Taxonomy of human social perception

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Abstract

In everyday life, humans encounter complex social situations that need to be encoded effectively to allow seamless interaction with others. Yet, principles organizing the perception of social features from the external world remain poorly characterised. We presented 234 movie clips containing various social situations to 1140 participants and asked them to evaluate the presence of 138 social features in each movie clip. We first addressed how social features perceived as binary (present or absent) or continuously (intensity) and how consistently people perceive them. This analysis revealed that some social features were perceived as binary while others on a continuous scale. Simple and immediately relevant social features were perceived most consistently across participants. To establish the low-dimensional perceptual organization for social features, we used principal coordinate analysis and consensus hierarchical clustering for the full dataset of social feature ratings. Dimension reduction using principal coordinate analysis showed that the social perceptual space can be represented with eight main dimensions while hierarchical clustering showed that social perception organizes hierarchically from the main dimensions. The results generalized across different datasets with different stimuli and participants. Altogether the results establish the taxonomy of human social perception, suggesting that emotional

valence, dominance, and cognitive versus impulsive functioning are the most fundamental dimensions in social perception.

Introduction

Social interaction is central to humans. We live in complex social systems (Tomasello, 2014) and both cooperation and social competition require perception, interpretation, and prediction of other people's actions, goals, and motives. Accordingly, social signals are granted priority in the attention circuits, and a large bulk of data show, for example, that human faces and bodies are rapidly noticed and prioritized in naturalistic scenes (Fletcher-Watson et al., 2008; Ro et al., 2007) underlining the importance of social information perception for the human species.

However, social perception is much more complex than just encoding isolated social features such as faces or bodies (Adolphs et al., 2016). Humans are capable of, for example, perceiving multiple simultaneously occurring social features unfolding in distinct temporal time scales, ranging from other people's identities, intentions and actions to the subtle affective characteristics of social interaction and hierarchy in social groups. Given the computational limits of the human brain and the requirement for fast and flexible responses in social interaction, it is unlikely that all possible social features in the current situation could be perceived and interpreted independently all the time (Freeman et al., 2012).

For other cognitive processes, such as predicting where a baseball will land, people use heuristics to make accurate and fast judgements without the need of complex computations (Gigerenzer & Brighton, 2009). Hence, the social perceptual system could use similar heuristics for rapidly extracting the main dimensions of the social situation based on the associations between the perceived social features which is also proposed by the social judgement theory (Wiltshire et al., 2014). These associations could be non-deliberative assessments of social features (e.g. seeing a shouting person, indicating that someone is angry or in distress) that help the perceiver to make fast inferences with minimal processing effort. Face perception studies suggest that emotional valence and dominance are the main dimensions perceived from facial characteristics (Oosterhof & Todorov, 2008) and the recognition of (social) characteristics from faces follow coarse-to-fine temporal hierarchy (Besson et al., 2017; Dobs et al., 2019) but a more detailed organization of social perception has yet to be resolved.

Although social perception involves encoding the interaction between the situation, people and actions, social psychology has studied the perception of these domains mainly separately. Extensive research has established taxonomies for related phenomena including emotions (Elfenbein & Ambady, 2002; Russell et al., 1989), personality characteristics and person perception (Abele & Wojciszke, 2014; Fiske, 2018; Goldberg, 1990; Lee & Ashton, 2004; McCrae & Costa, 1987; Simms, 2007), human values (Schwartz et al., 2012) or goals (Wilkowski et al., 2020) social situations (Parrigon et al., 2017; Rauthmann et al., 2014) and action understanding (Thornton & Tamir, 2022). Although these taxonomies describe distinct social and psychological phenomena, many of them are interlinked and overlapping (Horstmann et al., 2021; Wilkowski et al., 2020). The separation of person, situation and behavior in social interaction has been considered an outdated approach (Funder, 2006) and instead the organization of social perception would likely relate to multiple factors established for these phenomena. Indeed, using neuroimaging we previously showed that large-scale brain networks encode a limited number of primary socially relevant dimensions from the sensory input consistently across individuals (Santavirta et al., 2023), but a robust behavioral taxonomy for social perception is currently lacking.

Additionally, individual variation and the discrete versus continuous coding of specific features remain poorly characterized. For example, colour perception (Emery & Webster, 2019) susceptibility for visual illusions (Carbon, 2014) and facial expression recognition accuracy (Calvo & Nummenmaa, 2016) all vary substantially across individuals. Still, between-subjects consistency in the perception of different social features remains unknown. Finally, it remains unclear what kind of implicit coding scheme people use for evaluating the presence of different social features. For some social features, only the presence of the feature may be important to notice, but for other social features also the intensity may be relevant. Thus, the perceptual system may process some social features as binary (e.g. someone is talking or not) or continuous (e.g. how trustworthy someone is).

The current study

Here we investigated which kind of heuristic coding system humans use for unpacking social information in the audio-visual domain. We defined social perception broadly as the perception of all information extracted from other people that is potentially useful when interacting with them. We used large-scale online survey data where subjects (N = 1140) viewed short movie clips (N = 234) with varying social content. Subjects were asked to evaluate the prominence of a large set (N = 138) of different social features in the videos. We then analysed i) how people perceive and evaluate different social features, ii) whether the total set of social features can be reduced to a limited set of important and significant social dimensions using dimension reduction techniques and iii) tested whether the identified dimensionality in social perception generalize to an independent dataset. The results indicated that social perception follows theoretically meaningful main dimensions, the between-participant consistency of perception varies between different social features and social features are perceived either binary (present or absent) or continuously (intensity).

Results

Distributions of social feature ratings

Figure 1 shows the distributions of population average ratings for all studied social features. Features “Coughing/sneezing” and “Vomiting/urinating/defecating” were excluded from the analyses because they were perceived present in less than 5% of the movie clips. Based on both the bimodality coefficient and the Hartigan’s dip test (**Figure SI-1**), the following features expressed bimodality: talking, sitting, standing, making gaze contact, alone, feeling pain, feeling calm, and feminine. Additionally, bimodal coefficient favoured bimodality for other features also suggested by the visual representation of the features in **Figure 1** (e.g. masculine, laying down, jumping, nude, sexual, kissing/hugging/cuddling, romantic, flirtative, touching someone, joking, laughing, eating/drinking, hungry/thirsty, tasting something, crying, yelling, hitting/hurting someone and physically aggressive, verbally aggressive).

