Autobahn People: Distance Estimations Between German Cities Biased by Social Factors and the Autobahn

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Abstract. Re-analyses of a study on distance estimations between German cities [1] revealed that conclusions drawn from aggregated data sets can also be found on the individuals' data level. It could be shown that mental barriers, here the former iron curtain which has been physically absent for 15 years, while still assuming a significant role in social interactions, are powerful predictors for psychological distance estimations. Moreover, by integrating new demographical information about the participants, evidence can be found that social attitudes are often much stronger predictions for distance estimations than implicit or explicit geographical knowledge. For instance, it was revealed that the attitude towards German reunification plays a crucial role in estimating distances between cities crossing the former iron curtain: the more negative the attitude the more pronounced was the overestimation of distances. This trend was impenetrable by higher route knowledge measured implicitly by the extent of traveling experience and explicitly by ratings of geographical knowledge about Germany. Furthermore, participants appeared to base their estimations of direct (air) distances between German cities on distances resulting from their experience with the German Autobahn system.

Keywords: Mental map, cognitive map, distance estimation, distortion, social factors, representation, road, route, highway.

1 Introduction

Whenever we have to estimate direct distances between cities "as the crow flies", we are confronted with a task that we are not used to. Everyday experience on distances is mainly obtained by looking at signs, getting information from (e.g., GPS based) navigation systems or by implicitly calculating distances via the temporal length of journeys. All these procedures are based on the given road structures. An alternative way for estimating distances is given by imaging of cartographic maps, which is supposed to provide an overview of the whole geographic structure.

The present paper reinvestigates a data set provided by Carbon and Leder [1] in order to analyze whether German participants base distance estimations between German

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cities on map-related knowledge, precisely whether they can estimate direct air distances, or whether they use the prominent German Autobahn structure as a heuristic to solve this task. Furthermore, it was tested whether the former iron curtain, which was found to be a relevant factor in systematically overestimating distances across this historical border [1], can also be identified as a biasing factor when measured with alternative measures other than those provided by Carbon and Leder [1]. Ultimately, it was analyzed whether social factors, such as the participant's attitude towards German reunification, which strongly biases the estimation of distances crossing the former iron curtain, can be modified by traveling experience and geographical knowledge.

1.1 Distance Estimations and Distance Distortions

In the way finding and cognitive map literature, two major coding formats have been proposed for the mental representation of environmental information [2]: Egocentric information in terms of uni-directed routes with a specific starting point and destination, and allocentric information in terms of precise mental maps with distances coded in a bird's eye view [3]. Neither of the two modes of representation are commonly seen as competitive accounts for coding geographical information, but the allocentric mode is assumed to evolve from long-term practice of egocentric information. According to this developmental approach [4], mental navigation starts in the first stage with simple landmarks (highly distinct, and stable large-scale objects, such as buildings, signs, trees, etc.) that are loosely interconnected. Over time these landmarks get more and more interlinked to form a coherent travel route, which is only represented in a sequential way, thus, requiring a step by step activation procedure to enable way finding [5]. Only after extensive practice, a final step can be reached where topographical knowledge can be formed.

However, whether this final stage can ever be reached adequately remains an open question. In contrast to the predictions of representations based on accurate mental maps which have a structure similar to cartographic maps [3], a number of studies have demonstrated mild to severe deviations from such ideal mental maps. In general, Stevens and Galanter [6] showed that psychological distances and physical distances are related by a power function versus a linear relationship. However, it has only been demonstrated recently that the appropriateness of a power function depended on the specific regional structure to which the cities pertained [7]. Ekman and Bratfisch [8] showed systematic overestimations between cities that participants did not attach much emotional involvement[1]. Moreover, mental maps seem to be organized as complex hierarchical structures [9-12]. Last but not least, Carbon and Leder [1] revealed social attitudes as powerful enough to distort mental maps in a systematic way. Taking all these types of distortion factors into consideration, Tversky [13] concluded that there is no simple way to account for all of these factors, but that our mental maps are systematically distorted by a variety of influences.

1.2 The Specific Situation of Germany

For four decades, Germany was divided into two parts belonging to diametrically opposed political systems. Whereas the Federal Republic of Germany ("West

[1] Emotional involvement was measured by imaging something important happening in the cities and estimating their degree of emotional involvement in what might happen.

