The Compatibility Effect between Physical Stimulus Size and Left-Right Responses

Daniel Menzel, Florian Pätzold, Ramon Zacharias, Shari Hiltner
Universität Osnabrück, DE

REPLICATION STUDY July 31, 2020

Abstract

The processing of cognitive tasks based on somatosensory inputs and motor-sensory outputs is a deeply investigated field of study in the cognitive sciences. Former research proposes a theory of magnitude (ATOM, Walsh, 2003, 2015). The theory assumes that the brain uses a generalized magnitude-processing system where the perception of space, time and quantity overlap and interact on an intermediate level of processing antecedent to the response-selection stage. This means that specific properties of the three branches space, time and quantity share a certain representational system. ATOM is therefore regarded as a *shared-representations account*.

Here, we tried to replicate the study “Compatibility between Physical Stimulus Size and Left-right Responses: Small is Left and Large is Right” by Wühr and Seegelke (2018). In their study they found a statistically significant compatibility effect between physical stimulus size and horizontal response location. Participants responded quicker in trials with a compatible S-R mapping (left handed response for a small stimulus) and slower for incompatible trials. We did not replicate this effect through our experiment. Wühr and Seegelke also found a stronger compatibility effect for right-hand responses which we did not replicate either.

Keywords: ATOM; compatibility; congruency; stimulus size; response location; SNARC

Introduction

Compelling evidence for a generalized magnitude system coming from neuropsychological and neurophysiological data suggests overlapping brain structures for the processing of time, space, and magnitude information in the human parietal cortex (Cohen Kadosh et al., 2007; Kaufmann et al., 2008; see Bueti and Walsh, 2009, for review). In the past the focus of research regarding the ATOM framework lay on interactions of number and size and number and space (see above) but not on the relation between size and space. For example, it is well accepted that numbers can be represented spatially from left to right (see SNARC effect; Dehaene, Dupoux and Mehler, 1990; Dehaene et al., 1993) or that the numerical and physical size of numbers can faster be judged when they are congruent (see size-congruity effect; Besner and Coltheart, 1979; Henik and Tzelgov, 1982; Tzelgov, Meyer and Henik, 1992).

We here look at how differences in reaction times could support the idea of a horizontal response location representation of stimulus size. In particular we try to replicate the original paper “Compatibility between Physical Stimulus Size and Left-right Responses: Small is Left and Large is Right” by Wühr and Seegelke (2018). We thereby try to answer the question of whether, e.g. a left-hand response is faster for a stimulus of small size than for a stimulus of large size. For that, our task at hand is a classic stimulus – response compatibility task where the participant responds to a single stimulus in each trial, the compatible mapping condition being a left handed response for small stimuli and a right handed response for large stimuli; *vice versa* being the incompatible mapping condition. We then investigate whether the stimulus size – response location compatibility effect only occurs for right-hand or also for left-hand responses, as previous research, for example Ren et al. (2011) and Wühr and Seegelke (2018) already found a larger compatibility effect for right-hand responses than for left-hand responses. The study’s results can then be of further assistance for neuroscientific studies, expanding the theory of a shared-representation account, like ATOM.

To check whether the theory of a compatibility effect in reaction times is profound, the study addresses two hypotheses.
First of all, there is a direct compatibility effect on reaction times, which will be faster in the compatible mapping condition than in the incompatible mapping condition. Secondly, the stimulus size - response location compatibility effect is more pronounced for the right-hand than for the left-hand responses. This means that the difference in reaction times between compatible and incompatible mapping conditions is larger for right-hand responses than for left-hand responses.
To investigate both hypotheses, the below mentioned statistical ANOVA model uses the null hypothesis of no difference between the compared groups - the groups being compatible and incompatible mapping conditions for the first hypothesis and the differences in reaction times between both mapping conditions for right- as well as left-hand responses for the second hypothesis. The null hypothesis will then be rejected if a significant main effect (p-value < 0.05) can be found and we consequently accept the alternative hypothesis.