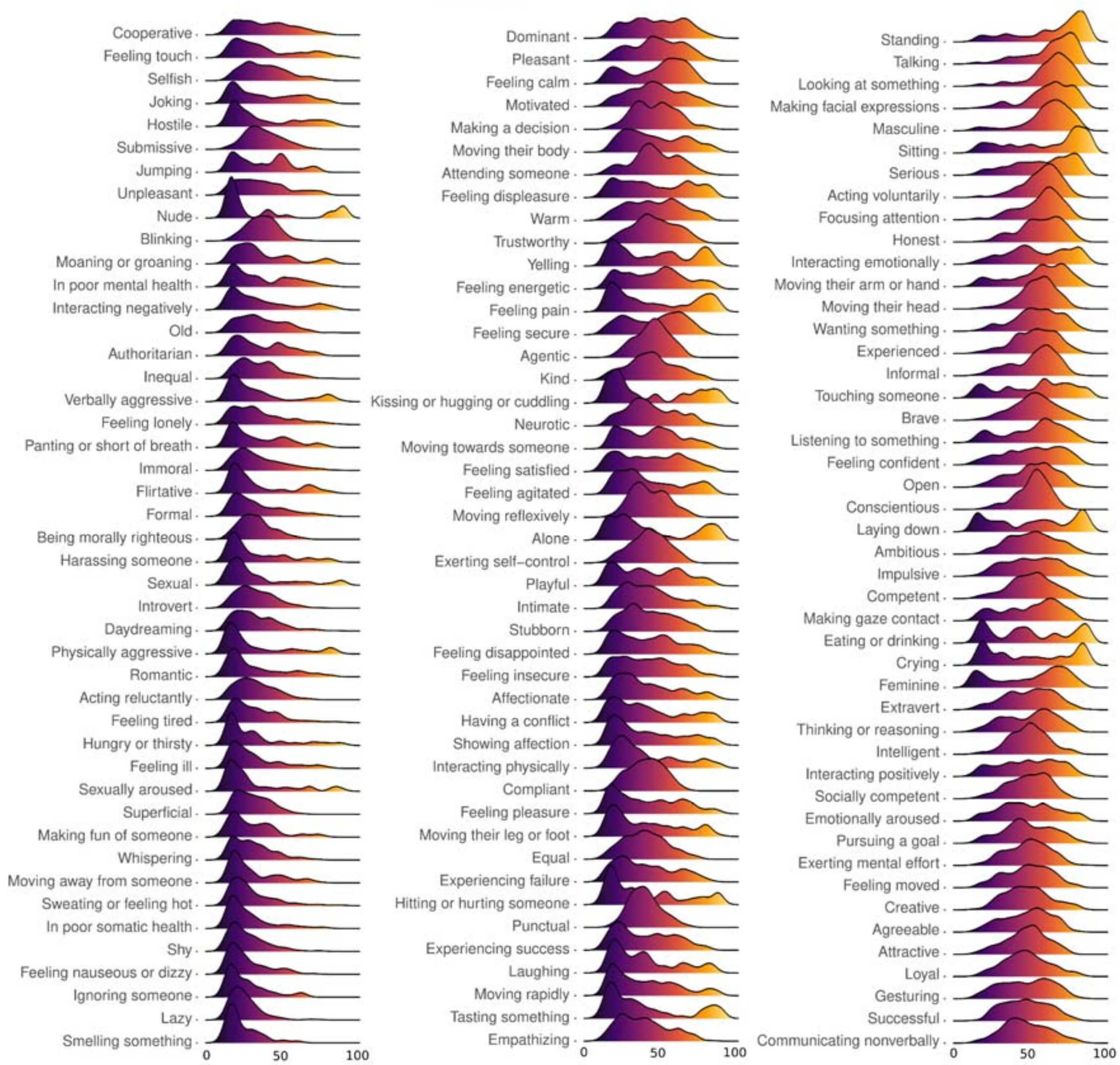

Figure 1. Distributions of the social feature ratings. The density plots visualise the estimated population level rating distributions for each feature (the rating from 0-100 in x-axis). Ratings under 5 (feature was not present) are not plotted for representative visualisation. The features are ordered based on the average intensity of the population level ratings.

Between-subject reliability and occurrence rate of social feature ratings

Figure 2 visualises the feature-specific between-subject ICC:s, occurrence rates and bimodality scores ICC:s of the ratings varied considerably between different social features (range: 0.08 - 0.75). ICC:s over 0.0, 0.2, 0.4 and 0.6 were considered to indicate poor, low, moderate and good between-subject reliability of the feature ratings, respectively. Features with good reliability (ICC > 0.6) related to concrete actions and interaction signals (e.g. sitting, eating, yelling, laughing, crying) and they were also perceived as binary (present or absent; **Figure 2)**. Features with poor reliability (ICC < 0.2) mostly described subtle person-related characteristics (e.g. introvert, conscientious, compliant, exerting self-control). Overall ICC:s showed a decreasing gradient from actions perceived in categorical manner (e.g. standing, hitting or hurting someone), physical characteristics (e.g. feminine, masculine) and emotions (e.g. feeling pleasure, feeling satisfied, feeling pain) towards subtle characteristics related to personality and qualities of the social interaction (e.g. lazy, shy, superficial, informal, equal). The population average ratings calculated over the sample of 10 participants were, however, considered reliable for all social features (ICC:s for average measures varied between 0.85 and 0.99) indicating that the average ratings were stable.

The mean occurrence rate for the analysed 136 features was 79% (range: 12% - 100%, **Figure 2**). Features with the lowest occurrence rate (occ < 20%) were rarely occurring binary features: nude, jumping, hitting or hurting someone, kissing or hugging, eating or drinking and laying down. While the occurrence rate was high for most of the social features, the rating intensities still varied between the movie clips indicating that stimuli presented variable social content to the participants (**Figure SI-2**).

Interdependence between perceived frequency, between-subject reliability, and bimodality of the social features

Occurrence rates and ICC:s correlated negatively ($r = -0.63$, $p < 0.001$), occurrence rates and bimodality coefficients correlated negatively ($r = -0.89$, $p < 0.001$) and ICC:s correlated positively with bimodality coefficients ($r = 0.84$, $p < 0.001$) indicating strong associations between the measures. Less frequently present features were perceived with higher between-subject reliability than frequently present features. Categorically perceived features (BC > 0.555) were consistently perceived either absent or present while the continuously perceived features were less frequently completely absent. Finally, categorically perceived features were evaluated with higher between-subject reliability than the continuously perceived features. Feature specific results for all outcome measures can be found from **Table SI-1**.

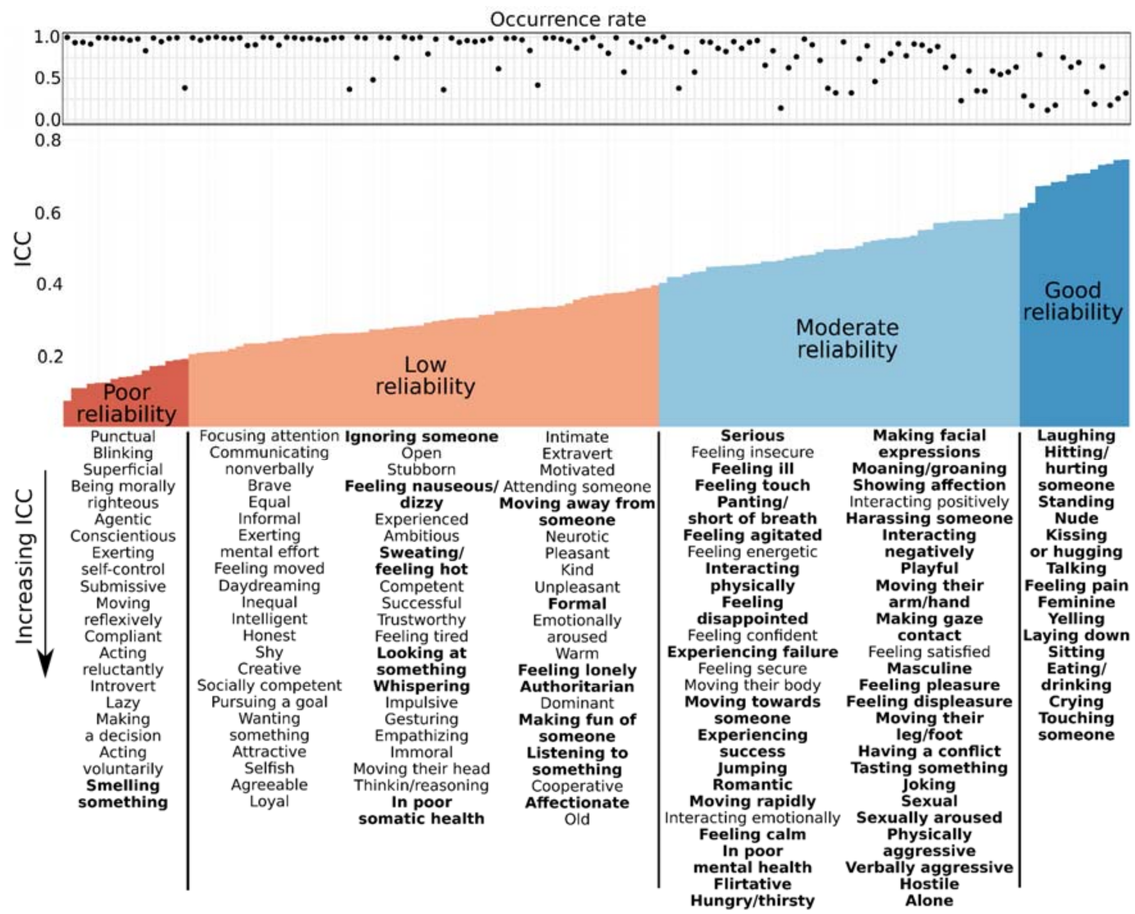

Figure 2. Feature occurrence rate, between-subject reliability, and bimodality. Pointplot visualises the occurrence rates (proportion of the movie clips) and barplots show the ICC:s of the social feature ratings. The features below the plot are listed from the lowest (Punctual) to the highest (Touching someone) ICC. Binary perceived social features are bolded (BC >

0.555).