Germany") was integrated in the NATO and European (Economic) Community, the German Democratic Republic ("East Germany") was a key member of the Warsaw Pact and the COMECON. Moreover, West Germany had a free market economy, whereas East Germany adhered to a socialist economy. Although both countries entertained permanent diplomatic relations with each other, in fact, both countries were strong opponents in these days. This antagonistic situation was even intensified by the construction of the Berlin Wall in 1961, which back then represented a visible sign of the political separation of both countries.

Germany has been reunified since 1990, merging these formerly sovereign countries. The reunified conglomerate consists of ten federal states in the former western part and six states in the former eastern part including one state, Berlin, which was formerly divided and pertained to both countries (West-Berlin and East-Berlin). In an experimental study, Carbon and Leder [1] investigated whether the former border between both countries still exists as some sort of "mental wall". They used a distance estimation paradigm based on the idea of Ekman and Bratfisch [8] that distances between two places with low emotional involvement will be systematically overestimated. When additionally taking the attitude towards German reunification into account, it could be demonstrated that those participants who had a negative attitude towards the reunification strongly overestimated distances across the former iron curtain. Interestingly, this was not found for people with a positive attitude towards the German reunification. After the Berlin Wall had been demolished more than 15 years ago, streets and bridges between both parts of Germany have been re-activated and today Germany does not have any physical borders within the country. Thus, this systematic distortion indicates a "mental wall" [1], which is rather resistant to political change. The authors concluded that this mental wall is a sign for the failure, at least in some respect, of the German (re-)unification.

1.3 The Aim of the Present Study

This study is based on the experimental data obtained by the study of Carbon and Leder [1]. In the original study, only *group* data, sampled over participants belonging to different levels of the social attitude towards German reunification, was analyzed. Further demographical variables, such as traveling experience or geographical knowledge about Germany were not integrated in the presented analyses. Furthermore, the authors did only test hypotheses with the psychological distance data, ignoring response[2] time data [14]. In addition, the authors only included the air distances as predictors, but did not test whether the participants based their estimations on relevant distances found in reality, such as kilometers on national highways (Autobahns).

The present paper aims to address all these points in order to facilitate a more comprehensive view towards distance estimation strategies in general and towards the mental wall between West and East Germany in particular.

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[2] Throughout the paper, the term *response time* is used instead of *reaction time* according to the terminology proposed by Luce [14] in which the term reaction time is only used for experiments for which measuring time aspects are the first priority. Here, in contrast, the major variable was the estimation of distances; therefore the term *response time* seems to be more adequate within this context.

2 Study

This study is a re-evaluation and extension of the analyses of Carbon and Leder [1] based on a distance estimation paradigm between German cities. To minimize redundancy, only key facts of the original study and newly calculated data and tested hypotheses are presented in the following sections.

2.1 Method

2.1.1 Participants

Eighty-three participants (54 female; 32 raised in the former western part of Germany; mean age: 25.9 years) participated in the study as volunteers. They were all naive to the purpose of the study.

2.1.2 Materials

11 well-known German cities, including Berlin, were selected as anchor points for following distance estimations. No federal state was represented by more than one of these cities. The 11 cities included five cities that were located in the western part of Germany; five in the eastern part of Germany and the 11th city was Berlin, the capital of Germany. Given this set of cities, 25 distances across the former iron curtain (across distances) and 20 distances within one of the two former parts of Germany (within distances) can be rated.

2.1.3 Procedure

First the participants were asked to provide demographical information (attitude towards German reunification, traveling experience within Germany, geographical knowledge about Germany, etc.). The attitude towards German reunification was measured on a four-point rating scale from 1 to 4 (1 --> very negative; 2 --> negative; 3 --> neutral; 4 --> positive). Then the participants had to estimate all possible air distances ("as the crow flies") between the 11 presented German cities in a sequential way by typing the exact distance in kilometers, thus realizing a spatial resolution of 1 km. The order of all 110 distance estimations (including Berlin and both directions, e.g. Berlin-Nuremberg and Nuremberg-Berlin) was randomized via an experimental control software [15] which also registered response times from the onset of the stimulus with a resolution of 16 ms.

2.2 Results and Discussion

In the original study, only sampled group data based on distance estimations were presented and contrasted with direct air distances. Here, analyses based on individual participant's data will be provided, which are also contrasted with relevant distances measured on German Autobahns. Furthermore, additional demographical data will be considered. Additionally, response time data will complement the data analysis of psychological distances. For all following analyses, people with a "*very* negative" and a "negative" attitude towards the German reunification were collapsed into one single group later on labeled as "negative" due to the low number of only 5 members pertaining to the "very negative" group.

