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Magnitude Estimation Is Influenced by Social Power

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Abstract

The action-specific perception account suggests that how people perceive the environment depends on their ability to act on it, assuming that estimation is influenced by inter-individual traits, but also by situated states. Moreover, several studies revealed that social power affects basic cognitive processes and even influences the way we perceive the physical environment. In the present study, we examined whether social power also influences estimation performance of spatial magnitudes (i.e., line estimation). Participants estimated the line length of a given number in an increase and a decrease condition, after (low versus high) social power had been manipulated between participants via role assignment. In the increase condition, low-power participants overestimated line lengths, whereas such a bias was not observed for high-power participants. In contrast, the power manipulation did not affect performance in the decrease condition, suggesting that proportion-judgement strategies might have been applied here, thereby reducing the overall bias in line estimations. Our findings support the notion that social power has an impact on the perception of the physical environment and that perception can depend on personal as well as situational factors. Moreover, the present research suggests that high (compared to low) social power may help people to overcome biases in overestimating magnitudes.

Keywords: magnitude estimation, social power, production task, bounded, unbounded

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Generally, we are confident that our perception of the physical environment is objective. However, according to the action-specific perception account, individuals' perception of the environment depends on their (subjective) ability to act on it (Proffitt, 2006; Witt & Proffitt, 2005). For instance, perceived distances appear to be larger for individuals wearing a heavy backpack than for those wearing no backpack (Proffitt, Stefanucci, Banton, & Epstein, 2003). Furthermore, individuals estimate the distance to a target as larger when they have to throw a heavy vs. a light ball (Witt & Proffitt, 2005). In line with this, the estimated height of a wall depends on people's ability to overcome this wall: Parkour experts who are trained to overcome barriers including high walls estimate the height of a wall as lower than novices do (Taylor, Witt, & Sugovic, 2011). Moreover, people overestimate the magnitude of geographical slants when being put in a sad mood as opposed to a happy mood (Proffitt et al., 2003).

These findings suggest that magnitude estimation in general might be influenced by inter-individual traits (e.g., physical constitution, and abilities), but also by situated states (e.g., mood, wearing a heavy backpack). However, while magnitude estimation is a standard task in numerical cognition research (e.g., Agrillo, Piffer, & Adriano, 2013; Barth & Paladino, 2011; Crollen, Castronovo, & Seron, 2011; Ebersbach, Luwel, & Verschaffel, 2013; Mejias, Grégoire, & Noël, 2012; Mundy & Gilmore, 2009; Siegler & Opfer, 2003; Stapel, Hunnius, Bekkering, & Lindemann, 2015), studies investigating possible influences of such inter-individual traits and situated states on number magnitude estimation are rather scarce so far. Moreover, previous studies focused on distances or heights in real world settings, but it has yet to be shown whether the influence of inter-individual traits and situated states also generalize to number processing tasks used in research on numerical cognition.

The present study sought to take a first step towards closing this gap. More specifically, we did so by investigating the role of having (high versus low) social power—as a situated state that may influence how people perceive the environment—for number magnitude estimation. Social power is, per definition, characterized by differences in the opportunity to take action. Individuals who have or experience high power have control over resources and, thus, a relatively wide scope of possibilities to act, whereas low power is characterized by more constraints and, thus, a more restricted opportunity to take action (cf. Fiske & Berdahl, 2007; Keltner, Gruenfeld, & Anderson, 2003). Consequently, according to the action-to-perception account, these differences in the (subjectively experienced) ability to impact the environment, induced by different levels of social power, should alter the processing of number magnitude information.

Number Magnitude Estimation and Social Power

The most commonly used magnitude estimation tasks in numerical cognition research either have a lower and an upper bound (bounded task) or no bound (unbounded task). Additionally, they either require the mapping of symbolic numbers onto non-symbolic magnitudes (production tasks; e.g., producing the number of dots or the length of a line, with a given target number) or the transformation of non-symbolic quantities into symbolic numbers (perception tasks; e.g., estimating the number of dots or the length of a line; for an overview see Ebersbach et al., 2013).