Method

Participants. Thirty-two volunteers (14 female, 17 male, one others) with a mean age of 33 years (age range: 19-77) participated in the experiment. All data included in the analysis was from right-handers, who were naive with respect to the purpose of the study. The data from left-handers was excluded.
Materials. A small black colored “X” sign as a fixation point, a small and a large black colored square serve as stimuli. While the small one is supposed to be 2x2cm and the big one 4x4cm, in practice we focus on the proportion of these two, as the experiment is conducted as an online experiment, which may cause the squares to differ in actual size on the participant’s screen. All stimuli are presented at screen center appearing on a white background and the participants respond by pressing either the left “f” key or the right “j” key. The participant’s task is then in each trial to respond with the corresponding key when the stimulus appears. This means that the participant has to press the left “f” key for a small stimulus and the right “j” key for a large stimulus in each trial in the compatible mapping condition and *vice versa* in the incompatible mapping condition.

Procedure. The experiment was implemented via the _magpie (“Minimal Architecture for the Generation of Portable Interactive Experiments”, Illieva, Xiang, Rautenstrauch, Franke) framework and executed solely online. That consequently means that the recording of reaction times slightly differ because of participants’ differing hardware properties. Prior to the main study, there was a pilot study with three participants.

The experiment consists of six parts:

1. introduction & instructions
2. practice phase first mapping condition
3. main phase first mapping condition
4. practice phase second mapping condition
5. main phase second mapping condition
6. post-experiment questionnaire

At the beginning, the participants are shortly informed about the general background of the experiment and also receive written instructions about the task at hand. The instructions emphasize that the participants should strive to optimize speed and accuracy. The instructions are followed by a practice phase (10 trials) as well as the main test phase (60 trials) for the first mapping condition. Afterwards, there is a practice phase (20 trials) and main test phase (60 trials) for the second mapping condition. While in the experimental main trials correct responses are not indicated for the participant, there is a short indication of correctness in the practice trials. We only use the data of the main trials for our data analysis.
Each experimental trial starts with the presentation of the fixation point for 1000ms, followed by the stimulus presented until a key is pressed. Correct responses are followed by a blank screen for 1500ms, for incorrect responses an error screen is shortly presented, followed by a blank screen for 1500ms. The amount of small and large stimuli appearing is balanced within each training and test block. Since the experiment is conducted with a *repeated measures design*, the order of compatibility mapping conditions is *counterbalanced* across

participants to control for order effects.
At the end of the experiment, participants are presented with a survey kindly asking them to provide socio-demographic information as well as their handedness. There is also space for further remarks.

Data preparation. We excluded left-handed people from our final analysis, because the handedness could significantly influence the outcome of the experiment, and for reasons of simplicity, we formulated our hypotheses only for right-handers, just like in the original study. Furthermore, only correct main trials were considered and individual ones with a reaction time below 100 ms were discarded, because that reaction time is humanly impossible. We also excluded trials above 1500 ms, as well as people who took more than 5 minutes to complete the whole experiment, considering that those people most likely did not commit to the experiment and including their outcome could corrupt the other data.

Analysis plan. The raw data as well as the analysis scripts can be found in the “additional files” section. In order to check the first hypothesis, individual trial specific reaction times (dependent variable) were analyzed using a one-way ANOVA. The independent variable was the factor mapping condition with the levels left and right. To check the second hypothesis we utilized a two-way ANOVA, again with dependent variable RT and the manipulated independent factors S-R mapping (with levels left, right), response (key location left or right) and the interaction between them.

Results

The ANOVA revealed marginal significance for the main effect of the S-R mapping conditions compatible (mean = 528 ms, sd = 196) and incompatible(mean = 514 ms, sd = 164), F value = 4.96 with a p-value of approx. 0.026 and MSE = 161486. But no significant effect of the response location could be found (p-value of approx. 0.48).
The Tukey post-hoc test reported a difference of approx. -13.9 ms CI[-26.1,-1.7] between incompatible and compatible trials. Analysis of the interaction between mapping and response location revealed a stronger interaction effect for left-hand responses although not significant (p-value = 0.31), F value = 1.03 and MSE = 33547. Incompatibility of response location and stimulus size shortened reaction times by approx. 20.1 ms, compared to the overall mean, for the left hand CI[-42.8, 2.5] and by approx. 7.5 ms for the right hand CI[-30.2,15.2]. Thus the incompatibility reduced reaction times by approx. 12.6 ms more when giving the response with the left hand.