Dimensional structure of social perception

Principal coordinate analysis revealed that social perceptual space can be reduced to eight statistically significant principal components ($p < 10^{-7}$, **Figure 3**). First three principal components (PCs) explained 55% and all eight PCs 78% of the total variance. PC1 (Pleasant - Unpleasant) ordered features based on their emotional valence from pleasant features “Pleasant”, ”Interacting positively” and “Feeling calm” to unpleasant ones “Feeling displeasure”, “Feeling disappointed” and “Feeling pain”. PC2 (Submission - Dominance) related to the perceived dominance structure of the social interaction from dominant features “Dominance”, “Authority” and “Stubborn” to affectionate and submissive characteristics “Intimate”, “Affectionate” and “Crying”. PC3 (Impulsive - Cognitive) ordered features from impulsive behaviour, physical interaction, sexuality and sympathetic activity (e.g. “Interacting physically”, “Nude”, “Feeling energetic”) to higher cognitive functions and controlled behaviour (e.g. “Thinking or reasoning”, “Formal” and “Intelligent”). PC4 (Careless - Conscientious) axis organized social perception from careless and relaxed behaviour and feeding (e.g. “Lazy”, “Superficial”, “Daydreaming”, “Eating something”, “Hungry / thirsty”) to conscientiousness (e.g. “Conscientious”, “Loyal” and “Brave”). PC5 (Introversion - Extraversion) related to the distinction between introversion (e.g. “Alone”, ”Pursuing a goal” and “Introvert”) and extraversion (e.g. “Talking”, “Making gaze contact” and “Extravert”). PC6 (Playfulness - Sexuality) described social contacts with regard to their affiliative (e.g. “Joking” and “Laughing”) versus sexual nature (e.g. “Sexual”, “Sexually aroused” and “Nude”). PC7 (Alone - With others) related to the number of people in the scene and PC8 (Femininity - Masculinity) described feminine and masculine characteristics. Beyond eight PCs, no component explained more variance than would be expected by chance even with a lenient thresholding ($p < 0.05$).

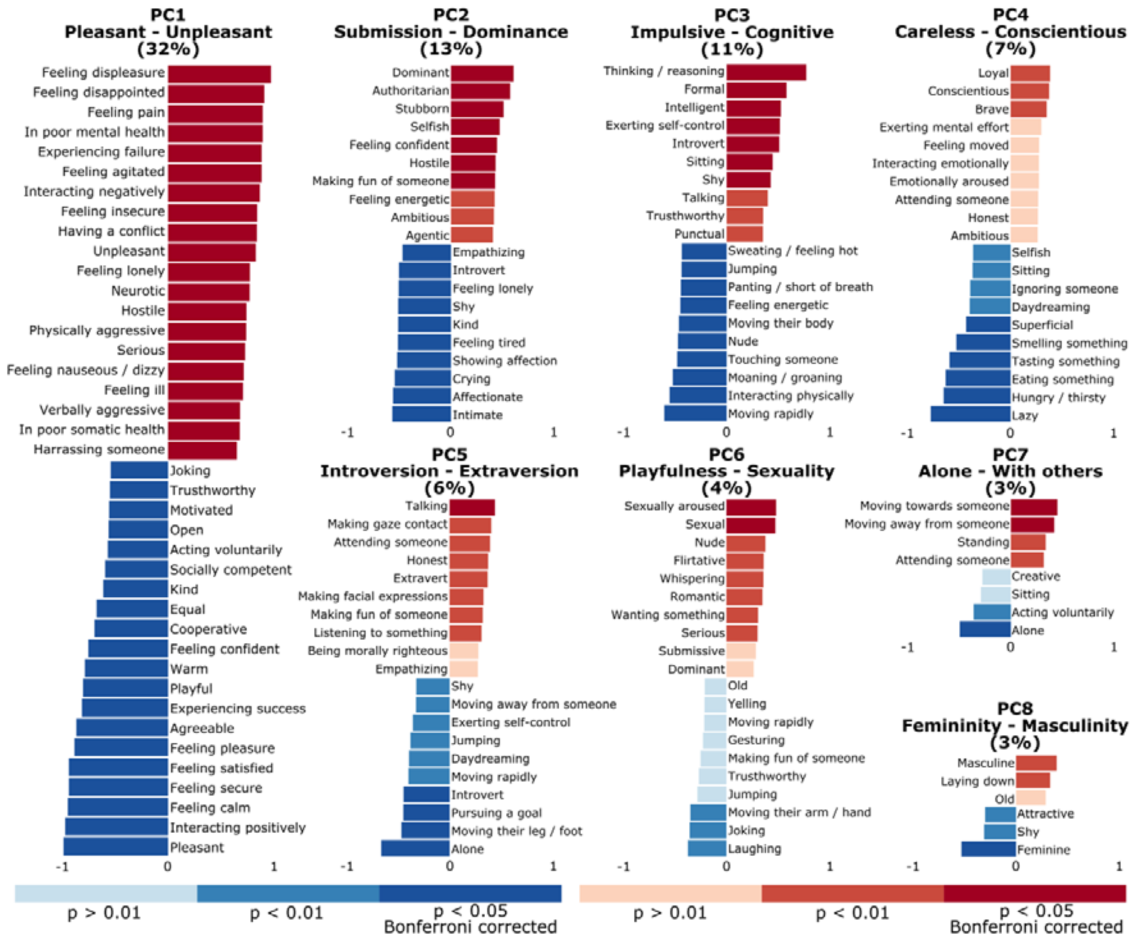

Figure 3. Results from the principal coordinate analysis. First eight principal components were statistically significant ($p < 10^{-7}$). Barplots visualise the strongest loadings (correlations between the PC and the original features) for social features for each PCs. The names for the PCs describe the underlying perceptual social dimensions. Explained variance for each PC is shown in parentheses and the statistical significance thresholds for feature loadings are displayed with colour gradient.

Organization of social perception based on hierarchical clustering analysis

Results for the consensus hierarchical clustering are shown in **Figure 4**. The results confirmed that social perception is organized around the perceived emotional valence (negative correlation between pleasant and unpleasant features). However, consensus clustering further grouped emotionally valenced features into finer-grained subclusters.

Pleasant features formed three clusters (Prosociality & pleasant feelings, Affection and Extraversion & playfulness) and unpleasant features two clusters (Antisociality and Unpleasant feelings). Introversion formed one cluster and together with the cluster relating to Extraversion & playfulness they established introversion - extraversion as a similar core social dimension as in the principal coordinate analysis. Feeding and Sexuality formed separate clusters, and communication-related features were clustered together into several clusters (Verbal communication, Nonverbal communication, Gesturing and Physical interaction). Masculine and feminine characteristics formed independent clusters, and features related to self-control, decision making, and achievement formed three related clusters (Self-control, Goal oriented behaviour and Achievement) describing characteristics often attributed to high-achieving individuals.

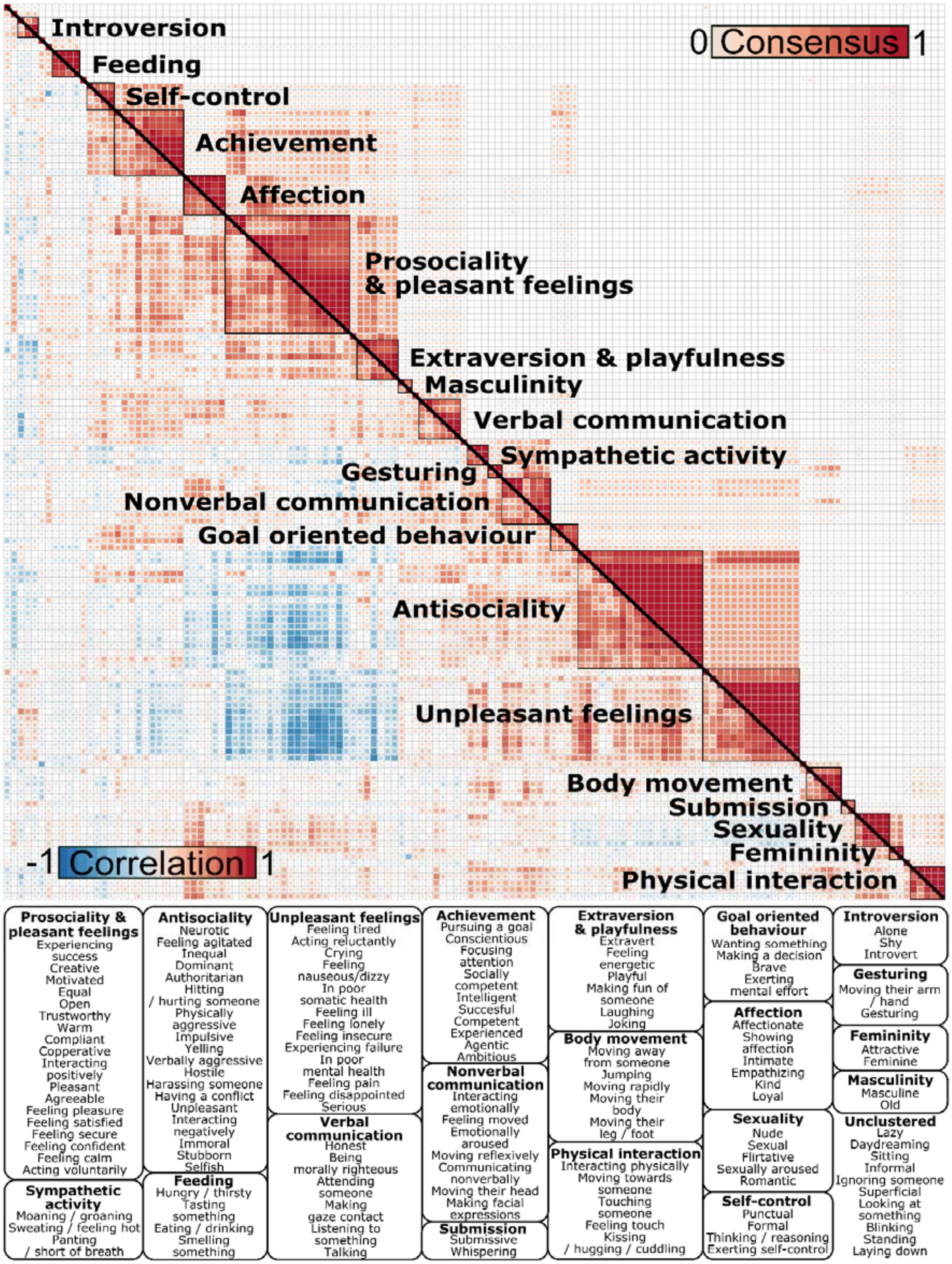

Figure 4. Results from the hierarchical clustering analysis. The lower triangle shows the correlation matrix of social features while the upper triangle shows the consensus matrix of