A typical example for a bounded production task is *bounded number line estimation*. Here, participants have to map the magnitude of a given symbolic number onto a physical line (i.e., a continuous magnitude) with a given start and end point (e.g., having to indicate where 71 is located on a number line ranging from 0 to 100; Siegler & Opfer, 2003). Different *strategies* are employed in this task version, resulting in various estimation patterns (for an overview see Dackermann, Huber, Bahnmueller, Nuerk, & Moeller, 2015). For instance, a particular prominent strategy which has been found in different task settings is the proportion-judgment strategy (e.g., Barth & Paladino, 2011; Hollands & Dyre, 2000). Following this strategy, participants use specific benchmarks (e.g., start, mid, and end point of the number line, e.g., Peeters, Degrande, Ebersbach, Verschaffel, & Luwel, 2016) when mapping symbolic numbers onto non-symbolic magnitudes. This strategy results in a specific pattern of over- and underestimation of magnitudes. For instance, when participants apply a proportion-judgment strategy using the start and end point as benchmarks, they tend to overestimate magnitudes smaller than the midpoint and to underestimate magnitudes larger than the midpoint. Bounded perception tasks are only very rarely used, but are assumed to be solved by applying similar strategies (e.g., Ashcraft & Moore, 2012). In sum, such *bounded* estimation tasks imply the use of specific solution strategies.

The estimation pattern is different, however, in *unbounded* estimation tasks. Here, two different biases arise, depending on whether a production task or a perception task is employed. In production tasks (e.g., producing the number of dots or the length of a line corresponding to a particular target number), participants usually *over*estimate the magnitude of symbolic numbers with increasing magnitude (i.e., produce more dots or a longer line than they should do; e.g., Cordes, Gelman, Gallistel, & Whalen, 2001; Crollen et al., 2011; Crollen, Grade, Pesenti, & Dormal, 2013; Whalen, Gallistel, & Gelman, 1999). In contrast, in perception tasks (e.g., telling the number of dots in a display), they usually *under*estimate non-symbolic magnitudes when their magnitude increases (e.g., Crollen et al., 2011; Kaufman, Lord, Reese, & Volkmann, 1949; Mandler & Shebo, 1982). Taken together, these findings indicate that participants performing an unbounded estimation task rely on "rough" estimation and rarely use specific solution strategies, such as proportional judgement.

In the present study, we were interested in how far magnitude estimation in a symbolic bounded and unbounded estimation task (i.e., when estimating the length of a physical line) depends on the perceiver's situated state. More specifically, we aimed at investigating how participants' social power affects magnitude estimation of physical lines.

Social power is (in social psychology) defined as actual or perceived asymmetric control over one's own and others' outcomes (Fiske & Berdahl, 2007). It, therefore, usually reflects a social relation between two or more individuals (e.g., the hierarchy between a manager and an employee), in which the high-power person controls resources (e.g., money, rewards, information) which the low-power person(s) depend(s) on. As a result, those high in power are relatively independent from others, which provides them with more freedom to act (compared to those low in power; Keltner, Gruenfeld, & Anderson, 2003) and enables them to focus their attention more exclusively on their current goals (e.g., a task at hand; cf., Guinote, 2007a). Indeed, it was demonstrated that social power affects basic cognitive processes and even influences the way people perceive and interact with their physical environment (Guinote, 2007a, 2007b, 2007c; Lee & Schnall, 2014; Wilkinson, Guinote, Weick, Molinari, & Graham, 2010; for evidence of the *social* perception on power and size, see Schubert, Waldzus, & Giessner, 2009).

Recently, Lee and Schnall (2014) showed that social power influences the perception of physical magnitudes in a weight estimation task. In their experiments, participants had to estimate the weight of cardboard boxes. The authors observed that participants who experienced low power perceived a box packed with books as heavier than participants who experienced high power. The authors assumed that low-power individuals would perceive themselves as having fewer resources than high power individuals (e.g., would feel less able to cope with heavy weights), which may explain why they estimated the boxes as heavier. Similarly, Weick and Guinote (2008) demonstrated that when estimating the time participants would need to complete a task, low-power individuals assumed that it would take them longer than high-power individuals guessed it would take them.

Though Lee and Schnall (2014) did not explicitly test perceived resources (or an ability) for being a mechanism explaining these effects, other research has, indeed, shown that social power does promote people's confidence (See, Morrison, Rothman, & Soll, 2011) and physiological functioning in demanding situations (as a potential outcome of more perceived resources; Scheepers, de Wit, Ellemers, & Sassenberg, 2012). In sum, these findings suggest that social power influences the way people perceive their environment—here, it specifically modulated the magnitude estimation of (physical) weights, such that low as compared to high power leads to estimating weights as heavier (i.e., 'overestimation').

The Present Research

In the present research, we conducted two experiments to investigate whether social power also influences estimation performance of *spatial* magnitudes. In Experiment 1a, we manipulated social power between participants via a well-established role assignment (Guinote, 2007b; see also Anderson & Berdahl, 2002; Fast, Gruenfeld, Sivanathan, & Galinsky, 2009; Galinsky, Gruenfeld, & Magee, 2003; Scholl & Sassenberg, 2014, 2015; for an overview see Smith & Galinsky, 2010) to test its effect on estimation performance. Participants in the low-power condition were assigned to the role of an assistant, whereas participants in the high power condition were assigned to the role of a manager.

