediate size - regarding the small and large square stimulus objects' edge lengths- in terms of the circle's diameter or the triangle's height.

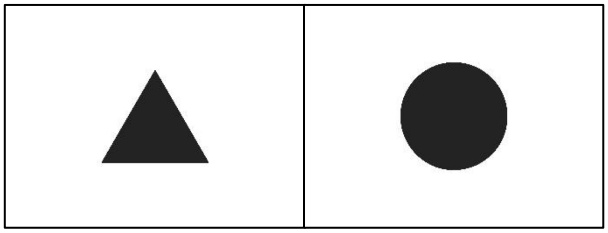

Figure 2: stimulus objects in the intermediate task - *circle(left) and triangle(right)*

Procedure. The experiment consists of ten parts:
(i) introduction

(ii) instructions for the first stimulus-response(S-R) mapping
(iii) training trial phase for first S-R mapping (10 trials)
(iv) main experimental trial phase for first S-R mapping (2 stimuli × 30 repetitions = 60 trials)

(v) instructions for the intermediate distracting task
(vi) intermediate distracting task trial phase (2 stimuli × 10 repetitions = 20 trials)

(vii) instructions for the second S-R mapping
(viii) training trial phase for second S-R mapping (10 trials)
(ix) main experimental trial phase for second S-R mapping (2 stimuli × 30 repetitions = 60 trials)

(x) post-experiment questionnaire

These parts can be further divided into **two main experimental blocks**, one for each of the two S-R mapping conditions (parts(ii)-(iv) for the first and parts (vii)-(ix) for the second S-R mapping condition), and **one intermediate** (non-experimental) **block** comprising instructions and trials of a distracting task(parts (v) and (vi)). Participants can take a rest between the different parts and start the next part at leisure via a button press.

We will vary the stimulus size - response (key) location mapping (S-R mapping) for the experimental blocks once over the course of the experiment. The order of S-R mapping conditions for the first and second experimental blocks (first = compatible – second = incompatible or first = incompatible – second = compatible) is determined experiment initially, uniformly at random once for each participant. In the compatible mapping condition, the small stimulus requires a response with the left (“q”) key, whereas the large stimulus requires a response with the right (“p”) key. The mapping is reversed in the incompatible mapping condition.

At the beginning of the experiment, participants are welcomed and given (not further specified) information about the general procedure, namely, that the experiment will consist of several parts, which again consist of several trials of tasks of similar structure. Participants are recommended to complete the whole experiment (to prevent dropouts from the beginning on), and they are given information about the approximate duration of the experiment (about 20 minutes).

More precise descriptions of the participant’s task are presented at the beginning of each block. These specific instructions include information about the sequence of events in a trial (fixation - stimulus presentation - key press or button click given the the assigned S-R mapping), i.e. which keys to press for "small" or "large" stimuli (corresponding to the respective S-R mapping condition) in the experimental task blocks, or which buttons to click on for “circle” or “triangle” in the distracting task block, as well as information on whether the next part belongs to training (for the experimental blocks) or experimental phase (as in the intermediate block). Additionally, all instructions emphasize that participants should strive to optimize speed and accuracy (this is not mentioned in the original paper but seems appropriate in this context, since a time-out occurs and an error message will be presented when participants' response time(RT) exceeds a period of 2000 ms). After having read the initial instructions of a new experimental block, participants firstly perform a training trial phase (10 trials) before they can proceed to the main experimental trial phase for the respective S-R mapping condition(2 stimuli × 30 repetitions = 60 trials). The first experimental block is followed by written instructions about the intermediate task, in which participants are shown either a circle or a triangle and have to classify the presented stimulus as “circle” or “triangle” by clicking on the respective button at the bottom of the screen. The intermediate task has (2 stimuli × 10 repetitions =) 20 main trials. The specific number of the intermediate task’s trials is not necessarily optimal, but we decided on this as a -hopefully well - balanced compromise between effective distraction and no unnecessary prolonging of the experiment. The order in which participants are shown either of the two stimuli in the intermediate task is determined uniformly at random. After completion of the intermediate block’s trials, participants are shown written instructions of the following experimental block (similar to the initial experimental block’s instructions, only different in the description of the S-R mapping, since it is reversed here). They then perform a training block (10 trials) and an experimental block with the respective second S-R mapping (2 stimuli × 30 repetitions).

