

Psychological attributes of house facades: A graph network approach in environmental psychology

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ABSTRACT

The interaction between humans and their living environments is of ubiquitous nature, however the relationship between environmental psychology and cognitive neuropsychology has scarcely been explored. Environmental psychology has approached the human-environment relation through psychological concepts such as affordance, attachment, identity, safety, or aesthetic preference. Cognitive neuropsychology, on the other hand, frequently uses houses as stimuli in object- and face-processing research. This study combines concepts from the two disciplines (cognitive neuropsychology and environmental psychology) to explore the interrelation between the architecture of living environments, human cognition and emotion.

Using network analysis, we aimed to examine the underlying relationship between self-reported psychological attributes, and to explore the role of differences between three countries in appraisals of house facades. To that end, we used 50 images of house facades selected from a well-controlled data set of Canadian houses (DalHouses). 305 participants from Denmark, Germany, and Canada rated the houses on 12 psychological attribute dimensions.

Results showed the highest strength for the nodes “friendliness”, “likability”, “invitingness”, “safety”, and “freedom”, while “typicality” and “familiarity” were unexpectedly low in strength. In terms of cultural differences, the three countries diverged in some correlations, e.g. facelikeness and loneliness, loneliness and freedom, but not in others, e.g. typicality and safety. Similar to the DalHouses study, “facelikeness” was not correlated with “typicality” nor with “liking”.

Taken together, the present results identify psychological attributes that cluster together and could be particularly important in the characterization of house facades on a universal level, but also specific to different cultural and geographical backgrounds.

1. Introduction

Environmental psychology as an academic discipline aims to understand multiple different aspects of the interrelation between human cognition, emotion, behaviour, and the surrounding environment (Gifford, 2014). Research has focused on both theoretical and applied aspects of this interrelationship. Already during the late 1960's, the psychologist James Gibson presented the term *affordance* to define the relationship between human beings and their surrounding environment (Gibson, 1966), showing that an environment could have a stimulating character. Beside stimulation, environments can also be places for

emotional *attachment* and identity (Low & Altman, 1992). Affordance of and attachment to certain environments are expressed through individual appraisals and assessments (Craig & Zube, 1976; Sussman & Hollander, 2021). A recent issue of the Journal of Environmental Psychology follows up on the above-named connection between places and identity (Devine-Wright & Clayton, 2010).

Following Gifford (2014), we define environmental appraisals as an individual's *person-centred* impression and environmental assessment as *place-centred*. For understanding the appraisal and assessment of a certain place, estimates of different individuals are obtained. An environmental assessment based on an individual observation, makes use of

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the perceptual abilities to estimate the meaning and characteristics of a specific stimulus or place (Bradley & Lang, 1994).

In the cross field between cognitive neuropsychology and environmental psychology, both interior and exterior environments are of high importance (Tawil et al., 2021). The investigation of living environments such as houses has been part of a distinct interest, as they share attributes and can be compared with human faces. It has been suggested that children and adults from around the world tend to generate recognizable facial patterns when they draw houses, which has been referred to as a “primal pattern” (Sussman, 2019). With a more elaborated scientific approach, computer vision scientists have worked on algorithms that can detect facial features (and their emotional expression) in pictures with house facades (Abbas & Chalup, 2021). A similar form of anthropomorphism but for cars has been demonstrated by our own lab showing that participants display face-related brain activity when seeing car fronts that they describe with human-like attributes (Kühn et al., 2014). A Canadian study from Filliter et al. (2016), the so called DalHouse Study, asked students to rate the edited photographs of 100 houses on three dimensions regarding their typicality, likeability, and facelikeness. The findings illustrate a positive association between typicality and likability (Filliter et al., 2016). We set out to repeat this study using 50 of the 100 houses, but adding a broader range of rating dimensions such as familiarity, freedom, and emotional aspects such as safety versus threat of a place (Rollwagen, 2015). In addition, potential cultural differences regarding the assessment of a house were taken into focus by investigating three different countries. Hereby, we combine the neuropsychological theme of object processing with the environmental psychological question of architectural assessment with a cultural angle when looking at photographs of houses.