Estimation performance of spatial magnitudes was assessed using a length production task (e.g., Shaki, Sery, & Fischer, 2015). In this task, participants had to transfer the magnitude of a symbolic number (i.e., numbers from 1 to 10) to the length of a physical line on a touch-screen, considering the length of a provided line segment. Moreover, we manipulated the length of the initial line segment in two different within-participant conditions resembling unbounded and bounded versions of number line estimation tasks (i.e., increase vs. decrease condition, as described in the following).

In the *increase* condition, participants were provided with a line segment corresponding to the length of the Unit ‘one’; they had to extend the length of this segment until its length corresponded to the magnitude of a respective (symbolic) target number. This condition can be connected to *unbounded* number line estimation (cf. Cohen & Blanc-Goldhammer, 2011). In unbounded number line estimation, participants are usually given a start point and the length of a unit. Based on this information, they have to estimate the length corresponding to a given target number. Cohen and Blanc-Goldhammer (2011) found that adult participants apply direct estimation as well as a dead-reckoning strategy in this task. When applying a dead-reckoning strategy, participants first estimate the length of a particular number (e.g., 5) and then use this length as a basis for estimating the length of larger numbers. However, in the study by Cohen and Blanc-Goldhammer (2011), the average size of this working window was about 10, which was not a feasible size in the present study, because there it was the maximum length of the line. Hence, we expected participants to apply a direct estimation strategy (i.e., rough estimation) in the increase condition.

In contrast, in the *decrease* condition, participants were provided with an initial line segment equal to the length of the Unit ‘10’; they had to decrease the length of this segment until its length corresponded to the magnitude of a respective (symbolic) target number. This condition is comparable to *bounded* number line estimation in which participants have to estimate the location of a target number on a given number line with labelled end points (e.g., 0 and 100). Just as in our decrease condition, in bounded number line estimation tasks, participants were given the full length of the number line. Thus, we expected participants to apply similar strategies in the decrease condition as are typically found in bounded number line estimation: as indicated above, the most prominent strategy of adults in bounded number line estimation is the proportion-judgment strategy, which involves part-whole considerations based on benchmarks (e.g., start, mid, and end point). A very similar strategy can be applied when estimating the length of target numbers in our decrease condition. For instance, to estimate the line length of ‘6’, participants may first aim at producing a line half the length of the initial line (representing ‘10’) and then add another unit.

We expected generally better estimation performance for the *decrease* condition (than for the increase condition), because adult participants usually perform better in bounded compared to unbounded number line estimation (e.g., Link, Huber, Nuerk, & Moeller, 2014). This finding is supposedly due to their use of the specific proportion-based estimation strategies. Importantly, the use of such strategies in bounded estimation tasks may overrule other estimation biases.

In contrast, as is typical for production tasks, we expected an *overestimation* of target numbers in the increase condition—that is, participants should increase here the initially depicted line to a greater extent than necessary. Similar to the results of Lee and Schnall (2014), we hypothesized that this overestimation of target numbers should be more pronounced for participants in the low-power as compared to participants in the high-power condition. In particular, we expected participants in the low-power condition (but not in the high-power condition) to overestimate the line length in the increase condition. This is because the increase condition relies more on rough estimation (rather than specific strategies) when to stop—in other words, people here need to roughly estimate at what point they had moved their fingers far enough to increase the line length. Accordingly, we expected that when increasing the initial segment until its length corresponds to the magnitude of the target number, low-power individuals will do so more (i.e., extend the initial segment more, resulting in more overestimation). In contrast, high-power individuals should stop earlier increasing the starting segment—just as Weick and Guinote's (2008) findings suggested that high-power individuals would assume they could stop earlier when completing a task. In short, we expected that estimates of line length should, as a function of social power, differ only in the increase (but not in the decrease) condition.

Notably, the manipulation of high- vs. low-power does not provide any information in which direction estimates of participants with low- or high-power are influenced as compared to baseline (cf. Lee & Schnall, 2014). Therefore, we collected additional data from a non-overlapping sample of participants (Experiment 1b) whose social power was not manipulated; this data served as a baseline to examine whether the manipulation led to an over- or underestimation by participants with low- or high-power, respectively.

Method

Participants

Experiment 1a

Thirty-two subjects (22 female) were recruited to participate in the experiment (mean age = 22.16 years, *SD* = 2.26 years; range: 18 – 29 years). Prior to the experiment, they signed informed consent forms. Participants were randomly assigned to either the high- or low-power condition. Independent of power condition, they received financial compensation for participating in the study.