During the training phases participants will get accustomed to the task, specifically to the respective S-R mapping, by completing the given amount of practice trials. Practice trials differ from main trials in that participants receive a short feedback message, telling them whether their answer was correct (namely: “Correct!” or “Incorrect!”).

The order in which individual trials are presented in the training and experimental phases is determined uniformly at random and on the fly for each participant.

Experimental trials within the training and main phases are structured as follows (see also Figure 3 below):

- Each trial starts with the presentation of a fixation point (a small black plus sign) for 1000 ms in the center of the screen.
- Afterwards, one of the two stimulus objects is displayed until a keypress(experimental blocks) or button click(intermediate block) occurs. In the experimental blocks, participants respond by pressing the left “q” key or the right “p” key on their keyboard. Participants should operate the left key (“q”) with the index finger of their left hand and the right key (“p”) with the index finger of their right hand. In the intermediate task, participants respond by clicking on the “circle” or “triangle” button at the bottom the screen.
- A correct response with an RT below 2000 ms is followed by a blank screen for 1500 ms. If a wrong key or no key is pressed within the maximum response period of 2000 ms, a corresponding error message(precisely: “Try to respond more quickly!”) is shown for 1500 ms in black color (Courier font, font size 24).

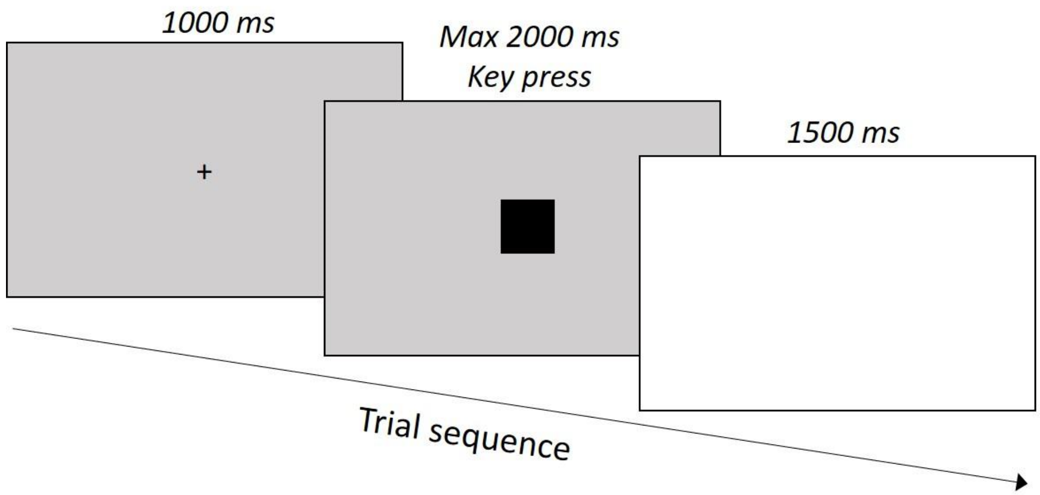

Figure 3: schematic illustration of the sequence of events in a typical trial

Finally, the experiment terminates with a post-experiment survey asking participants for their preferred hand (left or right) and to optionally supply socio-demographic information (age, gender, level of education, native languages, whether there were any technical issues experienced during the experiment)and leave comments on the experiment.

Explanation of design choices.

