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Body maps of loves

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ABSTRACT

Love is an essential biological, psychological, sociological, and religious phenomenon. Using various conceptual models, philosophers have often distinguished between different types of love, such as self-love, romantic love, friendship love, love of God, and neighborly love. Psychologists and neuroscientists on the other hand have thus far focused predominantly on understanding the emotions and behavioral and neural mechanisms associated with romantic love and parental love. We do not yet know how the models construed by philosophers are related to actual experiences of love, and to which extent they are merely nominal creations connecting phenomena that in fact have little to do with each other. We lack empirical knowledge of how different types of love are experienced as embodied feelings, and how these experiences are related to one another. Here we distinguished between 27 different types of love. Using self-report methods, we measured 1) how subjective feelings of different types of love are topographically embodied; 2) how different types of love are associated with self-reported emotional valence, strength of the bodily and mental experience, association with touch, time elapsed since last experienced, and controllability; and 3) how similar different types of love feel. Our study provides the first mapping of embodied experiences associated with different types of love. The results show that the subjective feelings associated with the love types form a continuum from strongly to weakly felt loves.

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Experience of emotions; positive emotions; close relationships

Introduction

Love in social relationships is associated with human flourishing (Vaillant, 2012), psychological well-being (Kim & Hatfield, 2004; Oravecz et al., 2020), mental and physical health (Esch & Stefano, 2005a; Major et al., 2018), positive emotions (e.g., Fredrickson, 2001, 2016), and reduced stress (e.g., Floyd & Riforgiate, 2008). However, there is little consensus on what "love"

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in fact is, and how it feels. When asked, people easily list more than eight different subtypes, but can even include over a hundred types of love (Fehr & Russell, 1991). The word "love" is used to refer to experiences as disparate as sexual craving, a mother's affection for her child, a bond between friends, religious devotion, or helping strangers, just to name a few paradigmatic usages. One might well wonder what the feelings and behaviors referred to as "love" ultimately have to do with each other.

The polysemous nature of "love" has of course not prevented philosophers and theologians from analyzing the concept, nor psychologists or neuroscientists from measuring love-related phenomena. Using various conceptual models, scholars in the humanist disciplines distinguish between different kinds of love, such as the classical Greek division of *storge* (affection), *eros* (sexuality), *philia* (friendship), and *agape* (love of God) (Lewis, 1971). Other divisions distinguish self-love, erotic love, romantic love, parental love, friendship, brotherly love, love of humanity, and love of God (see Fromm, 1956; White, 2001). Sometimes mate-selection and long-term bonding, parental love, and *agape*-love are mentioned as the basic divisions within love (Ruse, 2017). In contemporary analytic philosophy of love, a *commodious* approach to the concept of love has been recently defended. This approach involves the pluralist premise that besides other humans, also non-human and non-living objects may be relevant objects of love (Shpall, 2016). While these kinds of models, irrespective of how commodious they are, undoubtedly pick out some essential aspects of love, it is not clear how exactly the models construed by philosophers and other humanists coincide with the word lists generated by laypeople, and how these models are related to actual human experiences of love.

On the other hand, psychologists and neuroscientists have thus far focused predominantly on understanding the emotions, behaviors, and neural mechanisms related to love in couple relationships (often called romantic love) and parental love. Evolutionary psychologists have studied romantic love and parental love in terms of adaptive desire, attachment, and care-giving (Buss, 2003, 2006; Fisher, 2006, 2017; Fisher et al., 2005, 2006; Kenrick, 2006; Lampert, 1997; Shiota et al., 2014). Other psychological accounts focus on, for example, measuring romantic love (Rubin, 1970), distinguishing romantic love from sexual desire (Gonzaga et al., 2006; Horikawa et al., 2020) or on analyzing couple-relationships on the axis of romantic love and companionate love through the concepts of passion, intimacy, and commitment (Sternberg, 1986, 2006). A theory of six different "love-styles" (*eros, ludus, storge, pragma, mania, agape*) or "love-attitudes" in romantic relationships has also been proposed (Berscheid, 2010; Hendrick & Hendrick, 2006; Lee, 1973); and a meta-analysis of higher-order factors in the study of romantic love suggests a tripartite division of romantic love into general love, romantic

obsession, and practical friendship (Gonzaga et al., 2001; Graham, 2011; Shiota et al., 2011). Cognitive neuroscientists have also studied mainly romantic love (Acevedo et al., 2012; Aron et al., 2005; Bartels & Zeki, 2000; de Boer et al., 2012; Esch & Stefano, 2005b; Fisher et al., 2005; Ortigue et al., 2007; Scheele et al., 2013) and maternal love (Bartels & Zeki, 2004; Esch & Stefano, 2005b; Noriuchi et al., 2008), typically measuring brain activity using functional Magnetic Resonance Imaging (fMRI) (Beauregard et al., 2009; Wagner et al., 2015); for meta-analysis see (Ortigue et al., 2010).

Love has been recently studied using a topographical *emBODY*-tool (Nummenmaa et al., 2014, 2018). As part of their extensive mapping of the human feeling space, Nummenmaa et al. (2018) showed that humans experience love as a positively valenced emotion felt widely across the body. These studies, however, assumed that love is a singular emotion. The embodied, subjective feelings related to different types of love have not yet been investigated. Previous work in prototype theory has shown that the number of subcategories of an emotion concept such as interpersonal love is indefinite or "fuzzy", and that scientists tend to use a narrower concept of love than their experimental subjects (Fehr & Russell, 1991). Dividing an emotion concept to subtypes due to its fuzziness is certainly not specific to "love" and similar subcategorization can also be applied to all "basic" or prototypical emotions.