Experiment 1b

To assess a baseline, 24 additional participants were recruited (23 female), but no power manipulation was applied. Mean age of the sample was 24.38 years (*SD* = 3.37 years; range: 20 – 34 years). Participants signed informed consent forms prior to doing the experiment and their participation in the study was reimbursed financially. All aspects of the two experiments were approved by the local ethics committee.

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Materials & Procedure

Experiment 1a

The study was advertised under the title “art and number processing”. Participants were seated in front of a laptop on which they received all further instructions. To emphasize the theme of the study, printed pages with different paintings of famous artists were placed next to the laptop. Participants read the information that the experiment consisted of two parts. The first part involved the investigation of the cooperation of two individuals, whereas the second part assessed numerical skills.

Social power (high vs. low) was manipulated as part of the ‘first experiment’ using well-established role assignments (following standard procedures; e.g., Guinote, 2007b, 2007c; Scholl & Sassenberg, 2015). Participants anticipated performing a cooperation task with another person in another room, acting either as manager or assistant for the organization of an art exhibition. Allegedly, participants were assigned high- or low-power roles (manager vs. assistant) based on their self-ratings of twelve personality related adjectives (“Please indicate how well these adjectives describe your personality”—e.g., self-confident, open, flexible), a self-regulation questionnaire (Sassenberg, Ellemers, & Scheepers, 2012), and three items on their creative thinking and interest in art. However, participants were actually randomly assigned to either the high- or low-power condition.

Participants learned that assistants were good at following instructions and generating ideas, whereas managers were good at instructing others about their tasks. Social power was manipulated as control about the other’s outcome: The managers received a fixed amount of reward for their performance (5€), but the assistants’ rewards (starting at 4€) could allegedly be raised by the manager (up to 5€ at maximum), depending on the manager’s evaluation of the assistant’s performance. Then, participants were told to get back to the experimenter to perform first the other part of the experiment (and to complete after that the cooperation task, which, in fact, did not take place anymore; see Guinote, 2007b, 2007c; Scholl & Sassenberg, 2015).

Participants then performed the estimation task as the ’second experiment’. Performance was measured by a 23" Dell touch screen (resolution: 1920 × 1080px) which was placed horizontally on a table. Participants stood in front of the touch screen at a distance of about 75cm. Instructions were given by the experimenter. In both the increase and the decrease condition, participants saw a black line on the screen with one black square each below the left and right end (see Figure 1). Their task was to put their index fingers on the squares and, as soon as the target number appeared, to either *increase* or *decrease* the length of the line by sliding both index fingers to the left or right, respectively (i.e., away from the body midline in the increase and towards the body midline in the decrease condition) until reaching the estimated target’s line length.

Target numbers for both conditions were 3, 4, 6, and 7, all presented above the middle of the line segment in Font Segoe UI at size 64pt. Each target number was presented ten times, resulting in 40 items for each condition and 80 items in total. In the increase condition, participants were presented with a line segment representing the magnitude of one (2.40cm) and their task was to extend the length of the line by increasing the distance between their index fingers (see Figure 1A). In the decrease condition, participants were presented with a line segment representing the magnitude of 10 (24cm) and their task was to decrease the length of the line (see Figure 1B). Order of these two within-participant conditions was counterbalanced across participants.

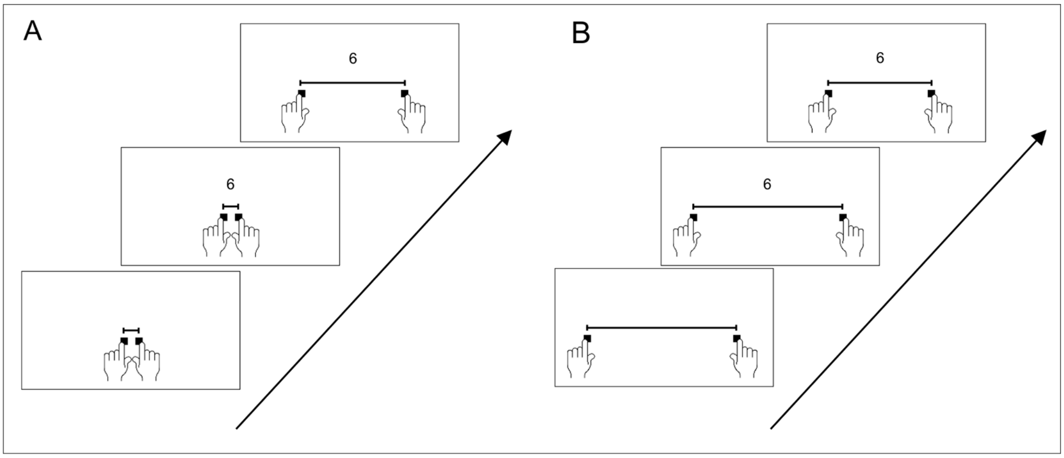

Figure 1. Schematic illustration of the two estimation task conditions. Panel A depicts the *increase* condition in which participants were supposed to increase the line length of the given Unit 1 until reaching the estimated length of the target number (here, '6'). Panel B depicts the *decrease* condition in which participants had to decrease the line length, starting at a line length of 10, until reaching the estimated length of the target number (here, also '6').