the features from the consensus clustering analysis. A consensus matrix visualises how many times (out of all subsamples) each pair of features were clustered together. Labels for the clusters were defined based on the included features.

Concordance between the PCoA and HC solutions

PCoA and HC revealed generally similar organization for social perceptual features, but the results were not identical due to different analytical approaches. For example, HC found semantically distinct clusters within emotionally valenced features while PCoA revealed the main dimension from unpleasant to pleasant features. The t-SNE visualisation suggested that the two alternative analysis approaches have structural relationship since HC clusters formed clearly separable groups in this t-SNE space (**Figure 5**). HC clusters would have been unidentifiable in the t-SNE of PCoA feature loadings if there was no structural relationship between the solutions from the two methods.

To further investigate the relationship between individual HC clusters and PCoA dimensions we obtained average PC loadings for each HC cluster (**Figure SI-3**). Some HC clusters loaded mainly on one corresponding main dimension in the PCoA solution, indicating that these perceptual dimensions were similarly captured by both analysis methods. The cluster Prosociality & pleasant feelings was based on features that loaded as pleasant in PC1 (Pleasant - Unpleasant), Unpleasant feelings from unpleasant features in PC1, Self-control from cognitive features in PC3 (Impulsive - Cognitive) and Feeding from the eating related features that loaded as careless in PC4 (Careless - Conscientious). Clusters Femininity and Masculinity loaded significantly on the opposite ends of PC8 (Femininity - Masculinity). Overall, these results support that pleasantness, cognitive functioning, feeding and femininity-masculinity are perceptual main dimensions captured similarly by the alternative analysis methods.

HC did not find an independent cluster for dominant characteristics even though dominance was considered the second main dimension in PCoA. However, the concordance analysis revealed that pleasant and unpleasant characteristics formed semantically distinct clusters based on the perceived dominance structure supporting the existence of dominance as a perceptual dimension. Features in the cluster Antisociality loaded as unpleasant (PC1) and dominant (PC2) distinguishing antisocial behaviours from unpleasant feelings (unpleasant but not dominant characteristics). Similarly, features in the cluster Affection loaded as pleasant (PC1) and affective/submissive (PC2) while features in the cluster Extraversion & playfulness loaded as pleasant (PC1) and dominant (PC2) distinguishing these pleasantly perceived characteristics from the solely pleasant features in the cluster Prosociality & pleasant feelings (**Figure SI-3**). HC clusters also supported that introversion, extraversion and sexuality are perceptual dimensions, but HC clustering added more fine-grained social context for these dimensions. The features in the cluster Introversion cluster as introvert (PC5) but also submissive (PC2), cognitive (PC3) and careless (PC4) while the features in the cluster Extraversion & playfulness loaded as extrovert (PC5) but also pleasant (PC1), dominant (PC2), impulsive (PC3) and playful (PC6). Features in the sexuality cluster loaded as sexual (PC6), pleasant (PC1), affective (PC2) and impulsive (PC3).

While most of the HC clusters followed semantically the main dimensions from PCoA, HC also identified clusters for different communication types (clusters Verbal and Nonverbal communication, Gesturing and Physical interaction), body movement, achievement and goal-oriented behaviour. These clusters combined information from multiple main dimensions and had semantically distinct meaning not related to any main dimensions suggesting that semantically independent social clusters can be perceived as complex associations from multiple main perceptual dimensions. See supplementary media for 3D visualizations of the social perceptual space based on PCoA loadings and HC clusters (https://github.com/santavis/taxonomy-of-human-social-perception/).

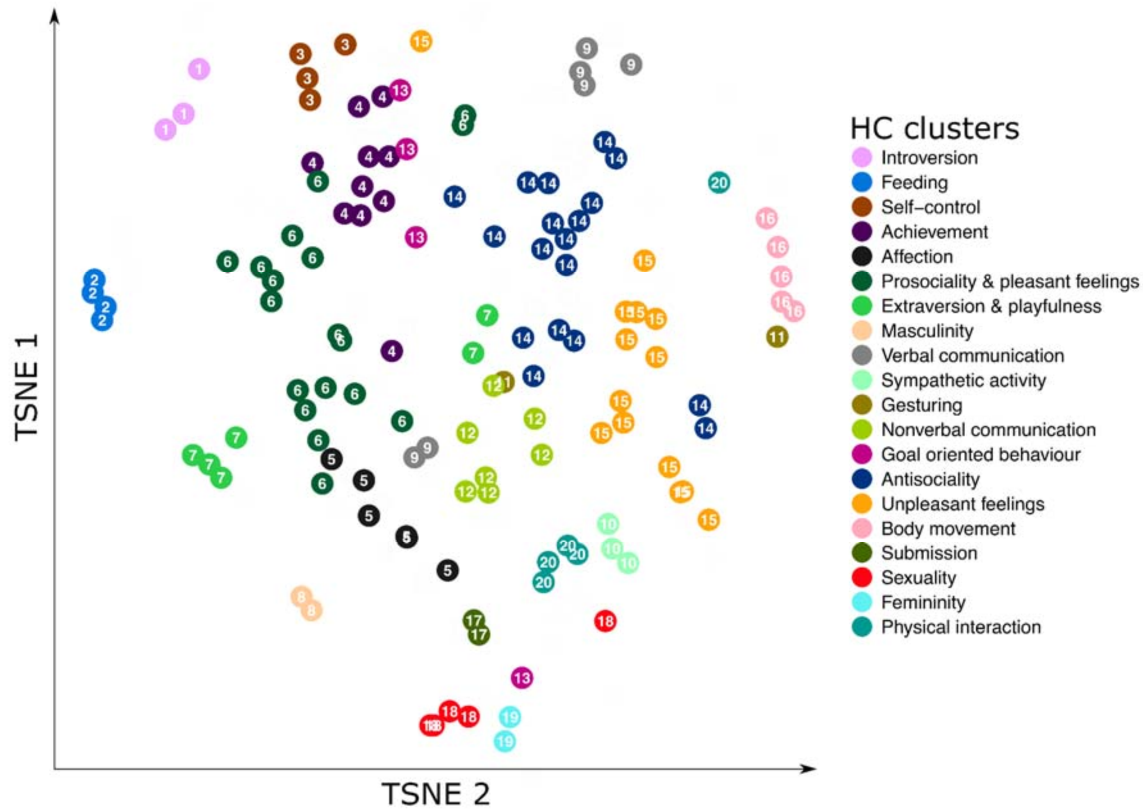

Figure 5. Relationship between HC and PCoA organizations for social perception. The t-SNE projection visualises candidate social features in 2D space based on their PCoA loadings for the eight significant main dimensions from PCoA. The colour and number of the social feature (point in the 2D space) mark which cluster the social feature was assigned to in the HC analysis. The visualisation shows that the HC clusters were well separated from each other based on the social feature loadings of the main dimensions in PCoA.

Generalizability of the structure of social perception

To test for the generalizability of the observed structure for social perception, we conducted PCoA and HC analyses for an independent dataset where a full-length movie was used as stimulus. Both PCoA and HC analyses showed statistically significant generalization between the datasets **(Figure 6).** Permutation tests for the PCoA analyses showed that the movie clip dataset with 76 social features (features common to both datasets) could be described with seven PCs and the full movie dataset with ten PCs (PCs with $p < 0.05$). **Figure 6a** shows the statistically significant correlations of the PC feature loadings between the two datasets. Each PC in the primary movie clip dataset showed significant correlation with a corresponding PC in the validation full movie dataset indicating that the corresponding PCs shared similar information. For HC analysis a representative number of clusters was addressed independently for both datasets (**Figure-SI4**). Based on the Mantel test for similarity of two independent matrices the covariance structure between social features was highly similar across the datasets (Correlation matrices: $r = 0.73$, $p < 10^{-7}$, Consensus matrices: $r = 0.63$, $p < 10^{-7}$, **Figure 6b**).