2.2.1 Autobahn Distances Versus Air Distances

In everyday life, we use the main routes to travel along long distances between cities. Although these routes are planned and realized as straight-lined as possible to minimize distances, political, geographical and topographical facts prevent perfect straightness. Thus, people might not base their distance estimations on direct air distances but rather on the given infrastructure. In Germany, this infrastructure mainly manifests itself in the so-called Autobahn system (the "Bundesautobahn" based on the former "Reichsautobahn"). As this system is strongly interconnected with a total length of approximately 12.000 km, its usage is toll-free and there is no speed limit, the Autobahn is a very popular infrastructure which might strongly bias people's cognitive maps. We analyzed this hypothesis by comparing air distances and distances on Autobahns with psychological distances. In order to increase the clarity of data (a) psychological data were related to both types of physical distances. The closer the index to the ideal ratio of 1.0 (i.e., psychological distance = physical distance), the more probable the estimation is based on this type of physical distance. (b) Only the sampled 45 undirected distances (all distances without Berlin as one of the anchors) were included in all of the following analyses.

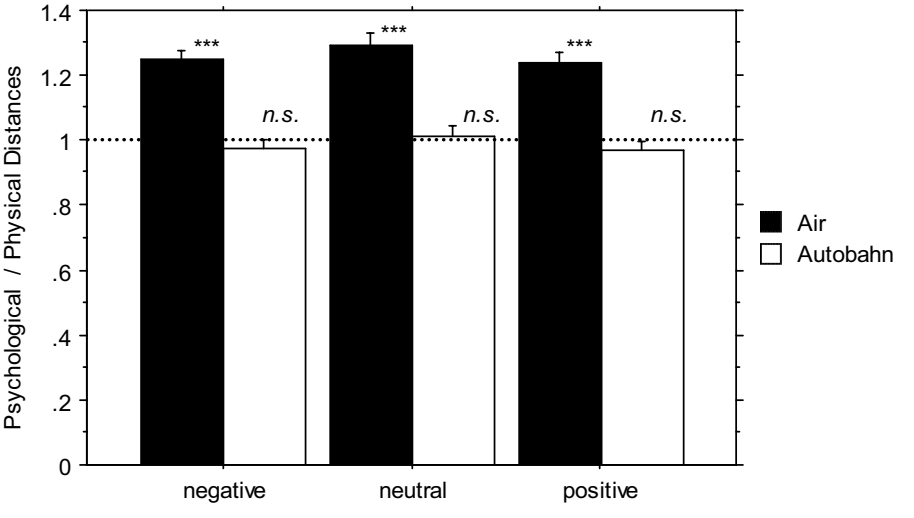

Fig. 1. Psychological distances compared with air distances vs. Autobahn distances. For each data bar, error bars as SEs of the mean and p-values of one-sample t-tests (two-tailed) against the hypothesized mean of 1.0 are shown ($p < .001$ equals ***).

Figure 1 clearly demonstrates that participants estimated the distances very close to Autobahn distances versus air distances, although both physical measures correlated very highly ($r^2 = .9734$, $p < .0001$). It is important to stress that the participants were forced to base their estimations on *air distances*. Nevertheless, the dissociate outcome of six independent one-sample *t*-tests against a hypothesized mean of 1.0 strongly favors