After performing the two numerical tasks, participants were instructed to get back to the first laptop on which they were debriefed about the alleged cooperation task in 'experiment one' (i.e., that this task would not take place any more). Finally, demographic data were assessed as well as any conspicuity features of the experiment participants had noticed.

Experiment 1b (baseline)

The estimation task here was identical to the one described above. In total, participants performed 80 items, 40 for each condition (i.e., increase / decrease). No manipulation of social power was applied.

Analysis

As the dependent variable, we considered the mean of participants' relative deviation of produced line length from the correct line length of the target numbers.

Experiment 1a

Trials with deviations from the correct line length larger than +/- 3 standard deviations from a participant's mean were excluded from data analysis. This resulted in a total loss of less than 1% of the data. We ran a linear mixed effect model (LME) to analyse the *average relative deviation from the correct line length*. Fixed effects in the analysis were condition (increase vs. decrease), power (low-power vs. high-power), and the interaction between condition and power. Furthermore, we included into the model a random intercept for participants. All predictor variables were effect-coded prior to analysis. The *p*-values for fixed effects were calculated using the Satterthwaite approximation for degrees of freedom as implemented in the R package lmerTest (Kuznetsova, Brockhoff, & Christensen, 2016).

Experiment 1b (baseline)

Since the sample size of the baseline group here (n = 24) was 50% larger than the sample size of each group in Experiment 1a (n = 16), we first checked whether the variances of the groups differed, because ANOVA and also LME (when assuming equal error variances) tend to be either more conservative or liberal, depending on whether groups with larger sample sizes have larger or smaller variances than groups with smaller sample sizes (Field, Miles, & Field, 2012). In order to verify whether factor-specific error variances for the factor power showed be included in the LME, we ran two LME using the R package nlme (Pinheiro, Bates, DebRoy, Sarkar, & R Core Team, 2016), one LME modelling factor-specific error variances for the factor power and one LME assuming equal error variances. Fixed effects in these models were condition, power and the interaction between condition and power. Additionally, we included a random intercept for participants. Model comparison using a likelihood ratio test revealed that the model including factor-specific error variances for the factor power provided a better model fit to the data, $\chi^2(2) = 11.45$, $p = .003$. Therefore, we included factor-specific error variances for the factor power in the analysis of the data of Experiment 1b.

In contrast to the R package lmer, there is no R package for nlme allowing to estimate degrees of freedom using the Satterthwaite approximation for degrees of freedom. Hence, we ran likelihood ratio tests to calculate *p*-values for fixed effects[i]. Moreover, post-hoc tests were run using the R package multcomp (Hothorn, Bretz, & Westfall, 2008). Finally, we employed ggplot2 for drawing figures (Wickham, 2009).

Results

Experiment 1a

The analysis revealed a significant main effect of condition, $F(1, 30) = 4.64$, $p = .039$, showing a tendency to underestimate the correct line length in the decrease condition (*M* = -0.13 units, *SD* = 0.74 units, in cm: *M* = -0.31 cm) and to overestimate the correct length in the increase condition (*M* = 0.16 units, *SD* = 0.98 units, in cm: *M* = 0.38 cm); the main effect of the factor power was not significant, $F(1, 30) = 3.22$, $p = .083$. This was qualified by a significant interaction of the factors condition and power, $F(1, 30) = 6.63$, $p = .015$, suggesting that the effect of increase vs. decrease condition differed as a function of low vs. high power. The increase vs. decrease effect was more pronounced in the low-power (*M* = 0.63 units, *SD* = 0.78 units, in cm: *M* = 1.51 cm) as compared to the high-power condition (*M* = -0.06 units, *SD* = 0.72 units, in cm: *M* = -0.14 cm; see Figure 2).

Post-hoc tests revealed that, as expected, the estimated line length differed significantly between high- versus low-power participants in the *increase* condition, $t(58.2) = -3.03$, $p = .004$, but not in the *decrease* condition, $t(58.2) = 0.27$, $p = .785$. Moreover, only low-power participants showed a relative deviation from correct line length in the increase condition that differed significantly from zero, *M* = 0.47 units, *SD* = 0.75 units, in cm: *M* = 1.13 cm, $t(58.2) = 3.20$, $p = .002$, but not high-power participants, *M* = -0.16 units, *SD* = 0.56 units, *M* = -0.38 cm, $t(58.2) = -1.08$, $p = .285$.