Different types of love have been previously associated with different behaviors and have, to an extent, differing neural correlates (see e.g., Ortigue et al., 2010). Therefore, it makes sense to ask whether differences in behavioral context and neural activation patterns associated with different types of love also imply differences in somatic experience or feeling of love in the body and mind.

Here we used the *emBODY*-tool, dimension rating, and similarity mapping to measure subjective feelings associated with 27 different types of love. Instead of defining "love" in the sense of postulating or claiming to have discovered necessary and sufficient conditions of love, in this descriptive research we understand "love" as a word used in particular historico-linguistic, cultural, social, and phenomenological contexts. The word "love" refers to (among many other things) a type of feeling consisting of multiple subtypes, the construction and discovery of which is bound only by the limits of language and human experience. Here we assume an n-dimensional universe of discourse with a plurality of variables, values, relationships, and types. In our metrics, types are context specific proximity or similarity categories, denoted by words naming the types. A type of "love" is understood as a linguistic construction, such that "love" is connected to another word in a way that the other word conditions "love", is "love's" subject, object, attribute, or any other kind of qualification; e.g., "maternal

love", "romantic love", "love for God" or "love of tobacco". In particular, in our study the names of the types of love refer to the subjective feelings associated with the names of the types by language users.

As the word "love" can in principle be used in any linguistic context, and love (understood as a feeling) can be potentially felt for any object, in our view it makes little theoretical sense to attempt the construction of a rigid taxonomy for subtypes of love. An n-dimensional universe of love consists of an indefinite amount of types of love.

Hence, our aim was not to generate or define a conceptual taxonomy for love, but rather to understand how different or similar various embodied feelings of different types of love are to each other. Therefore we decided to choose a wide variety of types of love, that in our opinion provide a broad aggregation covering some of the most common objects and qualities associated with "love". In our current studies, the basic objective frame of reference is the Finnish word "rakkaus" [love], as it is felt in various subtypes among contemporary Finnish language users. We chose to use the Finnish language as it is the language we know best. In order to ensure that our selection of love types covers the most paradigmatic aspects of the concept of love, we chose to include in our study types of interpersonal love, that have previously been shown to be highly prototypical (in English) (Fehr, 1994; Fehr & Russell, 1991). The corresponding Finnish names of these love types are also commonly used within the Finnish linguistic community. We further included less prototypical love terms denoting love for non-human objects or a quality of love, which terms are nevertheless well-known and used routinely in philosophical and (Christian) theological literature (see e.g., Crisp, 2000; Denis, 2017; Murdoch, 2001; Nussbaum, 2013; Wollstonecraft & Lynch, 2009). Following Nummenmaa et al., we understood the term "feeling" broadly to mean "the current, subjectively accessible phenomenological state of an individual" (Nummenmaa et al., 2018, p. 1).

In order to delineate the core areas of the concept and feelings of love in relation to the human feeling space (Nummenmaa et al., 2018), and to explore the bodily activation patterns associated with different types of love, we asked: i) Where are different types of love felt in the body? ii) How are the feelings associated with different types of love related to emotional valence, bodily and mental experience, lapse and controllability? iii) How similar are different types of love in relation to each other, in body and in mind? To foreshadow our results, our study shows that 1) different love types have topographically different embodiments. The loves that are felt widely across the body are also the most strongly felt loves in terms of bodily and mental salience. 2) The topographical bodily sensations associated with the love types form a continuum from strongly to weakly felt loves. Together with previous findings from prototype theory and emotion

research, our results suggest that "love" (as a term which names some embodied feeling(s)) may be viewed as a hypernym for a fuzzy emotion category, such that different types of love form an open set of distinct albeit non-discrete subtypes of continuous gradients of emotional feeling (Cowen & Keltner, 2017).

Materials and methods

We are building theoretically on previous studies of bodily topographies of feelings, and used the same data collection procedures and analysis strategy as Nummenmaa et al. (2018). The data was collected in three online experiments using convenience sampling. As the study is a first exploration of subjective experiences associated with multiple types of love, we opted for a convenience sample before investing in more expensive sampling strategies. The data collection platform did not allow the use of touchscreen devices. We advertised the studies on social media platforms, university newsletters and e-mail lists. Before the experiments, the participants received general information about the study and were asked to provide informed consent. We collected demographic information on the participants' gender, age, native language, education, parenthood, religiousness, and sexual orientation. Before starting, the participants were given detailed instructions on how to conduct the tasks. There were no practice trials or tutorials in any of the three experiments. The participants did not receive monetary compensation for participating (except for the possibility to attend a movie voucher lottery). The data collection was fully anonymous.

Stimuli

The stimuli were 27 love terms naming each type of love in the Finnish language. The chosen stimuli included types of interpersonal love that are highly prototypical and commonly used within the Finnish linguistic community (cf. Fehr, 1994; Fehr & Russell, 1991). We also included less prototypical love terms denoting love for non-human objects or a quality of love, which terms are nevertheless well-known and used routinely in philosophical and (Christian) theological literature (Crisp, 2000; Denis, 2017; Murdoch, 2001; Nussbaum, 2013; Wollstonecraft & Lynch, 2009).

Participants

In the three experiments, there were 833 registrations (Experiment 1: 203, Experiment 2: 290, Experiment 3: 340) and 558 completed tasks (Experiment 1: 137, Experiment 2: 168, Experiment 3: 253). Any individual person could register in one, two or all three experiments. Thus, the final

sample of the three experiments likely contains partially overlapping set of participants. However, as the data collection was fully anonymous, we did not track if the same individual registered to more than one experiment. For the analyses, we only included data from participants who completed the whole task.