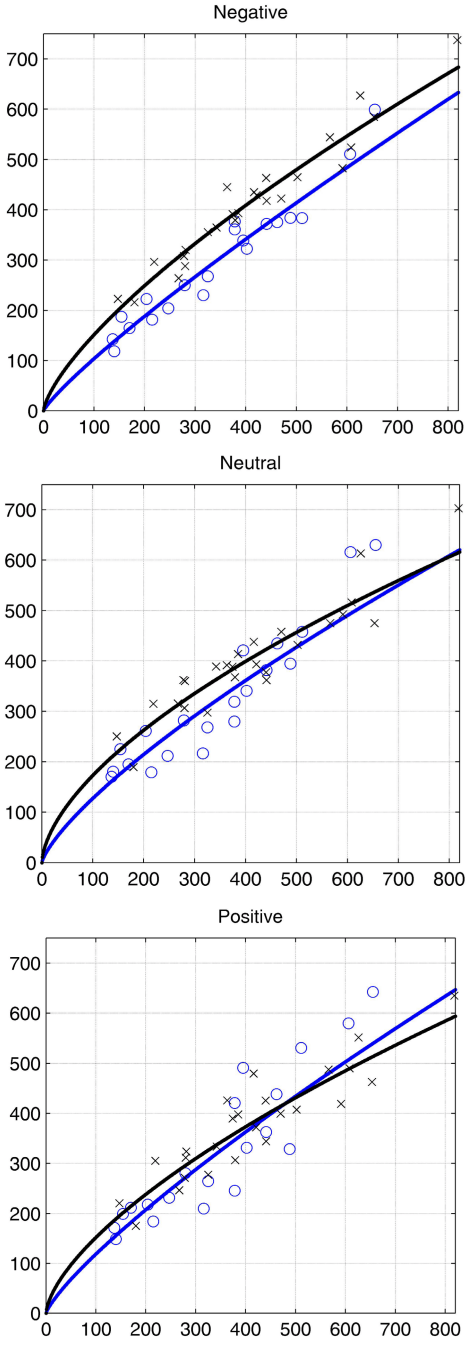

Fig. 2. Curve plots (power functions) for all attitude groups (negative, neutral, positive) split for within (blue circles) and across (black crosses) distances. On the x-axis the air distances, on the y-axis the psychological distances are given.

the idea that the participants based their distance estimations on distances measured on the Autobahn which mirror their everyday life experiences (see *p*-values in Figure 1).

The high fit between psychological and Autobahn distances (see Figure 2) was also revealed by regression analyses of the 25 across and 20 within distances for each attitude group (negative, neutral or positive attitude towards German reunification).

Table 1 outlines the curve parameters and the fits as the correlations between estimated and modeled distances. None of the correlations were below .90.

Table 1. Fit functions for the group data level split by the *attitude* towards the German reunification and the *distance type*

Attitude	Distance Type	Fit Function	Correlation
Negative	Across	$y = 5.64 \cdot x^{0.71}$	.9694
Negative	Within	$y = 1.98 \cdot x^{0.86}$	.9685
Neutral	Across	$y = 10.73 \cdot x^{0.60}$	.9237
Neutral	Within	$y = 3.98 \cdot x^{0.75}$	.9286
Positive	Across	$y = 7.76 \cdot x^{0.65}$	.9093
Positive	Within	$y = 2.92 \cdot x^{0.80}$	.9009

Thus, it is highly plausible that the most important basis for estimations of *air distances* in the present study was the German Autobahn system.

2.2.2 The Mental Wall Between East and West

Carbon and Leder [1] based their main argument for the mental wall between East and West Germany on (a) regression analyses and (b) 6 pairs of distances which were comparable in length. Here, also evidence for the mental wall on the basis of the relation between the psychological distance and the physical (Autobahn) distance will be presented.

A mixed-design ANOVA with the between-subjects factor *attitude* (negative, neutral, positive) and the within-subjects factor *distance type* (across, within) revealed a main effect of *distance type*, $F(1, 80) = 13.00$, $p < .0005$. Most importantly, there was a significant interaction between both factors, $F(2, 80) = 6.15$, $p = .0033$, illustrated in Figure 3.

Further analyses of the simple main effects (see Figure 3) showed that *across* distances were particularly overestimated in comparison to *within* distances for the negative attitude group. For the neutral group there was, in accordance with the original findings, also a weak, but reliable, effect of *distance type.* Nevertheless, there was no effect for the positive attitude group.

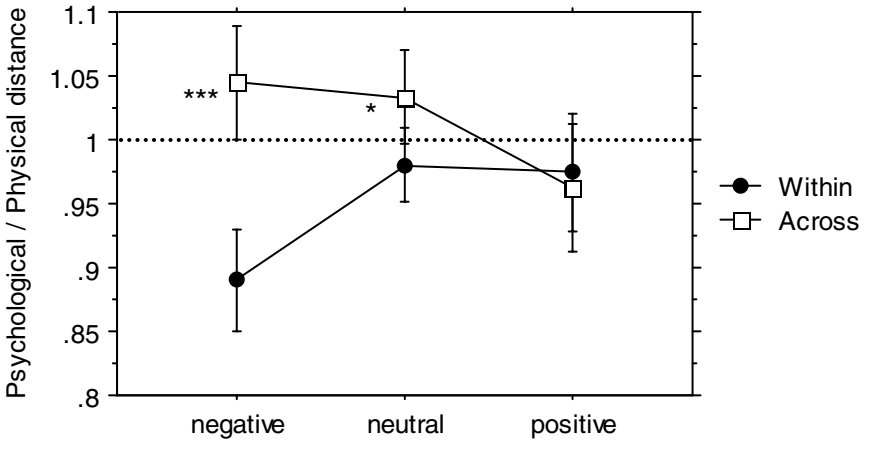

Fig. 3. The effect of *distance type* (across vs. within) on the relation between psychological distances and physical (Autobahn) distances. For each data bar, error bars as *SE*s of the mean and *p*-values of the simple main effects for each *attitude* group are shown ($p < .001$ equals ***, $p < .05$ equals *).