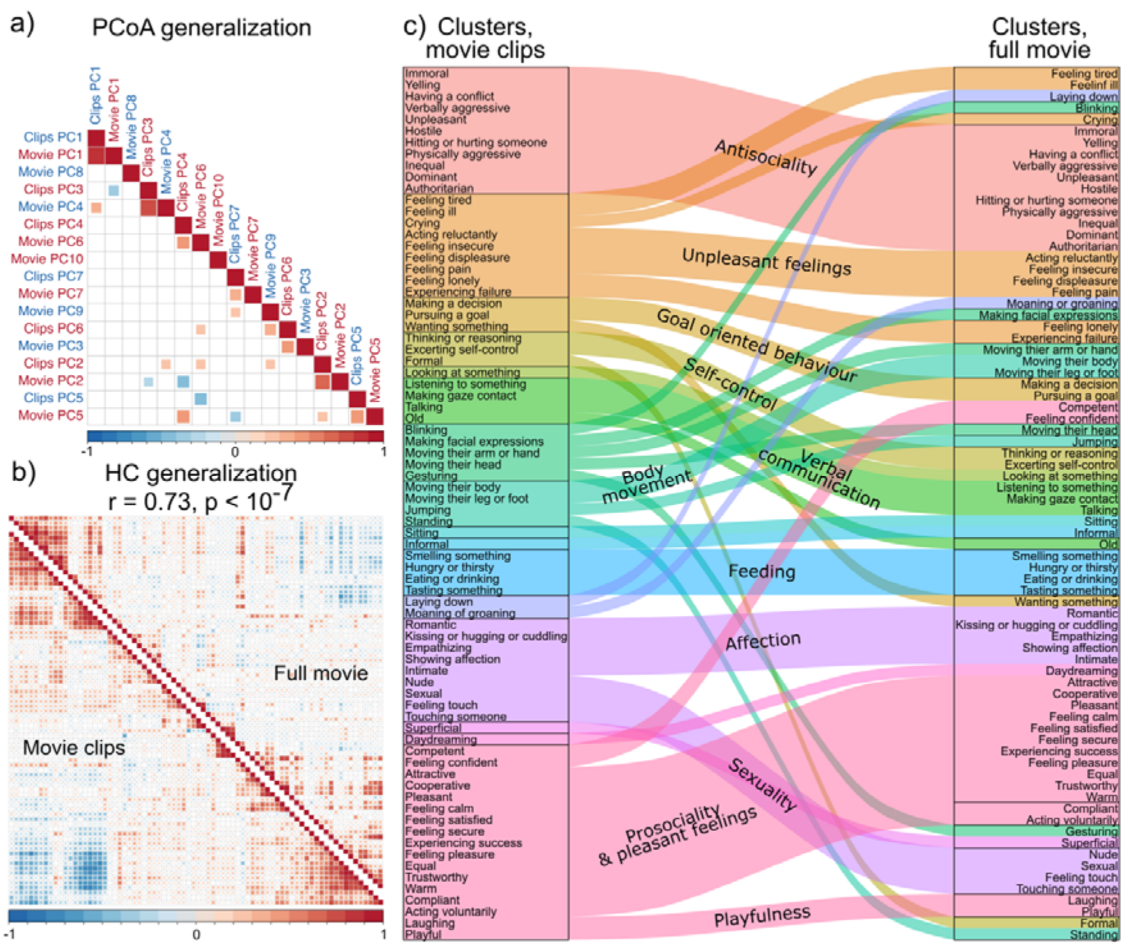

Figure 6. Generalizability of social perception across datasets. a) Correlations between the PC feature loadings from independent datasets. Only statistically significant ($p < 0.05$)

correlations are shown. b) Hierarchically ordered correlation matrices from HC analysis. The clustering result showed statistically significant ($p < 10^{-7}$) correlation between independent datasets. c) The alluvial diagram shows the similarities and differences of the clustering results from the independent datasets in detail. The order and grouping of the individual features follow the clustering results obtained independently for both datasets.

Discussion

Our data revealed the currently most detailed taxonomy of human social perception. Different social features were perceived with varying consistency between people, and social features with highest between-subject consistency were perceived as binary (present or absent) while features with low consistency as continuous (intensity). Dimension reduction techniques revealed that the social perceptual world can be described using eight main dimensions: Pleasant - Unpleasant, Submission - Dominance, Impulsive - Cognitive, Careless - Conscientious, Introversion - Extraversion, Playfulness - Sexuality, Alone - With others and Femininity - Masculinity. Complementary clustering analysis supported the existence of these main dimensions but also revealed semantically distinct higher-level social perceptual clusters. This taxonomy of social perception generalized between two datasets with different stimuli and observers indicating that the organization was not dataset dependent. Altogether the results establish how social perception is organized around the potential benefits, harms, and predictability of the social interaction, and how processing of the most critical features is facilitated by categorical rather than continuous perception.

Is social perception binary or continuous?

We collected the perceptual ratings on a continuous VAS scale to enable analysis of the rating distribution shapes (**Figure 1**). This revealed that the distributions of some social features are perceived categorically either present or absent (**Figure 2**). Presence of simple interaction signals (e.g. talking, making gaze contact, touching someone, crying, yelling, laughing), feelings (e.g. feeling pain, feeling calm), pair-bonding and features related to sexual behaviour (e.g. nude, sexual, kissing/hugging/cuddling, romantic, flirtative) and femininity and masculinity were typically perceived categorically. This does not mean that people cannot perceive or distinguish, for example, different intensities of feeling pain or varying degrees of femininity, but instead, on most occasions the detection (present-absent) of these features is sufficient for guiding subsequent actions in the situation. Categorical perception has been previously established in numerous perceptual domains (Goldstone, 1994). People perceive colours as discrete even though people can perceive continuous changes in the colour spectrum (Pilling et al., 2003) and the perception of facial expressions is categorical even though the physical changes of the facial appearance between stereotypical facial expressions are continuous (Fugate, 2013; Sauter et al., 2011). Our results thus suggest that perception for social features which carry important social information that may require rapid responses based simply on their absence or presence (such as crying, laughing, feeling pain and features describing sexual behaviour) is initially resolved by categorial perception despite intensity information being present in the scene.

The consistency of social perception across observers

The between-subject consistency of the ratings (measured with ICC) revealed a decreasing gradient from high agreement in simple actions (e.g. talking, standing, eating), external person characteristics (e.g. nude, feminine), and intense feelings (e.g. feeling pain, feeling pleasure), towards low agreement in subtle person and interaction characteristics (e.g. punctual, being morally righteous, superficial) (**Figure 2**). Features with high agreement were typically dependent on the perception of simple audio-visual features (e. g. hearing voice and seeing person’s lips moving means that the person is talking). The features with high immediate relevance such as emotional scenes may also capture attention similarly across individuals (Lauri Nummenmaa et al., 2006) and are hence perceived with higher agreement than features with low relevance. In line with this, emotionally charged features (e.g. crying, laughing, feeling pain, feeling (dis-)pleasure, sexual) also showed high consistency.

Conversely, the features with low agreement were characterised by the need for multiple perceptual inputs and more holistic processing of the social scene (e.g. evaluating the morality of someone's actions). It is also possible that the judgment of features with low agreement is largely influenced by top-down signals and perceptual information has low or mixed effect in the inference (e.g. perceivers disagree with the semantic meaning of the social feature), or that perceivers may need to accumulate information for a longer period of time to evaluate the features, leading to larger variability particularly in the experimental conditions with short stimulus displays. These explanations are however mutually exclusive and, yet categorically perceived features were perceived with the highest consistency between participants suggesting that the simplicity of the perceived feature drives the perceptual consistency.

Taxonomy of human social perception

The present results revealed the currently most comprehensive model of the organization of social perceptual features in humans. Previous studies have established taxonomies in related psychological domains such as emotions, person perception, human values and goal, social situations and social actions (Goldberg, 1990; Lee & Ashton, 2004; McCrae & Costa, 1987; Parrigon et al., 2017; Rauthmann et al., 2014; Schwartz et al., 2012; Thornton & Tamir, 2022; Wilkowski et al., 2020), but none of these taxonomies describe the complex and dynamic perception of the social in real life. Instead, person perception studies have usually investigated self- or peer-reports of personality traits and other studies have used self-reported recollections of social situations or judgments of semantic similarities of words describing social attributes. Studies mapping the emotional dimensions of social perception in turn have typically used static pictures or brief videos of facial expression to study emotion recognition. Our results, in turn, are based on perception of dynamic and audio-visual life-like social situations in movies, thus reflecting how social perception unfolds during natural perception.