From the final analyses, we excluded non-native Finnish speakers and subjects who did not register their age (predetermined criteria). Additionally, from experiment 1 we excluded one participant as an outlier (compared across all responses, the participant had a Z score > 16 for the total amount of paint for one stimulus), one for painting in less than half of the bodies, and one for painting symbols on the body that were clearly not meant to represent bodily sensations (e.g., question mark). Although these criteria were not strictly predetermined as such, we did not make the decisions based on any downstream statistical analyses. We only excluded participants with very obviously anomalous painting behavior, for example, we did not exclude participants who reported (symbolical) heart shaped sensations.

For experiment 1 the final sample size after exclusions was 128 (man/woman/other or do not want to define: 11/104/13). In experiment 2 the final sample size was 162 (man/woman/other or do not want to define: 19/119/24). In experiment 3, the final sample size was 249 (man/woman/other or do not want to define: 32/203/14). Across all three experiments, the majority of participants were under 35 years old (ages 18–25: 47.1% of participants, ages 26–35: 38.0% of participants). For more detailed information about the participant demographics, see Table S1.

Experiment 1 (n = 128): embodiment of love types

In the first experiment, we used the emBODY method developed by Nummenmaa et al. (2014). emBODY is a self-report task where the participants are asked to paint (with a computer mouse) inside simple pictures of human bodies where they feel bodily sensations when experiencing the given type of feeling or emotion. In this experiment, the participants were shown an outline of a single body on the computer screen, and they were asked to paint the areas where they feel sensations when experiencing a certain love type. The love concepts were presented as words and in random order.

The raw data of the emBODY method are the locations where the participants pressed or held down their mouse button (i.e., painted) during stimulus presentation. Each mouse press increases the paint intensity by value of one. In our preprocessing pipeline, these values were saved in a matrix where rows and columns represented the two-dimensional coordinates of the computer screen. This matrix was filtered with a Gaussian filter

to recreate the brush size of the online painting tool. Following Nummenmaa et al. (2018), in the statistical analysis, the filtered paint intensity value of each pixel was tested against zero in one sample t-test (two-sided tests with 127 degrees of freedom, 50291 tests in total for each body map), however, it should be noted that the paint intensity values do not follow normal distribution according to Kolmogorov-Smirnov tests. For multiple comparisons correction, Benjamini-Hochberg FDR correction with a false discovery rate of 0.05 was used. After FDR correction, the statistically significant t-test values were visualized as effect sizes (Figure 1). The effect size was defined as the t-value divided by the square root of the sample size. Data consistency for each pixel was investigated with split-half analysis with 100 permutations. In the split-half analyses, the consistency was calculated from the paint intensity values as Spearman's correlation between two halves of the dataset. That is, we calculated how consistently the 27 stimuli were rank correlated for the strength of the paint in each pixel across the two random halves. The results are visualized in Fig. S4. We also ran split-half analysis with 5000 permutations based on the total amount of paint in the bodies (Fig. S5).

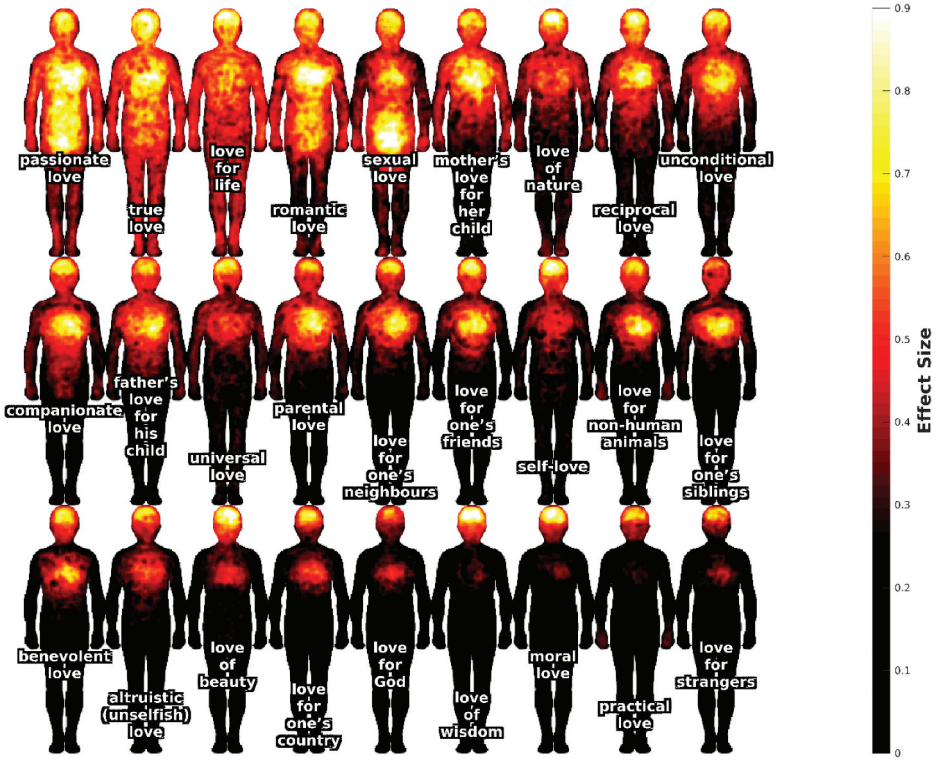

Figure 1. Across-subjects bodily sensations maps from experiment 1 ($n = 128$). Colors represent statistically significant pixelwise t-values as effect sizes. Maps are ordered according to the sum of the statistically significant t-values in each map.

