“Compatibility between Physical Stimulus Size and Left-right Responses: Small is Left and Large is Right” - A replication study

F. Japtok, J. Kettler, R. Pfennigschmidt, R. Zollner

This study is a replication of the experiment “Compatibility between Physical Stimulus Size and Left-right Responses”, conducted and published by Wühr & Seegelke in the Journal of Cognition in 2018.

All corresponding experimental files to this study, including picture material, the collected and analyzed dataset, the proper analysis files, plus experimental design plan and preregistration report can be found under this link: https://github.com/regg-sketch/compatibility_effect

Abstract

The theory of magnitude (ATOM, Walsh, 2003, 2015) proposes that cognitive representations of quantity, space and time share a general magnitude code. The research gives evidence, based on neuropsychological and neurophysiological data, that there exists a generalized magnitude system, suggesting overlapping brain structures for the processing of time, space, and magnitude information in the human parietal cortex. (4,5) To investigate this phenomenon, various research has been conducted that examines the relationship between the three.

In a prevailing study, Wühr, P., and Seegelke investigated the correlation between stimulus size and response location.

Results showed significantly faster response times for large stimuli and right-hand responses than for large stimuli and left-hand responses. (There was however no significantly faster response for small stimuli and left-hand responses.) This proposes a compatibility effect between the processing of stimulus size and the spatial location stimuli are found in. (6)

In our experiment we aim to replicate the findings of Wühr P., and Seegelke by reproducing their experiment, examining whether there is a compatibility effect between large stimuli and right-hand responses, as well as between small stimuli and left-hand responses.

keywords: compatibility effect; theory of magnitude; ATOM; congruence; stimulus size; response location

Introduction (Background)

Based on previous research, we concerned ourselves with the relation between physical stimulus size and spatial (mostly horizontal) response location. For this purpose, we conducted an experiment investigating whether stimulus responses are significantly faster if particular stimulus sizes are paired with specific response locations. (More specifically we examined the relation between large stimuli and right-hand responses, and small stimuli and left-hand responses respectively.)

In 1990, Dehaene, Dupoux and Mehler firstly showed a compatibility effect between stimulus size and response location, as they found that left-hand responses were faster for smaller numbers and right-hand responses faster for larger numbers. (1)
Ren et al (2011, exp 4) investigated a similar effect for names of small and large objects - they hypothesized that left hand responses were faster for the names of small objects and right hand responses were faster for the names of large objects. However in this experiment, only right-hand responses delivered significant results when addressing large objects compared to small ones, whereas left-hand responses gave no significant findings.(2)

Also, in an experiment conducted by Tzelgov et al. (1992, exp 1,2) a size-congruity effect occurred (Tzelgov et al. not only varied the numerical, but also the physical size of the numbers. They found that judging number magnitude was faster when the irrelevant physical size is congruent rather than incongruent with the to-be-judged numerical magnitude). (3)

The experiment we conducted is a replication of a study by Wühr and Seegelke (C. 2018). Their previous research also suggests a correlation between stimulus size and response location. While Wühr, P., and Seegelke could find a significant relation between large stimuli and right-hand responses, the investigated left-hand responses didn't show significant results for small stimuli. (6)

Method

Hypotheses:

The hypotheses we created to investigate a corresponding compatibility effect are:

I. **There is a stimulus size - response location compatibility effect.**

Left-hand responses are significantly faster (have a significant smaller RT) for small stimuli compared to large stimuli. Respectively, right-hand responses are significantly faster (have a significant smaller RT) for large stimuli compared to small stimuli.

II. **Significant stimulus size - response location effects are limited to right-hand responses.**

Only right-hand responses are significantly faster (have a significantly smaller RT) for large stimuli compared to small stimuli in contrast to left-hand responses, which are not significantly faster (have no significantly smaller RT) for small stimuli compared to large stimuli. Or can they also be obtained in left-hand responses (left hand - small stimuli)?

Participants:

Participants for our study gave informed consent before the study to be right-handed, with normal or corrected-to-normal visual acuity, and to only proceed with the experiment when working on a computer or a tablet with a keyboard. Also, all participants were naive to the purpose of the study. As for the number of participants, we investigated 33 participants (15 female, 18 male and 0 diverse). Mean age of our participants was 31 years (within a range of 18 to 80 years); all participants were german native speakers; 14 confirmed to have graduated high school, 7 to have graduated college, and 10 stated a higher degree (the other 2 participants made no statement towards their educational level).
None of the participants were compensated for the experiment.

Materials:

We provided our own pictures (see above) but we sticked to the sizes presented in the original study using a 2cm*2cm square as the small stimulus and a 4cm*4cm square as the large stimulus. Stimuli were consistent over the course of the experiment and were neither varied in color, nor in shape, so that the effect of the spatial location variable maintains the investigated priority.