The aim of the present study is twofold. On the one hand, the study aims to investigate and illustrate the underlying correlational structure and relationships between the different rating dimension, and to characterize which dimensions cluster together using psychometric network analysis methodology (Borsboom et al., 2021). Network analysis is applied to explore and analyse statistical associations in multivariate psychological data and is particularly useful when strong prior theory on how variables are related is absent. Our approach extends a previous attempt to run network analysis only focusing on attributes of indoor architecture (Coburn et al., 2020).

On the other hand, we set out to study potential differences between the three countries in the perception and the evoked emotional appraisal when looking at (Canadian) houses.

2. Method

2.1. Participants

305 individuals, 105 from Germany (mean age = 29.6 years, SD = 9.7 (18–68), 47.6% females), 100 from Denmark (mean age = 27.8 years, SD = 8.7 (18–61), 48% females) and 100 from Canada (mean age = 32.3 years, SD = 11.2 (18–69), 37% females) took part in the study, matching the following eligibility criteria: age 18–75 years, native or fluent language skills in the respective language of the target country, and current country of residence in the target country. In total, 136 participants were students, 169 were not students. Participants were recruited via the online platform Prolific (prolific, 2021).

2.2. Ethical considerations

The local psychological ethics committee of the University Medical Center Hamburg-Eppendorf, Germany, approved of the study (LPEK-0269) as well as the Danish Research and Innovation Organisation (RIO) of the University of Southern Denmark (no.11.298).

2.3. Procedure

The experiment was implemented online using Inquisit 6 (millisecond, 2021). Participants were sent the link to the study as well as a participation number. Participants were presented with the study information, asked to give their informed consent to participate and to confirm matching the eligibility criteria. In case of participation, participants first saw photographs of house facades (see Stimulus material below) one by one and were asked to “write down adjectives that you think would go well with the house shown” to complete the sentence “This house is ...”. After this, they saw the same facades again, always in a randomized order and generated free text responses to complete the sentence “This house makes me ...”. Then participants saw the house facades again, also in randomized order, but this time they had to respond to 12 statements in a row namely: (1) The house has a face. (2) This house is a typical house. (3) This kind of house looks familiar. (4) This house looks childlike. (5) This house looks inviting. (6) This house looks friendly. (7) I like this house. (8) I would feel safe in this house. (9) This house looks threatening. (10) In this house I would feel lonely. (11) In this house I would feel free. (12) I would like to live with others in this house. The participants responded to these statements on a slider ranging from 0 = “not applicable at all” to 100 = “very applicable”. At the end of the questionnaire participants filled in a short version (Schiffhauer, 2015; Wullenkord, 2017) of the Individual Differences in Anthropomorphism Questionnaire (IDAQ) (Waytz et al., 2010) consisting of 9 items. Participants received around 11€ for study participation. In total, the experiment lasted for about 75–90 min.

2.4. Stimulus material

We used 50 house facades from the so-called DalHouses, depicting Canadian houses, that were previously used in a study investigating the typicality, likeability, and degree of similarity to faces of house stimuli (Filliter et al., 2016). We selected only 50 of the 100 stimuli, due to time constraints caused by the number of questions we wanted to ask per house. We selected the pictures by ranking them according to the mean facelike judgement and then selected every second image.

2.5. Data analysis

Data was prepared using SPSS 26 and analyzed using RStudio Version 1.4.1717 (r-project, 2021). We computed the residuals by means of predicting each of the 12 rating dimensions separately with crossed random factors for participant ID and picture number using the *lme4* package (version 1.1–27.1). We did this separately for the data from each different country. Then we used the *qgraph* package (version 1.6.9) and the *bootnet* package (1.4.3). We used the *cor_auto* function to compute the partial correlation coefficient matrix for all countries together and each country separately. These coefficients range from –1 to 1 and encode the remaining association between two nodes after controlling for all other information possible (Epskamp & Fried, 2018). Then we used the *estimateNetwork* function to perform a ‘least absolute shrinkage and selection operator’ (LASSO) regularized estimation of the partial correlation networks. LASSO utilizes a tuning parameter to control the degree of regularization. This parameter was selected using the Extended Bayesian Information Criterion (EBIC) (Foygel & Drton, 2010) (EBICglasso in *bootnet*) with the hyperparameter $\gamma = 0.5$. We decided to create unsigned networks, treating negative correlation coefficients as relevant connections. In a second step, we used the *averageLayout* function to compute an average layout over the three different graphs of the different countries.