Principal coordinate analysis revealed that eight orthogonal components were sufficient for describing the organization of the social perceptual space (**Figure 3**). The first three main dimensions describing pleasantness, dominance and cognitive functioning already explained 55 % and eight main dimensions altogether explained 78% of the total variation in the correlation structure between the social features. The first PC (Pleasant - Unpleasant) explained 32% of the variation and related closely to emotional valence from major emotion theories (Russell et al., 1989) but also links with agreeableness structure in personality theory (Goldberg, 1990; McCrae & Costa, 1987). Positive-negative dimension is also included in various taxonomies for social situations. For example, positivity (Situation is potentially enjoyable) and negativity (Situation is potentially anxiety inducing) were identified in the eight dimensional DIAMONDS taxonomy (Rauthmann et al., 2014) and positive and negative valence were identified in the seven dimensional CAPTIONS taxonomy (Parrigon et al., 2017).

The second PC (Submission - Dominance) explained 13% of the variation and was related to the social hierarchy between people. Dominance is an evolutionary social strategy for maintaining social rank (Maner, 2017) and is considered a basic motivation for humans (Schwartz et al., 2012). The two most important social perceptual dimensions, valence and dominance, are previously found to be the basic evaluative dimensions for faces (Morrison et al., 2017; Oosterhof & Todorov, 2008) generalizing across cultures (Jones et al., 2021). These dimensions are also evaluated from body shapes (Hu et al., 2018; Morrison et al., 2017; Tzschaschel et al., 2022) and even people's voices (McAleer et al., 2014). Accordingly, our data show that valence and dominance consist of the rudimentary social evaluative dimensions across a broad range of social situations and contexts: Positively valenced situations promote cooperation, while negative valence would indicate threat or harm promoting avoidance or defensive behaviours. Dominance in turn informs the people about the social hierarchy and relates with social competition, thus encoding the dominance dimension is critical for avoiding conflicts with higher-ranking dominant individuals but also for forming coalitions against the dominant ones.

The third PC (Impulsive - Cognitive) characterized social perceptual features from impulsive to cognitive functioning. The dual-process theory of higher cognition divides cognitive processes into intuitive, automatic, effortless, fast and stimulus driven processes (Type 1) and slow, analytical, reflective, controlled and cognitively demanding processes (Type 2) (Evans & Stanovich, 2013). In situations requiring fast actions, impulsive reactions can be advantageous while complex choices benefit from controlled analytic processing. Therefore, perceiving the cognitive processing types of conspecies is vital for understanding and predicting the actions of others and thus enables people to tune their own actions accordingly. PC4 (Careless – Conscientious) and PC5 (Introversion – Extraversion) closely resemble the corresponding dimensions (conscientiousness and extraversion) in the Big Five and HEXACO personality theories (Goldberg, 1990; Lee & Ashton, 2004; McCrae & Costa, 1987) indicating that established dimensions in personality traits are also routinely perceived from people in dynamic social situations.

Perception of feeding was included in the careless and relaxed characteristics in PC4. Eating is a basic need and shared meals are important for promoting social bonds (Jaeggi & Van Schaik, 2011) and therefore it is beneficial to perceive the possibility to eat and feed with others. PC six (Playfulness - Sexuality) described playful / friendly characteristics versus sexuality / mating related features. Perceiving playfulness could help people to evaluate whether to form friendships with others. Humour is a tool to make other people laugh and social laughter enhances social bonding highlighting the importance laughter and playfulness for social bonding and forming non-reproductive alliances (Dunbar, 2012; Manninen et al., 2017). In contrast, perception of sexual features help to evaluate a mating partner. Playfulness and sexuality were opposite ends of a single dimension, suggesting evaluative distinctions between friends and romantic/sexual partners. The seventh PC (Alone - With others) simply described whether the situation involved other people or not and the eighth PC (Femininity - Masculinity) pertained to the (fe-)maleness of the individuals in the scenes. This accords with face perception showing that femininity-masculinity is a stable perceptual dimension (Little & Hancock, 2002; O'Toole et al., 1998) and traditionally femininity and masculinity have been treated as a single bipolar dimension describing the (fe-)maleness as a set of characteristics used to evaluate possible mates (Little et al., 2011; Mitteroecker et al., 2015).

Concordance analysis of PCoA main dimensions and HC clusters

PCoA revealed that eight basic perceptual dimensions are sufficient for explaining the social perceptual world. Hierarchical clustering analysis showed high concordance with the PCoA organization for social perception (**Figure 4 & 5**). The analysis revealed clusters that closely resemble the main dimensions in PCoA supporting that people perceive pleasantness, dominance, cognitive functioning, feeding, sexuality, playfulness, introversion-extraversion and femininity-masculinity from life-like social scenes.

In addition to the aforementioned clusters, HC analysis revealed fine-tuned clusters that combined perceived information from multiple main dimensions (**Figure SI-3**). For example, features in the cluster Unpleasant feelings could be explained with a combination of dimensions related to unpleasantness and submission in the PCoA analysis. Conversely, features in the cluster Antisociality could be explained with a combination of dimensions related to unpleasantness and dominance. Similar fine-tuning for pleasant features were identified based on their dominance structures: Prosociality and pleasant feelings (solely pleasant), Affection (pleasant + no competition) and Extraversion & playfulness (pleasant + competition). Thus, both pleasant and unpleasant features formed clusters with distinct dominance structures highlighting the joint importance of pleasantness and dominance.

HC also identified clusters with no clear semantic link with one or few main dimensions in PCoA. Instead, the features in these clusters loaded significantly in multiple PCoA dimensions and introduced semantically distinct social clusters not identifiable from the main dimensions alone. For example, HC grouped communication types into distinct clusters (Verbal and Nonverbal communication, Gesturing, and Physical interaction) and identified clusters Achievement and Goal-oriented behaviour that formed from characteristics often attributed to high-achieving individuals. Overall, the concordance analysis indicated that while social perception can be modelled with fundamental basic dimensions from PCoA, fine-grained social clusters arising from combined information from multiple basic dimensions can be identified with HC.

Generalizability of social perception across persons and situations

We replicated our results using an independent dataset. The results from both analytical methods (PCoA & HC) generalized well between different stimuli and raters (**Figure 6**). The findings suggest that the established main dimensions and their relationships reflect the organization of the social perceptual system, not just the properties of the primary stimuli. Previous research has shown that the perception of some social and affective facial characteristics generalize between stimuli and cultures. Perception of valence and dominance characteristics from faces show generalization (Jones et al., 2021) and emotion recognition from facial expressions shows general but also culture-specific characteristics (Gendron et al., 2018). The present data thus suggests that the perceptual system pays attention to a limited set of relevant social features consistently and independently of the specific condition where it arises when interpreting the fast-changing social world.

Limitations

The social dimensions and clusters established here are dependent on the stimuli and the social features selected for evaluation. However, the organization in social perception generalized across independent stimuli and subjects suggesting that the social perceptual structure was not specific to the primary stimulus set and the dimension reduction techniques suggested that our candidate set of social features was more than extensive enough. Still, the pre-selected social features may not be fully representative of all possible dimensions and therefore our results do not rule out the existence of other dimensions. Additionally, movies represent stereotypical or amplified versions of real-life social interaction. Despite this limitation, movies have the advantage of being naturalistic in a laboratory. This is significantly more alike to real life than traditional studies using static pictures or lexical studies describing semantic similarities of different words. Nevertheless, it would be important to test how well our model performs in stimuli selected to represent fully natural everyday life where the observer becomes involved in social interaction. Social perception can be very fast (Lauri Nummenmaa et al., 2010), and therefore we used sufficiently long (~10sec) movie clips for studying immediate social perception in naturalistic scenes. However, social perceptual information may unfold in longer timescales and these results cannot capture those slow perceptual processes. An interesting avenue would be to study the temporal changes in the perceptual ratings to understand how people accumulate information from different social features.

Conclusions

Our results establish the most detailed representation of how people perceive the social world to date. Our data indicated that social signals are perceived as binary (either present or absent) or continuously (how much). Simple social features and the features with immediate social relevance are perceived with the highest consistency between people indicating that perceptual simplicity and immediate social relevance drive the consistency of perception between people in natural observation. Social perception in life-like dynamic scenes organizes into eight main perceptual dimensions. Emotional valence, dominance, and cognitive versus impulsive functioning are the most fundamental perceptual dimensions and they explained over half of the variance in the whole data. Distinct social clusters can be represented based on the combined information from the main dimensions suggesting hierarchy from basic perceptual dimensions to integrated and fine-grained clusters in social perception. Finally, the established organization in social perception generalized across stimuli and participants validating the findings.