2.2.3 Analyses Based on the Individual's Level

The main argument of Carbon and Leder [1] for claiming the existence of a mental wall between the western and the eastern part of Germany is based on sampled group data. However, on the basis of group data it is not possible to test the slopes of the power functions of across and within distances for statistical differences. Here, curve fittings for both *distance types* (across vs. within) were conducted for all participants on an individual level.

Table 2. Fit functions for the individual data level split by the *attitude* towards the German reunification and the *distance type*

Attitude	Distance Type	Fit Function	Correlation
Negative	Across	$y = 42.05 \cdot x^{0.70}$	.8386
Negative	Within	$y = 3.60 \cdot x^{0.87}$	.8734
Neutral	Across	$y = 24.12 \cdot x^{0.64}$	.6745
Neutral	Within	$y = 11.84 \cdot x^{0.79}$	.7483
Positive	Across	$y = 12.46 \cdot x^{0.69}$	.6983
Positive	Within	$y = 8.52 \cdot x^{0.82}$	.7633

For each participant both curve parameters were calculated to define the power function and the correlation (see Table 2). Both curve parameters were averaged across the 3 *attitude* groups and the 2 *distance types* by the arithmetic means. Due to the steep distribution of correlations, all correlations were Fisher-*Z* transformed in order to further analyze them. The arithmetic means of these *Z*-values were then re-converted by inverted Fisher-*Z* transformation following the advice of R. A. Fisher. Again, the mean correlations, although based on fuzzy individual data, were rather high, none of them below .67. Furthermore, referring to the curve parameters, two-tailed *t*-tests revealed that multiplicands of the functions for across vs. within distances differed only significantly for the neutral attitude group ($p = .0320$) and as a trend for the negative group ($p = .0758$, *n.s.*). The exponents differed for the negative ($p = .0094$) and the neutral group ($p = .0044$), but only as a trend for the positive group ($p = .0509$, *n.s.*). Thus, the data on the individual level is quite compatible with the idea of a mental wall between the former western and the eastern parts of Germany proposed by Carbon and Leder [1], especially when participants had a negative attitude towards German reunification.

2.2.4 Integration of Further Demographical Information

Due to the specific social psychological approach adhered to in the original Carbon and Leder [1] study, only alterations of the mental map on the basis of the attitudes towards the German reunification had been analyzed. In order to generate a more complete picture of the effects, here, further variables were included in our calculations which might influence the "width" of the mental wall. These variables reflect the extent of geographical knowledge on Germany and the level of traveling experience throughout Germany. Both variables were assessed by 4-level ratings, whose levels were collapsed in such a way that 2-level variables were obtained which were comparable in size. Geographical knowledge was split in a low (bad and rather bad) and high (rather good and good) level of knowledge; traveling experience was split in a low (less than 10.000 km per year) and high (more than 10.000 km per year) level of experience.

Both variables were tested in two separate mixed-design ANOVAs due to the unequal number of participants per level. Both ANOVAs comprised one demographical between-subjects factor (*geographical knowledge* or *traveling experience*, respectively), the between-subjects factor *attitude* (negative, neutral, positive) and the within-subjects factor *distance type* (across vs. within). In accordance with the analyzes presented above, the relation between psychological distances and physical distances based on Autobahn kilometers, was used as dependent variable. Both analyses did not show any effect of any of the two other demographical factors nor an interaction with them, Fs < 1.43, $p > .2355$, *n.s.* Thus, the width of the mental wall was *not* influenced by implicit (traveling experience) or explicit knowledge (geographical knowledge) about Germany's geography!

2.2.5 Analyses of Response Time Data

For the original study only distance estimations but no response times were reported. Here we also present response times which are valuable as indirect distance measures in contrast to direct measures, such as distance or bearing estimations [16]. First, the quality of response times as an indirect distance measure will be investigated by

correlating response time data with physical (Autobahn) distances. Second, an index will be presented which relates response times with psychological distances.