In order to derive graph parameters that characterize the different networks, we used the function *centrality* to derive Betweenness, Closeness, Degree Centrality and Expected Influence (Opsahl et al., 2010) and the function *clustcoef_auto* to derive the following clustering coefficients: *clustWS*, which is a clustering coefficient for unweighted

networks (Watts & Strogatz, 1998); ClustZhang which corresponds to the clustering coefficients for weighted networks (Zhang & Horvath, 2005); ClustBarrat (Barrat et al., 2004) and ClustOnnela (Onnela et al., 2005).

To estimate the accuracy of the edge weights and the stability of centrality indices (Epskamp et al., 2018) and to obtain confidence intervals we conducted a non-parametric bootstrap procedure (n = 2500), since this requires no theoretical assumptions. The stability of centrality indices tests, whether the order of centrality indices remains the same when the networks are estimated with fewer cases. This stability of the centrality indices is quantified as the correlation stability coefficient (CS) representing the maximum proportion of cases that can be dropped. Values of CS above 0.7 are usually considered to be a large effect, values below 0.25 should not be interpreted, preferable are values above 0.5. In order to identify the nodes that are most central in the graph, we

determined strength, defined as the absolute sum of weights attached to edges belonging to a node and expected influence, which is identical to the formula for node strength, except that it retains the positive or negative value of the edge weight (Robinaugh et al., 2016). Moreover, we computed the centrality measures betweenness, which is defined as the number of times a node lies on the shortest path between other nodes, and closeness, which calculates the shortest paths between all nodes, then assigns a score to each node based on its sum of shortest paths.

In order to test for differences in typicality and familiarity of the house facades across the different countries, we used linear mixed models as implemented in the *lme4* package (version 1.1.27.1) (Bates et al., 2012). P-values were derived using Satterwaite.