Material and methods

Candidate social features

There exists no consensus on the detailed taxonomy for social perception. Furthermore, established taxonomies for describing regularities in the social domain are limited to specific areas such as personality or values. Yet, the dimensions described in these specific taxonomies are highly correlated between different domains which indicates that affective-cognitive phenomena cannot be fully distinguished from each other (Horstmann et al., 2021; Wilkowski et al., 2020). Therefore, we initially defined a broad set of candidate social features based on the existing taxonomies used for describing humans and their actions and mental processes in the social domain. This list was based on an updated set of features used in our previous neuroimaging study of social perception (Santavirta et al., 2023) and contained a total of 138 socioemotional features describing person's traits, physical characteristics, internal states, somatic functions, sensory states, qualities of the social interaction and motor components of the social signalling.

The full list of tested features and their associations with existing cognitive-affective taxonomies is listed in **Table SI-2**. Features describing person's traits (31 features, e.g. pleasant, agreeable, extravert, honest, intelligent, impulsive and kind) were selected based on the existing taxonomies (Abele & Wojciszke, 2014; Fiske, 2018; Goldberg, 1990; Lee & Ashton, 2004; McCrae & Costa, 1987; Parrigon et al., 2017; Rauthmann et al., 2014; Russell et al., 1989; Schwartz et al., 2012; Wilkowski et al., 2020). We also included socially relevant physical characteristics (8 features, e.g. feminine, masculine and old). Next, we selected features describing a person's internal, situational states (24 features, e.g. feeling insecure, exerting self-control and wanting something). Somatic functions (8 features, e.g. sweating, feeling ill, eating) and sensory states (8 features, e.g. feeling pain, listening to something) were also included. To broaden the scope to social interaction (rather than focusing on the individual agents), we included characteristics of social interaction. The social interaction characteristics were descriptors for the qualities of the social interaction (31 features, e.g. hostile, sexual, playful and equal) with the social communicative signals (14 features, e.g. talking, nonverbal communication, laughing, hitting/hurting someone). Finally, we included features describing the bodily and facial movements with potential social relevance (14 features, e.g. moving their body, moving towards someone, jumping, making facial expressions).

Video stimuli

The stimuli were short clips selected primarily from mainstream Hollywood movies (N=234). Movies are powerful stimuli for studying social perception since movies typically display natural, socially important episodes with high affective intensity and frequency, and consequently social neuroscience has successfully adopted movies for studying neural bases of socioemotional processing (Adolphs et al., 2016; Lahnakoski et al., 2012; Saarimäki, 2021; Santavirta et al., 2023). The average duration of the movie clips was 10.5 seconds (range: 4.1 - 27.9 sec) with a total duration of 41 minutes. The stimuli contained a previously validated set of socioemotional movies used in neuroimaging studies (Karjalainen et al., 2017, 2018; Lahnakoski et al., 2012; L. Nummenmaa et al., 2021; Santavirta et al., 2023) and was complemented with similar movie clips selected from YouTube (https://www.youtube.com/) by three independent research assistants. The assistants were instructed to search for movie scenes with social content and cut them to approximately 10-second-long continuous scenes. The clips should present scenes spoken in English that could depict real life social interaction (science fiction or animation movies were excluded). The assistants were instructed to search for clips that would contain as variable social contents as possible. No further instructions of what social contents the scenes should contain were given to make sure that the principal researchers' assumptions of the organization of social perception do not bias the stimulus selection. See **Table SI-3** for short descriptions of each movie clip.

Data collection

To ensure subject engagement and to reduce the cognitive demand of the study, each participant was randomized to evaluate a subset (39 clips) of the movie clips for a subset (6-8 features) of the social features (see section Experiment subsets in Supplementary materials). Participants were instructed to rate the perceived features in the video clip rather than their own internal states (such as emotions evoked by the films). They were asked to rate how much they perceived the given social feature from the movie clip by moving a slider on a continuous and abstract scale from "absent" to "a lot". The data were collected using online experiment platform Gorilla (https://gorilla.sc/) and the median experiment duration for the participants was 21 minutes and 18 seconds.

Participants

Participants were recruited through Prolific (https://www.prolific.co/). Only fluent English-speaking adults using a computer or a tablet were allowed to participate. All participants gave an informed consent and were compensated for their participation. Concerns have been raised about the data quality in online participants (Webb & Tangney, 2022) and different recruiting platforms (Peer et al., 2022). Accordingly, we used strict data quality screening and participant inclusion criteria (see section Data quality control in Supplementary materials). New participants were recruited until 10 reliable ratings were obtained for each social feature and video clip (see section Sample size estimation in

Supplementary materials). Altogether 1140 participants completed the study, and 44 (3,9 %) participants were excluded based on the data quality control. The final dataset included 1 096 participants from 60 nationalities with over 327 000 data points. 515 participants were female (46,9 %) and the median age of the participants was 28 years (range: 18 - 78 years). See **Table SI-4** for the nationalities of participants.

Analysing how people perceive social features

Some of the rated social features are omnipresent in everyday social interaction (e.g. facial expressions) while others (e.g. hitting or hurting someone) occur infrequently. To investigate how often specific social features are present and whether the movie clips contained sufficient occurrences of the targeted social features, we calculated the feature occurrence rate. A feature was considered present in a given movie clip if the average rating over annotators minus standard error (SEM) was above five (in the scale from 0 to 100) and occurrence rate was calculated as the proportion of all movie clips where the feature was present (Santavirta et al., 2023).

Some social features are inherently discrete and others continuous. For example, a person could be perceived as standing or not (binary perception) whereas someone could be perceived as more or less trustworthy (continuous perception). To reveal how people evaluate the category and intensity of the social features, we analysed the shape of the population average distributions for the feature ratings. Bimodality coefficient (BC) and Hartigan's dip test were used to test whether on average the people rate social features as unimodal or bimodal: Bimodality would suggest that the social feature is perceived binary as either present or absent while unimodal distribution would indicate continuous intensity levels in perception. Conservative Hartigan's dip test rejects unimodality at $p < 0.05$ and bimodality coefficient favours bimodality when $BC > 0.555$ (Freeman & Dale, 2013).

Finally, some social features are likely evaluated more consistently across observers than others. For example, people recognize others' sex from their facial appearance with almost 100% accuracy (Bruce et al., 1993), whereas evaluation of personality-related features such as shyness could be expected to be less consistent, particularly from the short samples provided by the stimulus clips. To assess the between-subject reliability in the ratings for each social feature we calculated intra-class correlation coefficients (ICC) (McGraw & Wong, 1996) for the feature ratings. Between-subject reliability was estimated by calculating the single measures ICC which measures the reliability of any single participants ratings compared to the others. For mapping the organization in social perception (section Mapping the low-dimensional space of social perception) we used average rating over subjects for each social feature. Therefore we also assessed the reliability of the population average ratings (measured as the mean of 10 ratings) by calculating average measures ICC:s. A two-way random model with absolute agreement (ICC2 for single measures & ICC2k for average measures) was selected for ICC calculations (Koo & Li, 2016).

Mapping the low-dimensional space of social perception

We obtained ratings for the occurrence of a total of 138 social features. Because it is unlikely that all individual features would carry unique and significant information independently of other simultaneously occurring features, we conducted a principal coordinate analysis (PCoA) (Gower, 1966) as a primary dimension reduction technique to establish the low-dimensional space of social perception in the movie stimulus. PCoA studies the dimensionality of data based on the covariance structure between the features. Our data contained social features that could be perceived either present or absent while some features may be perceived in every scene but with varying intensity. The Euclidean distance used by principal component analysis (PCA) would be insufficient in capturing the co-occurrence of these distinct data types which motivated us to choose to study the covariance between the features with PCoA instead.

PCoA can reveal orthogonal dimensions from any data, but the interpretation of the dimensions can be complicated and it is unlikely that the perceptual system in the brain follows any single mathematical algorithm. It is also possible that relevant social elements are perceived from a certain combination of information from the orthogonal dimensions established with PCoA (e.g. features with high loadings in both PC1 and PC2 form a social element that have a distinct semantic meaning). Therefore, we conducted a complementary consensus hierarchical clustering analysis (HC) (Murtagh & Contreras, 2012) to group social features into semantically distinct clusters.