We also calculated the percentage of the participants who reported sensations in any given location of the body surface. These percentages are visualized in Fig. S1, along with information on the number of subjects who reported any sensations at all to the stimuli (i.e., did not leave the body completely empty).

Experiment 2 (n = 162): dimensions of love experience

We investigated how the different love types are rated on five continuous Visual Analogue Scales (VAS), that were designed to probe basic dimensions of subjective experiences as hypothesized by Nummenmaa et al., according to whose hypothesis "four main dimensions (saliency of mental experience, saliency of bodily sensation, emotion, and controllability) would underlie the feeling space" (Nummenmaa et al., 2018, p. 5). The fifth scale measured the frequency of experience. As we are expanding on previous research in the body map paradigm and providing a more fine-grained investigation of a type of emotional feeling that has already been studied using that paradigm (Nummenmaa et al., 2014, 2018), it was reasonable for us to probe largely the same set of dimensions of subjective feelings as the previous study.

For this study, we also added a sixth dimension of "bodily touch". Behaviors related to bodily touch are self-evidently associated with some of the most prototypical types of love, such as maternal love (breast-feeding, bodily nurture) and romantic love (kissing, sexual touch), yet bodily touch seems to be absent from other culturally paradigmatic types of love, such as "love of wisdom" (philosophy). On this basis we hypothesized that touch would be an important dimension underlying some differences between the types of love in our study.

In the experiment, the participants saw each love concept at a time in a random order on a computer screen and were asked to think about the type of love in question and the feelings it elicits. The subjects were asked to evaluate: 1) How strongly does it feel in the body?, 2) How strongly does it feel in the mind?, 3) How pleasant does it feel?, 4) How much can you control the feeling?, 5) When did you last experience the feeling?, 6) How strongly do you associate it with bodily touch? The minimum value on each scale was 0 and maximum value 1000 (1,2,4,6: *not at all – extremely much*; 3: *extremely unpleasant – extremely pleasant*; 5: *less than an hour ago – over a year ago or never*).

We calculated the means, standard deviations, and standard errors of responses (Table S2). Due to ceiling effects (see Fig. S12), before further analysis, we scaled the data to have a range from −1 to 1 and Z transformed these values with inverse hyperbolic tangent function (Fisher Z transformation). We visualized the results as probability

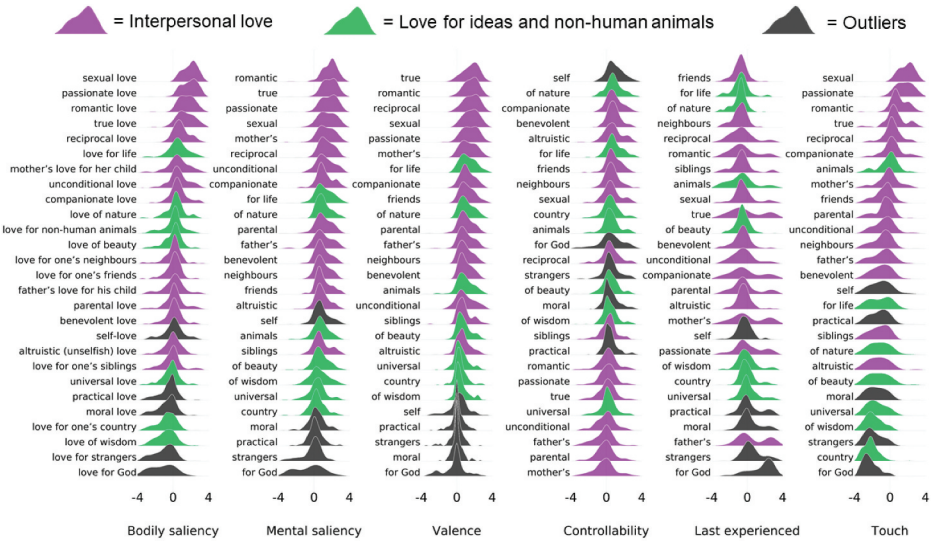

Figure 2. Probability density estimates of the ratings from experiment 2 (Z-transformed data). The love types are sorted according to the median rating on each dimension. The dimension "last experienced" is in reverse order (lowest median first), as in that dimension, lower values indicate that there has been less time elapsed since the love type was last experienced. Color coding is based on the DBSCAN clustering from experiment 3. For brevity, the love types from the second column onwards are abbreviated.

density estimates (Figure 2). Spearman's correlation was calculated between all dimension pairs based on the mean rating across subjects in the given dimensions (Figure 3). Following the method of Nummenmaa et al. (2018), the rating data were also visualized by plotting the mean rating values in the corresponding location of the MDS space from experiment 3, and smoothing the image with a Gaussian filter (Figure 4). Split-half consistency of the ratings was assessed with 5000 permutations (Fig. S6). We also analyzed the data from experiment 2 by excluding answers where participants had answered over 950 (maximum 1000) to the question regarding when they had last experienced the feeling. That is, we excluded participants who reported having experienced these feelings either a long time ago or never.