We tried to construct a design resembling the original experiment as closely as possible. However, we find the sequence of trials or experimental box in the original experiment questionable, as there are no obvious reasons stated by Wühr and Seegelke(2018) for why exactly they used the *tab* and *backspace* key as response keys, why their experiment was divided into *two big* blocks (one for each S-R mapping) and why the *number of training trials* was different for the first and second S-R mapping condition(10 : 20). Therefore, we propose an alternative design here, which we thought might address these problems and thereby increase the validity of this conceptual replication compared to the original experiment. Precisely, we do not take the original experiment's key mappings here (see section "Background"), because we thought that, on a standard keyboard, these keys("q" and "p") would be more convenient to use and are positioned in the same horizontal line of keys, whereas this is not true for tab and backspace key. We also deviate from the original experiment's procedure, in that we include an intermediate distracting task block, in which trials differ from experimental block trials only in the stimuli that are shown and the response mode, but the rest of the trial sequence remains the same (i.e. fixation cross, stimulus presentation, response, blank screen with optional error message if the response time exceeded 2000ms). We employ this intermediate distracting task block after the first main block (without RT measurement), so that participants might be distracted from the initial stimulus-response key mapping. Thereby, we hope to limit training effects regarding the key-mapping. This might allow for halving the number of training trials before the second main experimental block (from 20 to 10 trials), so that there are equally many training trials for the first and second mapping condition.

Alternative suggestions for the experiment's procedure. We have some alternative design suggestions listed below, which we took into consideration for our replication of the experiment from Wühr and Seegelke(2018), but finally decided against realizing them. These suggestions also try to address and handle the problems we identified in the original experiment's design in different ways.

1. Do not include the intermediate block. Instead, split the two big experimental blocks (including training and main trials for the two mapping conditions) up into four blocks, where mappings are reversed between blocks. We hope that by shortening the blocks for the two different response mapping conditions, training effects might be small, thus we uniformly put 15 training trials (average number of training trials in the original experiment) before each main experimental block:
   (i) introduction & instructions for first S-R mapping
   (ii) training trial phase for first S-R mapping (15 trials)
   (iii) main experimental trial phase for first S-R mapping (2 stimuli × 15 repetitions = 30 trials)
   (iv) instructions for second S-R mapping
   (v) training trial phase for second S-R mapping (15 trials)
   (vi) main experimental trial phase for second S-R mapping (2 stimuli × 15 repetitions = 30 trials)
   (vii) instructions for first S-R mapping
   (viii) training trial phase for first stimulus-response(S-R) mapping (15 trials)
   (iv) main experimental trial phase for first S-R mapping (2 stimuli × 15 repetitions = 30 trials)
   (v) instructions for second S-R mapping
   (xi) training trial phase for second S-R mapping (15 trials)
   (xii) main experimental trial phase for second S-R mapping (2 stimuli × 15 repetitions = 30 trials)
   (xiii) post-experiment questionnaire
   - We acknowledge that this (latter alternative) design variation might take much more time than the original experiment (average duration of 15 minutes according to Wühr and Seegelke(2018)), and that it might pose quite high cognitive demands on participants due to the multiple switching of key mappings, and that these might lead to high dropout rates.
2. Alteration of (1): Have 3 experimental blocks, complete half the trials of the first S-R mapping block, switch to second S-R mapping, complete 15 training and all 60 main trials, switch back to first S-R mapping, complete second half of trials:
   (i) introduction & instructions for first S-R mapping
   (ii) training trial phase for first S-R mapping (15 trials)
   (iii) main experimental trial phase for first S-R mapping (2 stimuli × 15 repetitions = 30 trials)
   (iv) instructions for second S-R mapping
   (v) training trial phase for second S-R mapping (15 trials)
   (vi) main experimental trial phase for second S-R mapping (2 stimuli × 30 repetitions = 60 trials)
   (vii) instructions for first S-R mapping
   (viii) training trial phase for first stimulus-response(S-R) mapping (15 trials)
   (ix) main experimental trial phase for first S-R mapping (2 stimuli × 15 repetitions = 30 trials)
   (x) post-experiment questionnaire
   - We thought this might be better in terms of balancing fatigue effects for the first and second S-R mapping condition.

3. Alteration of the here proposed design: Change the described response mode of the intermediate distracting task to a key press response instead of a button click using the same keys as in the experimental blocks, e.g. press “q” for circle and “p” for triangle.

References:

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