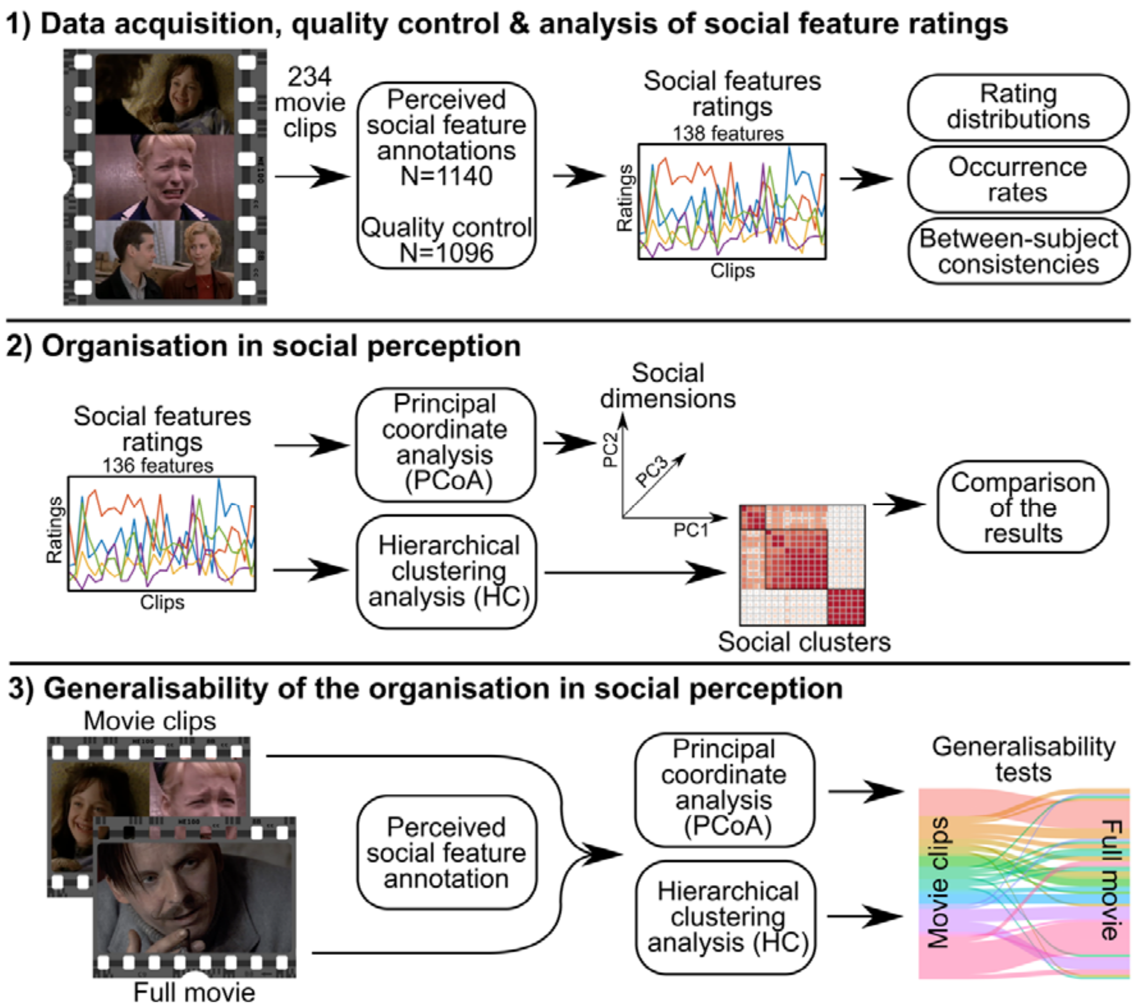

Figure 7. The experimental and analytic pipeline 1) A large set of perceived social features (N=138) were annotated from short movie clips (N=234) by 1140 participants. After data quality control distributions, occurrence rates and between-subject consistencies for the

features were determined. 2) Principal coordinate analysis and hierarchical clustering analysis were conducted for the social feature ratings to reveal the organization in social perception. 3) Generalizability of the organization in social perception was tested using an independent full movie dataset.

Principal coordinate analysis

PCoA was implemented using R function cmdscale (https://www.rdocumentation.org/packages/stats/versions/3.6.2/topics/cmdscale) and a Pearson correlation matrix of candidate social features was used as input. The statistical deviation from chance of each principal component (PC) eigenvalue and the loadings for social features for each component were tested with a permutation test. For each permutation round, a new dataset was generated by randomly shuffling the ratings of each social feature (columnwise) thereby breaking the synchrony between the columns of the data. Then a PCoA analysis was conducted for the shuffled dataset. The procedure was repeated 1 000 000 times to estimate the null distributions for the eigenvalues and the loadings of each PC. Finally, true eigenvalues of the PCs and the loadings of each PC were ranked to their corresponding null distributions to assess their statistical significance (exact p-value).

Hierarchical clustering analysis

Average hierarchical clustering (UPGMA) (Murtagh & Contreras, 2012) was used due to its simplicity and effectiveness in grouping social features in our previous study (Santavirta et al., 2023). To establish stable and generalizable clustering results we used a consensus clustering approach from diceR package (Chiu & Talhouk, 2018) in R software (https://www.r-project.org/). Since we did not know how many stable clusters the evaluated social feature space would form, a consensus clustering result was obtained by subsampling 80% of the items from the total sample and then performing clustering in each subsample for different numbers of clusters (from 5 to 40). The subsampling was repeated 1000 times for each number of clusters to establish a consensus matrix over different numbers of clusters and over all subsamples. Finally, a representative and stable clustering result was obtained from the hierarchically ordered consensus matrix.

Comparison of PCoA and HC

Both PCoA and HC analyses reduce the social perceptual space based on the covariance structure between the rated social features and the results were expected to converge. To investigate how well the orthogonal components from PCoA link with the HC clusters we projected the candidate social features into 2D space using t-distributed stochastic neighbour embedding (t-SNE) which is a non-linear dimension reduction technique to visualise high-dimensional data in 2D surface (Van der Maaten & Hinton, 2008). The featurewise PC loadings for significant PCs were given as input for the t-SNE and hence each candidate social feature was mapped into 2D projection based on its loadings for significant PCoA components, rather than the raw rating values. If social features form separable groups similar with the HC clusters in this t-SNE projection it would indicate that the PCoA dimensions and HC clusters reveal structural similarities and that the HC clusters can be described with the information from the PCoA dimensions. To assess the fine-grained connections between PCs and HC clusters, we obtained the mean PC loading for each cluster by averaging the feature PC loadings over all candidate features within the clusters. The statistical significance of the cluster loadings was then assessed similarly as the significance of the individual social features from the permuted null distributions. With this approach we could study in detail how each HC cluster could be described as combined information from the PCoA components.

Generalizability of the low-dimensional space of social perception

Finally, to test the generalization of the social perceptual space mapped in the study, we used a previously collected independent dataset of social feature ratings as a validation dataset. The stimulus for this validation dataset was a slightly shortened version of a Finnish feature film "Käsky" (Aku Louhiniemi, 2008, ~70min). The movie was spoken in Finnish while the present movie clip dataset contained only spoken English, thus the structural and linguistic variation ensured that we really tested the generalizability across distinct data types. The validation dataset contained 76 of the social features in the primary dataset. The social features in the validation dataset were collected in Finnish from five independent local Finnish subjects not participating in the movie clip dataset rating. The ratings in the validation dataset were collected in interleaved eight second intervals resulting in four second temporal accuracy while each movie clip in the movie clip dataset was rated only once (movie clip average duration: 10.5 sec).

We tested the generalizability of the PCoA and HC solutions for the organization in social perceptions between the datasets. For both analyses the initial dimension reduction was conducted separately for both datasets similarly as described in the section "Mapping the low-dimensional space of social perception**"**. For PCoA we then identified how many components were statistically significant in both datasets similar to the main analysis (null distribution generation with 1 000 0000 permutations) and correlated the feature loadings of the significant components between the datasets. Statistically significant correlations of component specific feature loadings between the datasets would indicate that these components share similar information. For HC analysis the similarity of the cluster structure between the datasets was tested by comparing the consensus matrices as well as the correlation matrices of the datasets with a non-parametric Mantel test with 1 000 000 permutations (Glerean et al., 2016).

Data and code availability

The anonymised perceptual rating data and analysis scripts are available in the project's Git https://github.com/santavis/taxonomy-of-human-social-perception/. The stimulus movie clips can be made available for researchers upon request, but copyrights preclude public redistribution of the stimulus set. Short descriptions of each movie clip can be found in the supplementary materials (**Table SI-3**).

Author contributions

SS designed the experiment, collected data, developed the analysis methods, analysed the data and wrote and reviewed the manuscript.

TM designed the experiment and wrote and reviewed the manuscript.

AE collected data and wrote and reviewed the manuscript.

LN conceptualized the study design, acquired funding, supervised the project, developed analysis methods, and wrote and reviewed the manuscript.

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Declaration of competing interest

The authors declare no competing financial or non-financial interests.

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