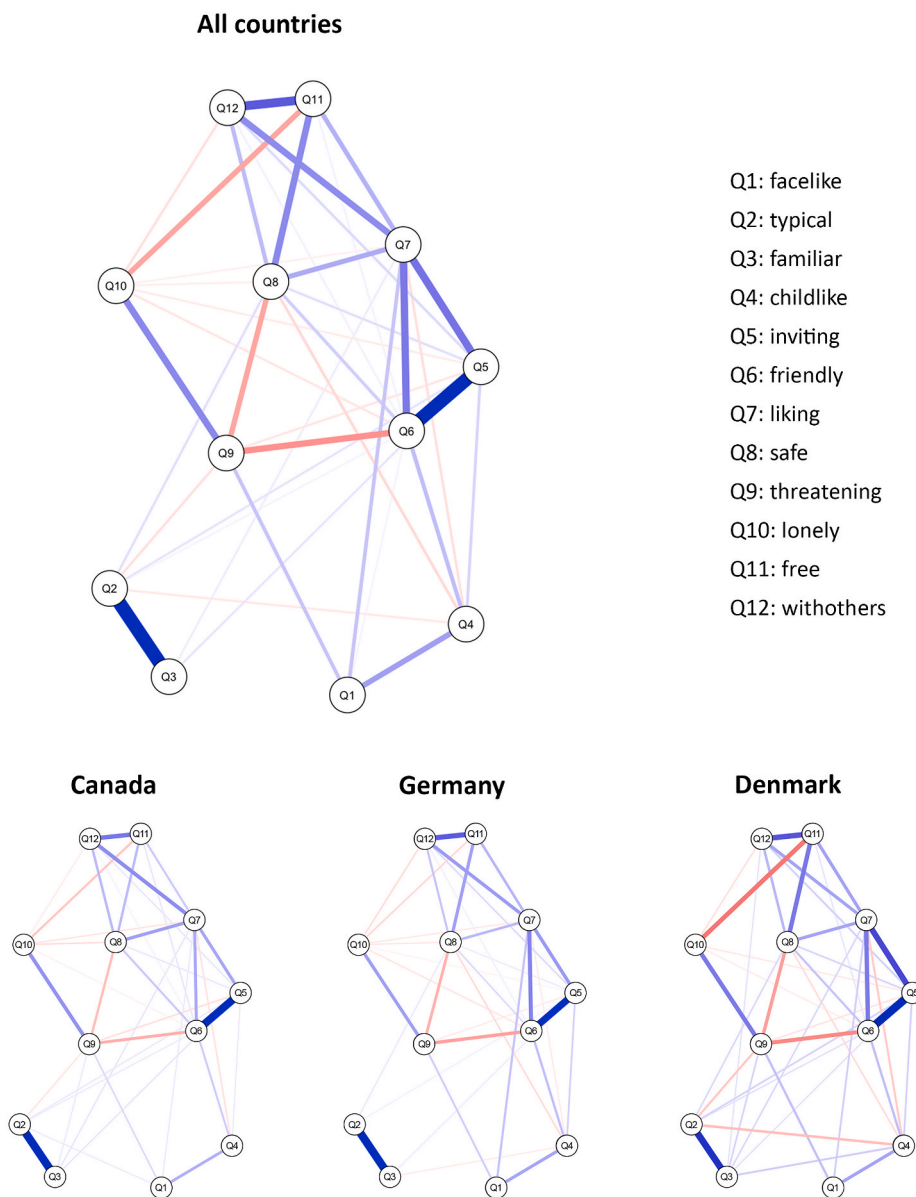


Fig. 1. Illustration of the regularized partial correlation network graph pooling the data of all three countries (left) and of the countries Canada, Germany and Denmark separately.

Note. Positive edges are blue and negative edges are red. The circles represent the nodes, the width and saturation of the lines connecting the nodes (edges), indicate stronger partial correlations of the edges. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

3. Results

Data from 305 participants from three countries were analyzed. There were no significant differences in gender across the three groups ($\chi^2(4) = 4.93, p = 0.29$). However, there was a difference in terms of age, with the population in Denmark being significantly younger than the participants recruited in Canada ($t(198) = 3.15, p = 0.002$). This was due to the fact that the participants available on Prolific in Denmark are much fewer than in Canada and Germany and younger in age. All other paired t-tests were not significant.

We computed an unsigned regularized partial correlation graph for the data pooled across the three countries and then for each country separately in Fig. 1. There was no tendency for positive or negative edges to be more strongly associated with larger weights (all countries: $t(64) = 0.42, p = 0.67$, Canada: $t(64) = 0.35, p = 0.73$, Germany: $t(64) = -0.03, p = 0.98$, Denmark: $t(64) = 0.42, p = 0.68$). The graph parameters are plotted in Fig. 2.

The CS-coefficients indicate that the parameters are fairly stable for strength (CS = 0.75), expected influence (CS = 0.75). The highest strength was seen for the nodes Q6_friendly, Q7_liking, Q5_inviting, Q8_safe and Q11_free, while typicality (Q2) and familiarity (Q3) were not particularly high in terms of strength and therefore not strongly related to the nodes highest in strength.

In order to formally test for differences between the countries, we ran linear mixed effects models controlling for age, sex, random effects of participant ID and picture number. We observed a significant effect of Denmark vs. Canada on Q2_typical ($\beta = 6.78, SE = 1.54, t(15250) = 4.39, p < 0.001$), but not of Germany vs. Canada ($\beta = 0.39, SE = 1.53, t(15250) = 0.26, p = 0.80$). In Canada, the typicality judgement of the Canadian house facades (mean = 44.89) was lower than the ratings in Denmark (mean = 48.85) and Germany (mean = 48.05). We computed the same linear mixed effects model to predict Q3_familiarity, with similar effects. However, neither Denmark vs. Canada ($\beta = 0.16, SE = 1.90, t(15250) = 0.08, p = 0.93$), nor Germany vs. Canada ($\beta = -2.29, SE = 1.89, t(15250) = -1.21, p = 0.23$) differed significantly. Descriptively, the mean ratings were highest in Germany (mean = 53.00), followed by Canada (mean = 49.94) and Denmark (mean = 45.45).

Regarding the relationship between loneliness (Q10_loneliness) and freedom (Q11_free), large differences of the correlations coefficients between the three countries were found. A highly significant difference

between correlations was found between Denmark and Germany (Denmark: $r = -0.539$; Germany: $r = -0.478$; $p < 0.001$) and Denmark and Canada (Canada: $r = -0.451$; $p < 0.001$), while no significant difference could be shown between Germany and Canada ($p = 0.17$).