Experiment 3 (n = 249): similarity of feelings

In this experiment, we studied how similar the different love types feel. Participants were shown simultaneously the 27 love words arranged in a random order on the left side of a computer screen. They were instructed to rearrange the words by dragging them into a square located on the right side of the screen. Participants were asked to arrange the words based on similarity of feelings: types of love that feel similar should be placed closer

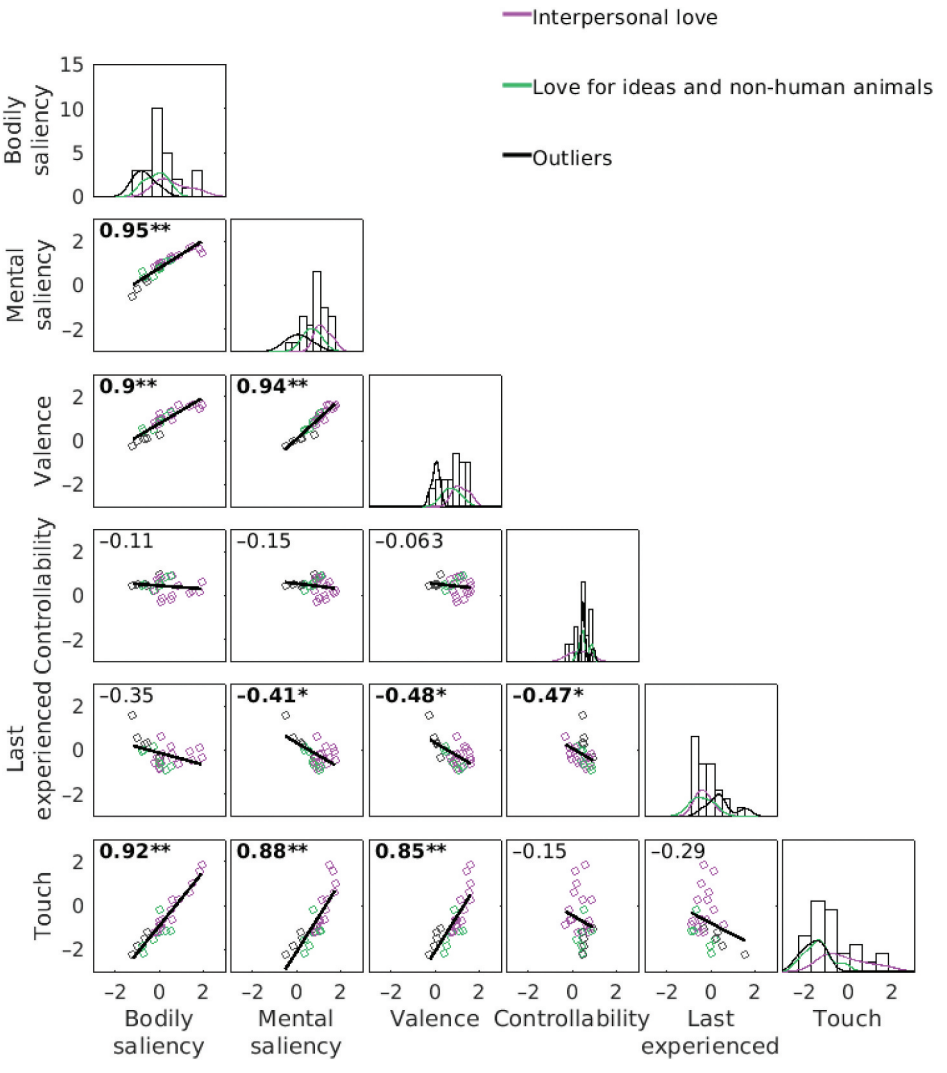

Figure 3. Relationships between the six dimensions from experiment 2 (Z-transformed data). The scatterplots show the mean rating scores for the 27 stimuli and least squares lines. Spearman's correlations between the mean responses for each dimension pair are shown in the upper left corners. Statistically significant correlations are indicated in **bold** (* $p < 0.05$, ** $p < 0.005$). Histograms on the diagonal represent how the mean responses of the 27 stimuli are distributed in each dimension. The probability density curves further visualize how the mean responses in each dimension are distributed in the love types from different DBSCAN clusters from experiment 3. Also, the dots representing the mean ratings are colored based on the DBSCAN results.

to each other and the types of love that feel dissimilar further away from each other.

For every participant, we calculated the Euclidean distance between each type of love based on the final locations of the love words on the computer screen. The pairwise distances were averaged across all participants and the