Experiment 1b (baseline)

Experiment 1a revealed that power influenced the estimation of line lengths. In a second step, we evaluated whether power leads to an underestimation or whether a lack of power leads to an overestimation, relative to a baseline. Therefore, we analysed the data from Experiments 1a and 1b together.

We found that the model including an interaction between condition and power provided a significantly better fit to the data than a model assuming only main effects for condition and power, $\chi^2(2) = 6.45$, $p = .040$ (see also

Figure 2). We examined this interaction by running two separate LMEs for the increase and decrease condition. Comparing models with and without the fixed effect power, we only observed a significant effect of power for the *increase* condition, $\chi^2(2) = 6.90$, $p = .032$, whereas for the *decrease* condition, this effect was not significant, $\chi^2(2) = 0.21$, $p = .902$.

Post-hoc tests for the increase condition indicated that estimated line lengths differed significantly for participants in the high- and low-power condition, *M* = 0.63 units, *SE* = 0.20 units, *M* = 1.51 cm, *z* = 3.12, *p* = .022; the other comparisons were not significant, low-power vs. baseline: *M* = 0.32 units, *SE* = 0.23 units, *M* = 0.77 cm, *z* = 1.35, *p* = .753; baseline vs. high-power: *M* = 0.31 units, *SE* = 0.22 units, *M* = 0.74 cm, *z* = 1.40, *p* = .724.

Finally, we evaluated whether in the increase condition, estimation performance of participants in the baseline was within the range of estimation performance of participants of the other two conditions. Therefore, we recoded the factor power into a continuous predictor with -1 for the low-power, 0 for the baseline, and 1 for the high-power condition. The fixed effect for the continuous predictor variable was significant, supporting our hypothesis, *M* = -0.31 units, *SE* = 0.11 units, *M* = -0.74 cm, *t*(54) = -2.73, *p* = .009.

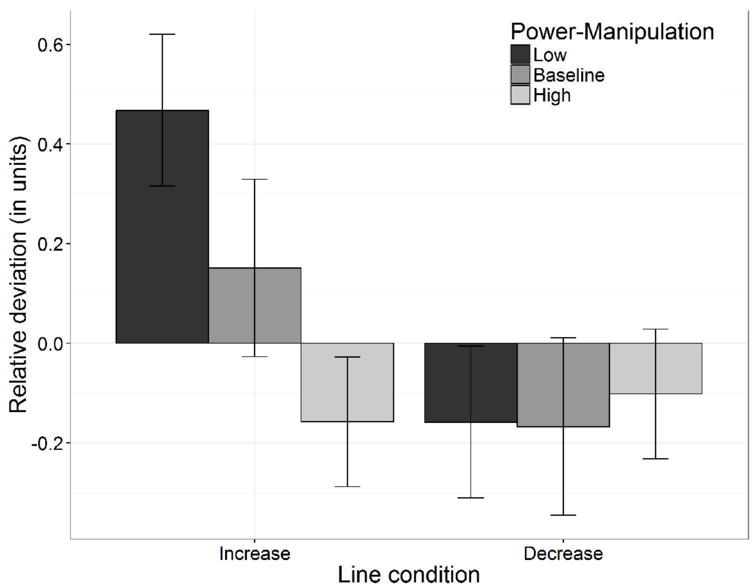

Figure 2. Relative deviations of line length estimations of participants in the low-power, baseline, and high-power condition, separately for the increase and decrease condition. Error bars indicate standard errors.

Discussion

In the present study, we examined whether estimation performance in a number magnitude estimation task is influenced by social power. Therefore, we conducted an experiment (and assessed a baseline) in which participants had to increase or decrease the length of a given physical line until its length corresponded to the magnitude of a symbolic number. Similar to an unbounded number line estimation task, participants had to estimate the respective to-be-produced length of the line, based on the length of the Unit 1, in the *increase* condition—that is, increasing the given part of a line until a depicted (symbolic) target number would be reached. In contrast, participants had to estimate the to-be-produced line length, based on the length of the

Unit 10, which resembles in the *decrease* condition a bounded number line estimation task—that is, here, decreasing the depicted line segment until the depicted target number would be reached. In Experiment 1a, participants' social power was manipulated using well-established role assignments of either a high (manager) or low (assistant) power role (cf. Guinote, 2007b; Scholl & Sassenberg, 2015). Experiment 1b assessed the same numerical task conditions in a sample without manipulating social power (i.e., as a baseline).