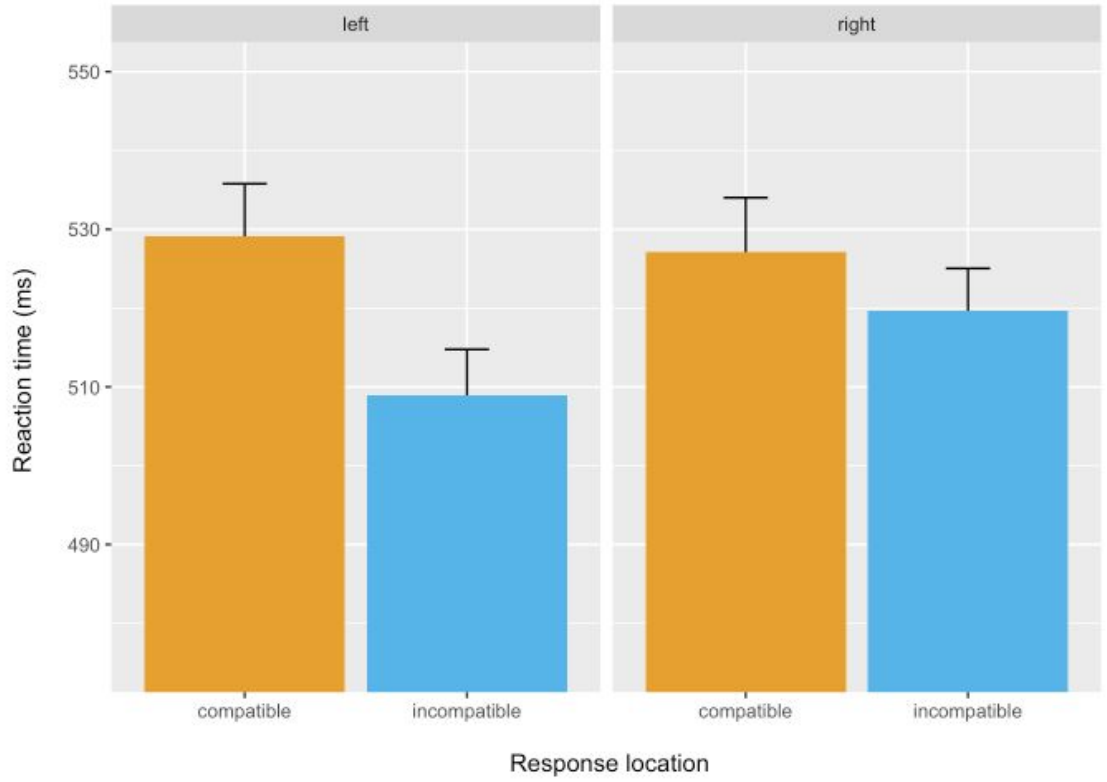

Figure 1: Mean RTs as a function of S-R mapping (compatible: small-left, large-right; incompatible: large-left, small-right) and response location (left, right). The error bars represent standard errors between participants.

Conclusion

The current experiment did not result in any evidence that backs up the original paper. We reject both the first and the second hypothesis. Evidence for an association between smaller stimulus objects with left-hand responses and between larger stimulus objects with right-hand responses resulting in a compatibility effect visible in reaction time, has not been found. Following up on this, an analysis of the second hypothesis seems redundant, considering that there is no initial sign for a compatibility effect at all. We also did not find any evidence supporting the second hypothesis - that the stimulus size - response location compatibility effect is more pronounced for right-hand than for the left-hand responses. Considering that previous studies have already shown evidence for the same or similar hypotheses as our own, it seems to be worth investigating the topic in further detail. First of all, one might invest in a study with more narrow specifications in terms of hand and arm location, preferably with a single PC in a clean experimental set-up for better continuity. We included data from participants with a high variety in age (from 19 to 77). Because of this and for better accuracy in general, it would help to increase the number of participants by a large amount. With a large number, one could also include left-handed participants for data investigation and for the potential draft of a third hypothesis regarding the differences between left- and right-handed people.