Procedure:

In contrast to Wühr and Seegelke, we were only able to perform an online experiment using the _magpie key-press method. _Magpie is an architecture which facilitates the development of online experiments. In the key-press method, participants have to press previously assigned keys to convey particular responses in the experiment (e.g. press Q if a small stimulus appears, press P if a large stimulus appears), instead of for example using mouse clicks like in a forced-choice paradigm.

Our experimental setup consists of 6 main parts:

1. *introduction & instructions*
2. *first practice phase*
3. *first experimental phase (mapping one)*
4. *second practice phase*
5. *second experimental phase (mapping two)*
6. *post-experiment questionnaire*

Introduction & Instructions:

After introducing the participants, the experiment started with the instructions describing the task, including the S-R mapping (stimulus-to-response mapping, meaning which key is assigned to which stimulus), and the sequence of events in the trials.

Participants were then instructed to press one of two assigned keys (p and q), respective to the answer they want to give. In one experimental condition they could for instance be told to press p for small stimuli and q for large stimuli, or vice versa. (It is important to mention here that q is always to be pressed with the left hand and p is always to be pressed with the right hand).
As a result of this assignment, two S-R mapping conditions arised, which were presented to the participants in different blocks.
In the *compatible* mapping condition, the small stimulus is assigned to the left hand (hence key: q) and the large stimulus to the right hand (hence key: p), whereas in the *incompatible* mapping condition the small stimulus is assigned to the right hand (key: p) and the large stimulus to the left hand (key: q).

(We chose these mapping conditions in alignment with our hypothesis that right-hand responses are faster for large stimuli and left-hand responses are faster for small stimuli - smaller reaction times (RT's) in the compatible condition would thus emphasize our hypothesis, while smaller reaction times in the incompatible condition would contradict it.)

Further, to standardize the experiment as much as possible, participants were instructed to use their index finger of the corresponding hand to press the respective key. (This way influence of the response time by use of different fingers can be avoided.)

Practice & experimental phases:

The experiment consisted of four trial blocks. Participants started with a block of 10 practice-trials, followed by an experimental block with the first S-R mapping (60 trials), followed by 20 practice trials and an experimental block with the second S-R mapping (60 trials). Participants were free to take a break between the first experimental block and the second trial block. The order of the S-R mapping was counterbalanced across participants (compatible-incompatible, incompatible-compatible), and S-R mappings in general were varied within participants.

Each experimental trial started with the presentation of a fixation cross in the center of the screen for 1000ms. Then the stimulus was displayed in the center of the screen until a key press response occurred, or for 2000ms (to avoid too large response times). As instructed before, participants were expected to press the key corresponding to the displayed stimulus. (Like the description above states, assignment of keys varies according to S-R mapping. Once again: in the compatible condition, participants are expected to press p if they mean to perceive a large stimulus and q if they mean to perceive a small stimulus - in the incompatible condition the key assignments are reversed).

A correct response with a RT<2000ms was followed by a blank screen for 1500ms. If the participant responded wrong or didn`t respond in time, an error message informing the participant to either react faster or correctly is shown for 1500ms in black color.

Post-experimental questionnaire:

The questionnaire finally asked participants for their gender (female, male or other), age, educational level, native language and further left them space for additional comments.

Data Analysis:

The raw data can be found in our github repository. Individual mean RTs and individual error percentages were analyzed using a separate two way repeated measure ANOVAs to analyze the 2x2 factorial design with the factors S-R mapping (compatible or incompatible) and Response (left or right). The S-R mapping is varied between, while the Response is varied within experimental blocks.
We excluded all data of trials with a RTs of less than 100ms or more than 1500ms. Furthermore, we excluded participants who had an overall error rate larger than 10%. This ensures that the participants are focused on the task, not randomly pressing buttons. (The threshold is so high since the task is relatively simple.)

Since we had prior expectations towards the direction of the mapping effect (the study of Wühr P. and Seegelke gave reason to believe that there is a compatibility effect that maps large stimuli with right-hand responses and small stimuli with left-hand responses), we conducted a one-tailed t-test to examine the differences in the conditions (compatible - incompatible). Further we used partial eta² as an effect-size estimate concerning our first hypothesis.

Results

Figure 1 shows a boxplot of the mean reaction times of participants split into compatible and incompatible mapping, as well as the response location.

We did not observe a significant effect for S-R mapping (F-value = 0.0182 and p-value = 0.8928) or response location (F-value = 0.1904 and p-value = 0.6626).

We did observe a significant interaction for *S-R mapping x response location* with a negligible effect size (F-value = 40.1507, p-value = 2.606e^-10, $\eta^2 = 0.00973$).