In line with previous findings on unbounded number line estimation (Cohen & Blanc-Goldhammer, 2011), we found that participants *overestimated* the magnitude of the physical line in the *increase* condition. Moreover, this bias was modulated by social power: the bias to overestimate magnitudes (i.e., line length) was more pronounced for those having *low power* (compared to high power)—in other words, those high in power were more accurate (i.e., overestimating less in the sense of stopping earlier) than those low in power when they had to increase a line segment to reach the respective target number.

In contrast, in the *decrease* condition, neither a bias of over- or underestimation nor a modulation of this bias by social power was present. This finding suggests that in the decrease condition, (all) participants may have used proportion-based strategies as previously found in bounded number line estimation (e.g., Link et al., 2014), such as using the line length of 10 as a benchmark, probably dividing it in half and calibrating the target numbers accordingly. This may have improved their task performance. In line with our hypothesis, this proportion-based estimation strategy in the decrease condition was not influenced by social power.

In general, our findings are in line with the findings by Lee and Schnall (2014) who employed a weight estimation task under different levels of social power. They observed that individuals with low power overestimated physical weights (e.g., the weight of a box with books) compared to individuals with high power. In the present study, we replicated this finding for physical line lengths and extended it by demonstrating a differential influence of power depending on specific task conditions. In the *increase* condition—comparable to the estimation task used by Lee and Schnall (2014) and also the time estimation task used by Weick and Guinote (2008)—low (vs. high) power led to an overestimation of physical length. In contrast, in the *decrease* condition—comparable to a bounded number line estimation task—estimation performance was unaffected by power. Therefore, when individuals had to rely on their mere estimation skills (and no other solution strategy, like the consideration of benchmarks, was available), individuals with low power seemed to overestimate line length compared to individuals with high power.

These findings are even more remarkable, as they are in contrast to studies in which anchoring effects have been observed: for instance, LeBoeuf and Shafir (2006) found that when provided with a short/long anchor line, participants tended to under-/overestimate the line length they had to produce. However, the experiments for investigating anchoring effects usually use anchors that remain visible throughout the estimation performance, which was not the case in the present study; in our study, participants had to actively change (increase / decrease) the length of the initial line segment (as a potential 'anchor'), which may have led to these differing results.

Our findings are in line with the assumption that a lack of action possibilities affects in particular powerless individuals (Lee & Schnall, 2014). By definition, power implies an imbalance of action possibilities, because it is characterized by an asymmetry of access to resources (Fiske & Berdahl, 2007; Keltner et al., 2003). Lee and Schnall (2014) suggested that potential for action of powerful people are higher than those of powerless people, because they have control over their own and other's resources (see also Keltner et al., 2003). As a result, a given task might be experienced as less demanding for high power individuals than for low-power individuals. According to the action-to-perception account (Proffitt, 2006; Witt & Proffitt, 2005), experiencing a high demand should result in overestimation, because personal resources are not seen as sufficient to adequately fulfil task requirements. In this vein, low-power participants might have experienced line length estimation as more demanding than high-power participants. High-power people presumably assumed that they could *stop earlier* (than low-power people) when estimating the line length in the increase condition (i.e., when increasing the line segment to match the target number)—similar to the findings of Weick and Guinote (2008) suggesting that high-power people estimate they would finish earlier in completing a task.

The combined findings of Experiments 1a and 1b suggest a linear trend of power in predicting overestimation—such that high power might diminish and low power might promote overestimation compared to a control condition. Indeed, prior studies have indicated that, relative to a neutral baseline group, low power can decrease (e.g., Scholl & Sassenberg, 2014; Smith & Trope, 2006; Willis, Guinote, & Rodríguez-Bailón, 2010) and high power can increase subsequent responses (DeWall, Baumeister, Mead, & Vohs, 2011; Fast et al., 2009; Schmid Mast, Jonas, & Hall, 2009; Smith & Trope, 2006). Similarly, results by Lee and Schnall (2014) suggest that weight estimation effects may be driven by high power (see Study 2) and/or low power (Study 3). Though not many studies have shown *both* effects, theoretical approaches to power (as outlined below) and our sum of findings do suggest that both high and low power might drive the effects.

On a theoretical level, our findings are in line with approaches how social power has impact on cognitive reactions and task performance. Due to their control over resources, high-power people are relatively independent from others, which should allow them to take prompt action towards and focus more on their current goals—such as the task at hand; in contrast, low-power people depending on the powerful are comparatively more distracted by other things (e.g., how others may evaluate them) and, thus, less focused on the goal (e.g., the task at hand; Guinote, 2007b; Keltner, Gruenfeld, & Anderson, 2003). Indeed, high (compared to low) power has been shown to facilitate goal-directed behaviour (e.g., Guinote, 2007a; Scholl & Sassenberg, 2014, 2015), to boost individuals' confidence and physiological functioning when solving tasks (Scheepers et al., 2012; See et al., 2011), and to improve task performance (e.g., Lammers, Dubois, Rucker, & Galinsky, 2013). Taken together, this research suggests that (high versus low) social power usually allows people to be more *precise* when performing a task.