Data Accessibility Statement

The raw data as well as the analysis scripts from the pilot and main experiment have been published as additional files for this paper (see below).

Additional Files

The additional files for this paper can be found on GitHub as follows:

- **Raw pilot data 1 (.csv)**, **Raw pilot data 2 (.csv)**, **Raw pilot data 3 (.csv)**
- **Raw main data (.csv)**
- **Pilot study analysis script (.Rmd)**
- **Main study analysis script (.Rmd)**

References

Besner, D., & Coltheart, M. (1979). Ideographic and alphabetic processing in skilled reading of English. *Neuropsychologia*, *17*(5), 467–472. DOI: https://doi.org/10.1016/0028-3932(79)90053-8

Bueti, D., & Walsh, V. (2009). The parietal cortex and the representation of time, space, number and other magnitudes. *Philosophical Transactions of the Royal Society B*, *364*(1525), 1831–1840. DOI: https://doi.org/10.1098/rstb.2009.0028

Cohen Kadosh, R., Cohen Kadosh, K., Linden, D. J., Gevers, W., Berger, A., & Henik, A. (2007). The brain locus of interaction between number and size: A combined functional magnetic resonance imag- ing and event-related potential study. *Journal of Cognitive Neuroscience*, *19*(6), 957–970. DOI: https://doi.org/10.1162/jocn.2007.19.6.957

Dehaene, S., Bossini, S., & Giraux, P. (1993). The mental representation of parity and number magnitude. *Journal of Experimental Psychology: General*, *122*(3), 371–396. DOI: https://doi.org/10.1037/0096-3445.122.3.371

Dehaene, S., Dupoux, E., & Mehler, J. (1990). Is numerical comparison digital? Analogical and symbolic effects in two-digit number comparison. *Journal of Experimental Psychology: Human Perception and Performance*, *16*(3), 626–641. DOI: https://doi.org/10.1037/0096-1523.16.3.626

Henik, A., & Tzelgov, J. (1982). Is three greater than five: The relation between physical and semantic size in comparison tasks. *Memory & Cognition*, *10*(4), 389–395. DOI: https://doi.org/10.3758/BF03202431

Kaufmann, L., Vogel, S. E., Wood, G., Kremser, C., Schocke, M., Zimmerhackl, L., & Koten, J. W. (2008). A developmental fMRI study of nonsymbolic numerical and spatial processing. *Cortex*, *44*(4), 376–385. DOI: https://doi.org/10.1016/j.cortex.2007.08.003

Ren, P., Nicholls, M. R., Ma, Y., & **Chen, L.** (2011). Size matters: Non-numerical magnitude affects the spatial coding of response. *PloS ONE*, *6*(8). DOI: https://doi.org/10.1371/journal.pone.0023553

Tzelgov, J., Meyer, J., & Henik, A. (1992). Automatic and intentional processing of numerical information. *Journal of Experimental Psychology: Learning*, *Memory*, *and Cognition*, *18*(1), 166–179. DOI: https://doi. org/10.1037/0278-7393.18.1.166

Walsh, V. (2003). A theory of magnitude: common cortical metrics of time, space and quantity. *Trends in cognitive sciences*, *7*(11), 483-488. DOI: https://doi.org/10.1016/j.tics.2003.09.002

Walsh, V. (2015). A theory of magnitude: The parts that sum to number. In: Kadosh, R. C. & Dowker, A. (Eds.), *Oxford library of psychology. The Oxford handbook of numerical cognition* (p. 552–565). Oxford University Press.

Wühr, P., & Seegelke, C. (2018). Compatibility between physical stimulus size and left-right responses: small is left and large is right. *Journal of cognition*, *1*(1), 1-11. DOI: https://doi.org/10.5334/joc.19