For all 3 *attitude* groups (negative, neutral, positive) and both *distance types* the correlations between response times and Autobahn distances were calculated. The only significant correlations were obtained for the *within* distances in the neutral group ($r^2 = .3469$, $p = .0090$), and for the *within* ($r^2 = .4493$, $p = .0015$) and the *across* distances ($r^2 = .1939$, $p = .0283$) in the positive group. This indicates that the distance estimations of the negative attitude group followed more complex cognitive mechanisms, probably social psychologically relevant ones that are related to the negative attitude towards German reunification, but cannot be described easily by linear functions of response times.

The response time data were further analyzed by calculating an index which relates response times to psychological distances. This index is a quasi measure for the estimation effort in milliseconds for each estimated km. A mixed-design ANOVA with the between-subjects factor *attitude* (negative, neutral, positive) and the within-subjects factor *distance type* (across, within) revealed main effects of *attitude*, $F(2, 80) = 4.48$, $p = .0144$, and *distance type*, $F(1, 80) = 67.40$, $p < .0001$. Most importantly, there was a significant interaction between both factors, $F(2, 80) = 6.42$, $p = .0026$, as illustrated in Figure 4.

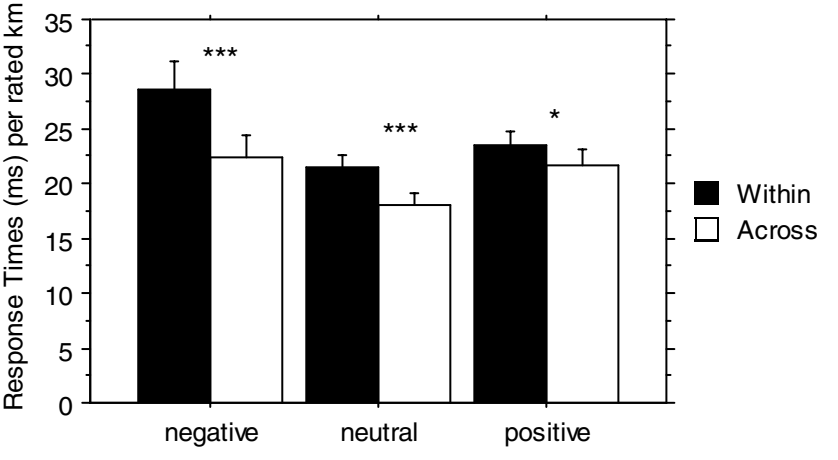

Fig. 4. The effect of *distance type* (across vs. within) on the relation response times and psychological distances. For each data bar, error bars as *SE*s of the mean and *p*-values of the simple main effects for each *attitude* group are shown ($p < .001$ equals ***, $p < .05$ equals *).

Further analyses of simple main effects of *distance types* on the different levels of *attitude* revealed large effects for the negative and neutral attitude group and a small effect for the positive group. Interestingly, the crossing of the former border did not cause an additional time factor, but systematically *decreased* response times. This might be an indication for generally different underlying cognitive processes for estimating distances *across* or *within*, probably based on simpler heuristics for distance estimations *across* the former border. Once again, these findings are in accordance with the idea of a mental wall between the former western and eastern parts of Germany.

4 General Discussion

The present study re-evaluated and extended the findings of distance distortions by social factors provided by the data of Carbon and Leder [1].

The participants in the present experiment were asked to estimate direct *air* distances. Nevertheless, comparisons between the physical distances of air distances and Autobahn distances indicated that they based their estimations not on *air* but on *Autobahn* distances. This indicates strong influences of experiential information on cognitive processes.

In accordance with the original analyses, it was shown that distances across the former iron curtain were systematically overestimated, particularly when the attitude towards the German reunification was negative. This "mental wall" [1] was *not* existent in terms of overestimations when participants had a positive attitude towards the reunification. These main conclusions could be drawn not only on the basis of sampled group data with reference to air distances but also with reference to Autobahn distances. Moreover, curve fittings on the basis of individuals' data also favored the idea of a mental wall which is mainly existent for the negative attitude group.

When response times were additionally taken into account, there were large effects in accordance with the idea of a mental wall only for the negative and the neutral attitude group. This demonstrates that taking response time data into account can be a valuable additional variable to test specific hypotheses in the field of spatial cognition.

Importantly, the reliable effects of distance overestimations which cross the former iron curtain were impenetrable both by implicit knowledge about German geography operationalized by participants' traveling experience, as well as by explicit knowledge about German geography operationalized by participants' geographical knowledge. Again, this underlines the strong impact of social attitudes on cognitive processing.

In short: we cannot understand human cognition without taking into consideration the complex interplay of social attitudes and experiential information [17].

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