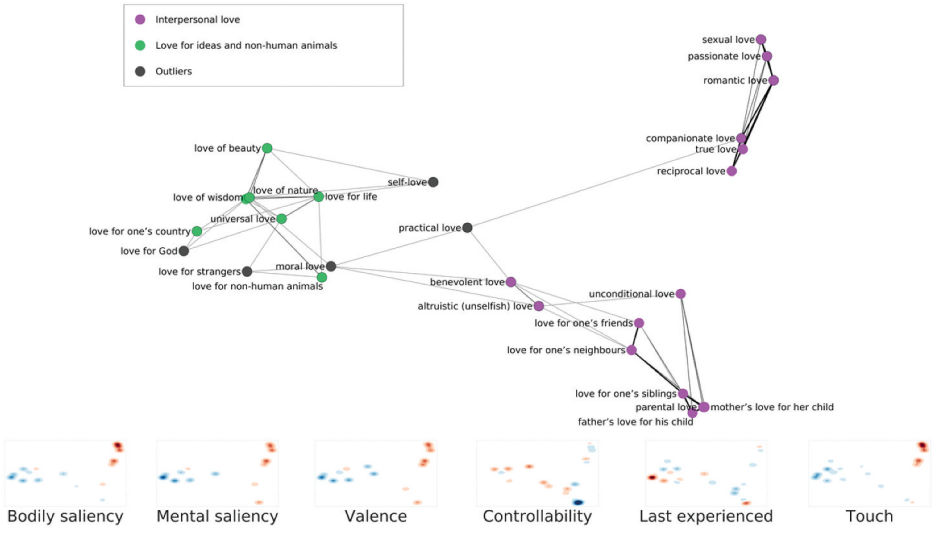

Figure 4. Two-dimensional multidimensional scaling (MDS) representation of the distances between the love types from experiment 3. Color coding is based on the DBSCAN results, with darker edges indicating that the love type is a border point. Each love type is connected to three love types to which it has the smallest distance to. The thick lines indicate that the distance is within the smallest 33rd percentile of all distances. In the lower part of the figure, data from experiment 2 is visualized. The colors represent how the love types in the MDS location were rated in the six dimensions of experiment 2, with red indicating higher ratings and blue lower ratings for love type in the given location. For example, in the first map the dark red colors in the upper right corner visualize that stimuli in that location (sexual, passionate, and romantic love) were rated high in their bodily saliency in experiment 2. Note that in the "last experienced" higher ratings indicate that more time has elapsed since the participants reported to have last experienced the love type in question.

resulting average distance matrix was subjected to a classical multidimensional scaling analysis. Data consistency was assessed by inspecting if mean and median distance matrices give similar results (Mantel test $r = 0.99$, $p < 0.001$), and by split-half analysis. The split-half consistency was calculated as Spearman's correlation of the pairwise distances between two random halves of the dataset with 5000 permutations. As the pairwise distances are not independent, statistical significance of the split-half consistency was assessed with Mantel tests between the split-half distance matrices. In the Mantel test, Spearman's correlation between the top triangles of the distance matrices was computed, and statistical significance assessed with permutation testing using 5000 permutations.

We used the DBSCAN clustering algorithm to explore the similarity data. We searched clustering solutions with different parameter values (ε from 0.01 to 0.35, minPts from 1 to 10). For selecting the optimal solution, we followed the criteria of Nummenmaa et al. (2018) and selected the solution with a maximum number of clusters and minimum number of outlier points.

We also analyzed whether the love types that were more similar in the similarity mapping were also more similar in terms of the reported bodily sensations and in terms of the ratings on the 6 dimensions measured in experiment 2. In an approach inspired by representational similarity analysis (Kriegeskorte et al., 2008), a distance matrix for the 27 love types was constructed from each data source and compared with Mantel tests. The distance matrices were based on Euclidean distances between the mean distances from experiment 3 ("Feeling similarity"), effect sizes of the body maps ("Bodily maps"), and mean ratings from experiment 2 ("Bodily saliency", ''Mental saliency', "Valence", "Controllability", "Last experienced", "Touch").

Results

Experiment 1, embodiment of love types

In the first online experiment the subjects were shown words signifying various types of love, and an initially blank silhouette of a human body was presented with each love concept. The task of the subjects was to color the body silhouettes according to where in the body they felt the type of love in question.

Figure 1 depicts how the subjects embodied different types of love. Color-coded body areas show statistically significant effects. Love types are ordered according to the strength of the sensations (see Methods). The ordering reveals a progression from the types of love "felt" strongly and extensively across the body (passionate love, true love) to weaker embodiments (moral love, practical love). The rank-order of the stimuli based on the total amount of paint was highly consistent across 5000 split-half permutations (median Spearman correlation = 0.954, see Fig. S5).

Interestingly, all love types were reported to "feel" strongly in head. Another body area implicated strongly in most love types is chest, but this embodiment and its extent progressively decreases depending on the love type. Some love types, logically, involve genital areas, and some are "felt" in the whole body. True love, love for life and passionate love, were felt in the whole body. Some weakly-felt love types localized only to the head (e.g., love of wisdom and strangers, moral love, practical love).

Experiment 2, dimensions of love experience

In the second experiment the subjects were shown the same love concepts as words on a computer screen. Using a slider, they were asked to evaluate the feelings associated with each love type with the following criteria: 1) How strongly does it feel in the body (bodily saliency), 2) How strongly does it

feel in the mind (mental saliency), 3) How pleasant does it feel (valence), 4) How much can you control the feeling (controllability), 5) When did you last experience the feeling (last experienced), and 6) How strongly do you associate it with bodily touch (touch).

The data are presented in Figure 2 as probability density estimates. The most positive mean feelings were reported for sexual, romantic, reciprocal, true and passionate love. On average, the shortest time was elapsed since the experience of love of nature, and the longest time since the experience of love for god. Subjects reported that they have the least control over types of love related to kinship relations (father's and mother's love for their child, parental love). The love type experienced to be most under one's own control was self-love. Especially love types related to sexuality (sexual, passionate, romantic) were reported to have strong bodily feelings. These three types of love were also the highest rated love types in terms of their association with bodily touch. Based on the mean ratings for the 27 stimuli, the dimensions of bodily saliency, mental saliency, valence, and touch were highly positively correlated (Figure 3).

In the analyses where participants were excluded if they had reported to have last experienced the love types either a long time ago or never, the strong positive correlations between the mean ratings in dimensions of valence, bodily saliency, mental saliency, and association with touch were also evident. Notably, in these analyses, the dimension concerning when the feeling was last experienced had statistically significant negative correlations also with dimensions of bodily saliency and touch (see Fig. S7).

Experiment 3, similarity of feelings

In our third experiment, the subjects arranged the love types (again represented as words) on a computer screen. Their task was to drag the words on the screen with the mouse such that the types that were felt to be more similar to each other were placed closer to each other, and the types that were felt to be dissimilar to each other were placed further away from each other. Group level consistency of the Euclidean distances between the words was highly stable (median Spearman correlation = 0.947 in 5000 split halves of the data), although individual level correlations were considerably lower (median of subject pair Spearman correlations = 0.175, median p-value of Mantel tests 0.013).