The combination *S-R mapping* x *response location* resulted in a 21ms mean difference for right hand responses and in 22ms mean difference for left hand responses.

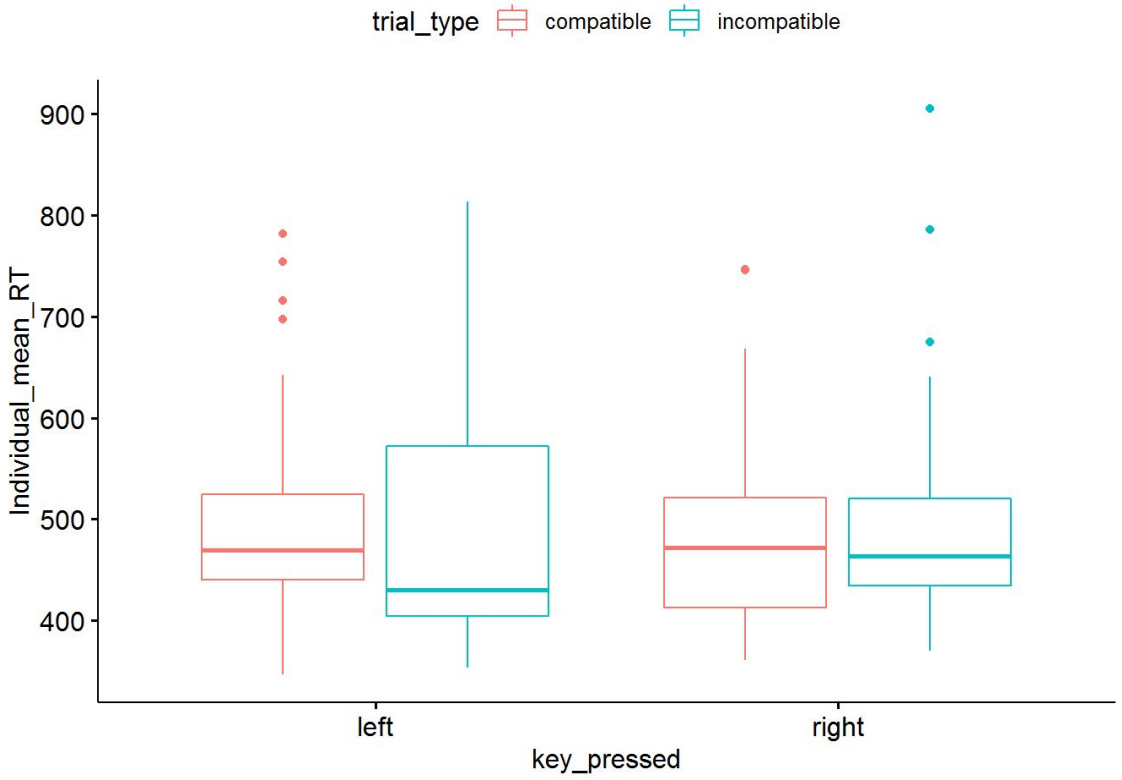

Figure 1: Mean RT's observed in the experiment.

Legend: Mean RT's as a function of S-R Mapping (compatible: small-left, large-right; incompatible: large-left, small-right) and response (Left vs. Right). The bold line in the boxes displays the respective median (50% of the data lies above and 50% below this line); the boxes themselves represent the upper and lower quartiles (upper: 75% of the data lie below the top end of the respective box; lower: 25% of the data lie below the bottom end of the respective box); outliers are marked as single points.

Discussion/Conclusion

In our experiment we were not completely able to replicate the compatibility effect between physical stimulus size and spatial response location as was shown in the previous experiment by Wühr P., and Seegelke (2018). Although we found that right-hand responses were significantly faster in the compatible-mapping condition - thus faster for large stimuli than for small stimuli - left-hand responses showed a significantly shorter RT in the incompatible-mapping condition - thus they were also faster for large stimuli than for small stimuli.
This gives evidence against our hypothesis of the existence of a compatibility effect between physical stimulus size and spatial response location.

Our findings rather implicate a correlation between physical stimulus size and reaction time, as responses to large stimuli were significantly faster in both hands. This effect could further be investigated in a subsequent study.

Potential weaknesses of our replication study might be that we had to trust the participants to make truthful statements about their handedness and their visual acuity. Furthermore, we have to consider that for a long time, ca. until 1990s, left-handed people got trained to become right-handed. Since we have also older participants this might have influenced our results. Additionally, the stability of the internet connection could also have an effect on the reaction times. However, none of our participants reported an unstable internet connection.
Since we cannot monitor the participants focus during the task, lack of sufficient concentration - due to fatigue, the length of the trial blocks or lack of interest - is another potential risk that could have tempered with the final experimental results.

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