The relationship between typicality and safety (Q2_typicality to Q8_safety) was tested, because there seemed to be a difference, with no edge in the Canadian sample. However, no significant differences were found between Canada and Denmark ($p = 0.22$); Canada and Germany ($p = 0.27$), and Germany and Denmark ($p = 0.48$).

4. Discussion

Our main aim was to investigate the correlative structure and relationship between psychological attributes characterizing house facades, and to identify nodes with high strength that are particularly important in the characterization of house facades. We utilized stimuli from the DalHouse study (Filliter et al., 2016) investigating facelikeness of house facades. The photos of the houses showed typical Canadian houses.

In literature that applied network analysis to the field of psychopathology (Robinaugh et al., 2016), the parameter of expected influence has been favored, instead of strength, since it considers negative and positive associations separately. However, in search of characteristics that are relevant when humans rate house facades, it is not of concern if certain nodes that are highly central are negatively associated with one another. Therefore, our focus was more strongly targeted on the strength parameter. Here, the most relevant psychological attributes characterizing facades that were identified were the triade of friendliness, liking and invitingness, that were highly positively interrelated, as well as the dimensions safety and freedom.

Surprisingly, typicality and familiarity were not particularly high in strength. Moreover, the rating dimensions highest in strength (friendliness, liking, invitingness) were quite separated from the dyade of typicality and familiarity, meaning that they (the group of the three variables friendliness, linking and invitingness) were not highly related to typicality and familiarity. Based on the previous literature on the so-called mere exposure effect (Zajonc, 1968), which describes the phenomenon that individuals tend to develop a preference for things when they are familiar with them, we would have expected a stronger connection between liking (Q7) and typicality (Q2) and familiarity (Q3).

Moreover, we would have expected that this positive appraisal for

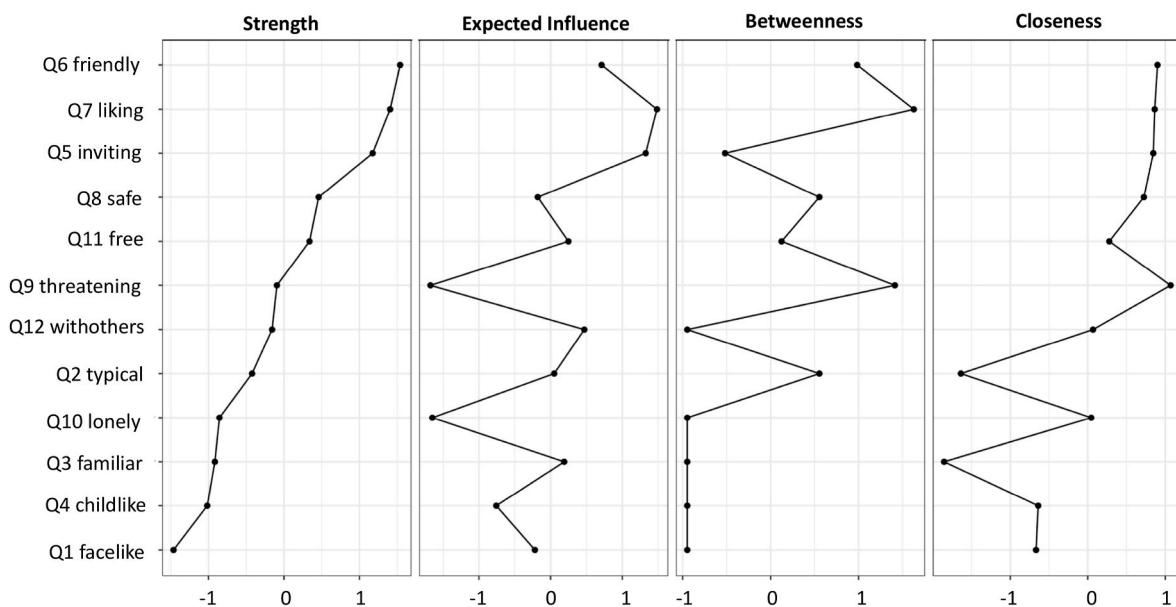


Fig. 2. Estimated graph network centrality coefficients derived from the graph “all countries” depicted in Fig. 1. Note. Variables are ordered by strength.