The data were subjected to cluster analysis, and the average similarity data was visualized with multidimensional scaling. Density-based spatial clustering of applications with noise (DBSCAN) found two top-level clusters in the similarity data that we termed i) Interpersonal love and ii) Love for ideas and nonhuman animals (Figure 4). Interpersonal love consists of the types of love where the object of love is by definition or by implication

another person, whereas love for ideas and nonhuman animals involves love for non-human entities and abstract objects. Within the interpersonal love cluster, types of love associated with romantic relationships have small distances with each other (Figure 4., see also Fig. S10). The remaining love types of the interpersonal cluster include mainly types of love associated with non-sexual human relationships. Within these non-sexual types of interpersonal love, we observe small distances among the types of love associated with one's family ("parental love", "love for one's siblings").

Discussion

Our experiments provide the first mapping of similarities between different types of love conceived as embodied feelings. Even though the psychological, philosophical and theological literature abounds with various taxonomies of love, experimental emotion research has thus far mainly proceeded as if love was a singular emotion, feeling state, or sensation (Campos et al., 2013; Cowen et al., 2019; Nummenmaa et al., 2014, 2018). Here we expand on the previous research, providing evidence for a more nuanced and broader picture of feelings of love. We endorse a pluralistic, commodious perspective on the different love types, which, besides interpersonal love, also includes types of love that are felt for non-human objects (Halko et al., 2017; Shpall, 2016). Taken together, the open set of types of love can be conceived to form an overall "love system" (Fredrickson, 2016).

Some recent psychological approaches to interpersonal love make the case that love is not necessarily bound up with romantic or parental relationships, but can be felt in any interpersonal relationship. The affective interaction associated with interpersonal love may consist of "positivity resonance" experienced through "micromoments" of shared positive emotion and biobehavioral synchrony mediated by the oxytocin system in close social interaction (Fredrickson, 2016). The feelings associated with (interpersonal) love may be based on the activation of neural attachment networks, such that the difference between the degrees of intensity of interpersonal love varies according to the familiarity of the parties in the interpersonal relationship (Feldman, 2017).

Our study points toward a gradation of feeling of different love types in a taxonomically open framework consisting of an indefinite amount of subtypes of love (cf. Cowen & Keltner, 2017; Cowen et al., 2019; Nummenmaa et al., 2018). The loves that refer to biologically more salient contexts (romantic and sexual love, parental love) are more strongly felt than those types of love where the object is distant from the subject in terms of genetic continuity (e.g., love for strangers). The loves referring to a cognitive concept or an abstract entity (e.g., moral love, love of wisdom) are also more weakly felt. The intensity of subjective feelings ("embodiment strength") of love is likely to

be neurohormonally modulated, and further research may illuminate how the subjectively felt difference between, for example, love for one's children and love for strangers may correlate with a quantifiable difference in neural and hormonal activity.

It is noteworthy, that love types that were more similar in their valence, bodily saliency, and mental saliency, were also more similar in their topographical distribution of feeling in the body (see Figure 5). In experiment 2, we also observed strong correlations between the rating dimensions of bodily saliency, mental saliency, valence, and touch (see Figure 3). In these dimensions, many of the prototypical interpersonal love types (such as sexual love and romantic love) were highly rated and many of the non-prototypical and non-interpersonal love types (such as love for strangers and love of wisdom) low-rated (see Figure 2). Thus, the high correlations in experiment 2 (as shown in Figure 3) are explained by the fact that the prototypical love types were experienced strongly and rated more positively than the more abstract love types. The correlation between the mean ratings

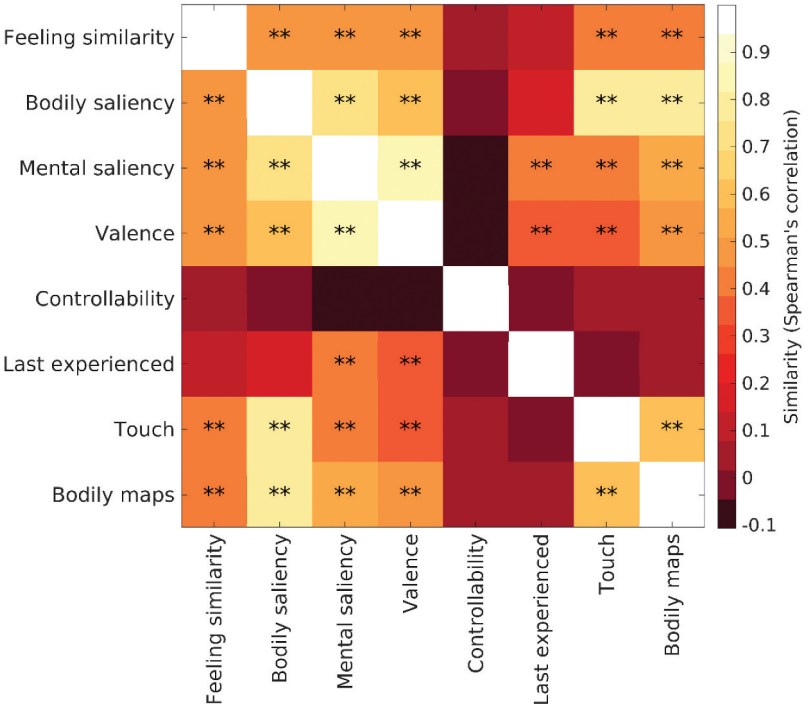

Figure 5. The heatmap shows the pairwise Spearman's correlations between upper triangles of distance matrices constructed from the different types of data from the three experiments. For distance measure we used Euclidean distances between the mean data for the 27 love types, based on the data from the similarity mapping (experiment 3), dimension rating (experiment 2), and the emBODY task (experiment 1, distances computed from effect sizes). Each cell in the figure shows the Spearman's correlation between the distance matrices, stars indicate statistical significance in a Mantel test (* $p < 0.05$, ** $p < 0.005$, p-values FDR corrected).

of bodily and mental salience is consistent with previous general findings concerning emotive sensations (Nummenmaa et al., 2018).