We assumed that this should also be the case for number magnitude estimations: here, those high in power should be more precise when estimating magnitudes—potentially due to their perceived higher resources and goal-focus (here, task-focus)—than those with low power. Indeed, those high in power showed less overestimation (in the increase condition) in our study than those low in power – descriptively, they even tended to underestimate. Future research should, thus, seek to investigate more closely the underlying mechanisms of these effects. Moreover, the present findings are also in line with the action-specific perception account (Proffitt, 2006; Witt & Proffitt, 2005) stating that how people perceive the environment—in this case, magnitudes—depends on the ability to impact on it (as influenced by their social power in the present case).

A potential limitation of the present study might be that we did not apply a manipulation check to evaluate whether the employed role assignment, indeed, altered the subjective sense of power as intended. However, the manipulation we used followed a well-established role assignment manipulation procedure (i) that has already been used repeatedly (e.g., Anderson & Berdahl, 2002; Fast et al., 2009; Galinsky et al., 2003;

Guinote, 2007b, 2007c; Scholl & Sassenberg, 2014, 2015; for an overview see Smith & Galinsky, 2010), (ii) that is well-validated with manipulation checks (and subjective sense of power measures) in this research, and (iii) that has also been used and validated repeatedly in our own lab. We are, thus, confident that the manipulation worked as intended in this study, too. Still, future research should aim at including a manipulation check assessing subjective sense of power.

Moreover, finger movement in our study might be considered as a power posing manipulation itself. However, all movements participants performed in both the increase and decrease condition were comparably small: the *increase condition* implied increasing a line of 2.4 cm to a maximum of 24 cm on the touch screen, whereas the *decrease condition* implied decreasing a line of 24 cm line to a min. of 2.4 cm. For both tasks, this had to be done while keeping one's index fingers on the respective end points of the manipulated line. Thus, the *increase condition* did not actually imply taking an expanded initial posture and changing it into a constricted one (or vice versa for the *decrease condition*), as would be the case for a power posing induction (here, participants usually adopt an expanded vs. constricted posture with their whole body while sitting or standing; Carney, Cuddy, & Yap, 2010; Cuddy, Wilmuth, Yap, & Carney, 2015; Garrison, Tang, & Schmeichel, 2016; Ranehill et al., 2015). In contrast, both conditions implied very restricted movements of fingers on the screen - similar to the standard lab setting when participants are seated in front of a PC to complete a study on a regular keyboard. Finally, power posture effects are currently under debate in social psychology — such that some researchers have successfully replicated them (Carney, Cuddy, & Yap, 2015), while others have not (e.g., Ranehill et al., 2015). It is, thus, at this point not entirely clear whether these effects replicate and if so under which conditions. Nevertheless, different power postures might play a role for line length estimations, which should be addressed in future studies.

Finally, we want to point out that Experiment 1b (baseline) was not assessed concurrently with Experiment 1a. However, this should not affect the main results of the present study, as we used independent samples in all three conditions. Moreover, the result that sensed social power influences performance in line length estimation originates from Experiment 1a and does not include a comparison with Experiment 1b. We conducted the control experiment, because it allowed us to explore in which direction the power manipulation modulates estimation performance (i.e., whether low or high power is more likely to drive the effect). Results indicate that low power reduces estimation performance, whereas high power seems to improve estimation performance. Nevertheless, future studies should consider collecting the data of all three conditions at the same time.

To conclude, people are usually confident that their perception of the physical environment—such as the perception of magnitudes of an object or number—is objective. However, this perception can depend on (personal as well as) situational factors. The present research demonstrated that high compared to low social power may help people to overcome biases in estimating numerical magnitudes. It, thereby, takes a first step towards outlining the important role of such situational factors for the perception of number magnitude.

Notes

i) Note that *p*-values for the results of Experiment 1a were virtually identical when using likelihood ratio tests instead of the Satterthwaite approximation for degrees of freedom.

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Competing Interests

The authors have declared that no competing interests exist.

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Author Contributions

Stefan Huber and Johannes Bloechle contributed equally to the study and should be considered shared first authors.

Ethics Approval

The study was approved by the local Ethics Committee of the Leibniz-Institut für Wissensmedien. All subjects gave written informed consent in accordance with the Declaration of Helsinki.

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