highly familiar facades may have been different for the different countries, where Canadian participants should overall score higher on familiarity and typicality ratings, since the facades were all photographs of Canadian houses. However, this was not the case. In fact, in Germany we observed the highest mean ratings for familiarity and in Denmark for typicality. To explain this, it might be relevant to note the similarities between the architecture styles prevalent in Nova Scotia (Canada) and those in Europe. First settlements started with the French Colonial style, and over its relatively short history of four centuries, the architecture of the vicinity was influenced by other styles emerging from Europe, after adaptation to weather conditions (Rosinski, 1994). This can be seen in the different images included in the stimulus set, which vary between old and new houses and present possibly familiar architectural features. This may have led to the observed absence of expected cultural differences in ratings of familiarity and typicality. The strong link between the nodes of typicality and familiarity comes with no surprise. The role of familiarity in determining typicality has been long proposed (Ashcraft, 1978; Malt & Smith, 1982; Schwanenflugel & Rey, 1986).

Contrary to our expectations, facelikeness (Q1) did not present itself as a central node with high strength, actually it is the node scoring lowest on network strength, not suggesting it as a relevant psychological attribute with respect to judgement of houses. And although invitingness (Q5) and friendliness (Q6) dimensions also refer to social aspects, the nodes were not strongly linked with facelikeness (Q1). This may be seen as evidence that judgements were rather made in relation to the architecture and aesthetic features of the houses than to any shared facial characteristics. However, in the present study we focused only on self-reported ratings, this does not exclude that implicit assessment methods such as eye tracking may reveal a subconscious processing of the house facades as faces (Sussman & Hollander, 2021). Nonetheless, the strong connection between both invitingness and friendliness dimensions is still interesting, as it may help to explain aspects of place attachment in a certain geographical environment (Lewicka, 2008). An interesting result, which repeated the results of the DalHouse Study (Filliter et al., 2016), was that facelikeness was not correlated with typicality nor with liking.

An interesting result were the differences observed when investigating loneliness and freedom. Modern architecture has been questioned regarding its effect on humans' loneliness (Caan, 2019), and loneliness in combination with public health has been widely discussed (Leigh-Hunt et al., 2017). Loneliness as a state of mind is often associated with poor mental health, and therefore we wanted to pose the question, if the appraisal of houses can be related to mental states as loneliness. Research has shown that housing and residential structures together with neighborhood can enhance the feeling of loneliness (Kearns et al., 2015). In Denmark, we observed a significantly stronger negative correlation between loneliness (Q10) and freedom (Q11), which might be supported by the stronger aspect of collectivism in the Danish society compared to more individualistic countries such as the US or Germany (Sivadas et al., 2008). The same argument might explain the positive relationship between typicality (Q2) and safety (Q8) in all three countries. Typicality as a recognition of a specific structure enhances the individual feeling of safety through meeting "beauty in averageness" (Vogel et al., 2021). This connection does not differ between the three countries.

5. Conclusion

To conclude, the present study aimed at characterizing potentially central aspects in the judgement of house facades and identified that the dimensions: friendliness, liking and invitingness, as well as safety and freedom seem to be of importance. Facelikeness however, although previously discussed with respect to house facades, does not seem to play a major role in explicit ratings of participants. Our findings could be useful in informing future studies assessing the psychological impact of architectural buildings, concerning the selection of useful rating

dimensions and offer a certain degree of confidence on the similarity of the interrelation between these dimensions across three, admittedly western, educated, industrialized, rich and democratic (WEIRD) (Henrich, 2020) countries. Future research may want to replicate this finding and use a more implicit assessment of facelikeness, e.g. by assessing eye tracking data, to compare eye movements during house processing with those typical eye movement patterns seen when viewing faces. The reported findings are of relevance for future studies in the field of architectural psychology aimed at investigating the perception of house facades, since they provide guidance on relevant rating dimensions to include.

Authors' contributions

KKR: Conceptualization of the study, Writing of paper SK: Conceptualization of the study, Data analysis SW: Conceptualization of the study, Data acquisition, Data analysis, Writing of paper, NT: Writing of paper.

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