Types of interpersonal love vary in the strength of subjective attachment to the object of love (from love for romantic partners or one's own children to love for strangers). The prototypical love types often rated high in the main dimensions are precisely the ones associated with close attachments. That is, the types of love associated with close attachments appear to be more salient and pleasurable than types of love associated with more distant others or more abstract types of love. It is therefore warranted to infer that the measured dimensions of subjective experience capture at least some of the changes in subjective experience associated with the variability of the closeness of attachment related to different types of love. Future studies could investigate in more detail whether the dimensions addressed in our study are indeed fundamental dimensions of the experience space.

In general, the most distinct areas of subjectively felt bodily activation in different types of love are the chest and the head, which probably indicates changes in heart rate, respiration, and facial expressions including potential blushing (Nummenmaa et al., 2014). On the other hand, the feelings associated with more weakly felt types of love tend to be concentrated in the head. This may be due to subjects associating more abstract concepts such as wisdom or morality with the brain and higher cognitive functions (Atari et al., 2020). In a previous study (Nummenmaa et al., 2018), participants reported cognitive functions (e.g., thinking, reasoning, memorizing) to be associated with sensations in the head. Thus, it is possible that the results for the weakly felt love types reflect association with deliberate cognitive processing, and not emotive sensations per se. Also, it is possible that the weakly felt love types do not actually induce bodily feelings, and that the results are due to participants' expectations that they need to report at least some sensations for each stimulus.

Recently, alternative instructions for the em*BODY*-tool were used to measure valence-related sensations by asking the participants to report their feelings of heaviness and lightness (Hartmann et al., 2023). Love was shown to be associated with sensations of lightness across the whole body. An extension of our current experiments would be to measure valence-related body sensations associated with different love types. For example, as mentioned above, many of our weakly felt love types were mainly reported to be felt in the head: would these love types also be associated with positively valenced sensations in the head? This type of experiment might resolve the issue of whether the sensations reported here were related mainly to cognitive efforts or were actually felt as pleasurable sensations.

Moving from one's closest relationships toward love for strangers, the decline in reported bodily sensations is more pronounced in the chest. This may be explained by the feeling of love for strangers being subjectively less

salient (possibly involving less change in heart-beat and respiration) and requiring more cognitive effort. This interpretation appears consistent with our subjects reporting the most biologically salient types of love to be the least in their own control.

The three most strongly felt loves of our body maps are "passionate love", "true love" and "love for life". As such, the term "passionate love" refers precisely to the most intense experience of love in the highly prototypical context of a sexual and romantic relationship. The high embodiment strength of "true love" and "love for life" may reflect the fact that "true love" represents a generic core of one's subjective emotive concept of love, and "love for life" may be considered the highest degree of subjectively felt survival salience. Interestingly, the most weakly felt loves (such as "love for strangers", "moral love", and "practical love"), which were also the least pleasurable and among the ones least associated with touch, were also outliers in the DBSCAN clustering of the similarity mapping data. Within interpersonal love the main distinguishing feature for similarity ratings appears to be the context of either a romantic or non-sexual relationship. The fact that the types of love for one's family members are more tightly clustered (in contrast with love for one's neighbors and one's friends), seems to imply a continuum of perceived similarity in non-sexual interpersonal love, such that experienced similarity of love increases or decreases on the basis of familial (or genetic) proximity, with love for strangers being the least similar. It can be noted that even though the DBSCAN clustering algorithm finds two clusters, that we termed "interpersonal love" and "love for ideas and non-human animals", the interpersonal love cluster could plausibly be further subdivided into two subclusters: "sexual interpersonal love" and "non-sexual interpersonal love". A different clustering algorithm could have found different clusters from those found with DBSCAN.

In this article, we use the term "types of love" to refer to the 27 love related stimuli, which in essence are various words connected with the word "love" in each instance. It should be noted, that our operational taxonomy of love types was not based on how the subjects themselves understand love and how they carve their experiences into different categories. Thus, the results might differ, if we would have included only love types that the subjects find personally meaningful. It should also be acknowledged, that some of our love terms, such as "sexual love" or "altruistic love", are closely related to terms like "sexual desire" or "altruism". Had we used these different terms instead of the love terms, it is likely that our results would be less similar across terms. We also emphasize that the presented results are group level (statistical) abstractions, and do not necessarily describe any given individual's experiences of love. Here, our aim was not to find universal categories or a rigid taxonomy of love types, but rather to survey how

the context and the object of love experience affect the reported subjective feelings. We believe the plasticity of human experience and imagination allow for love to be potentially felt for any object observed in the world or constructed by the imagination. Although the 27 types are not an exhaustive selection, they cover broadly the most prototypical types of love, and types of love that are often discussed in philosophical and religious traditions. We emphasize that even though the prototypicality of types of love associated with close interpersonal relationships has been established in previous research (Fehr, 1994; Fehr & Russell, 1991), our choice of the specific set of 27 love terms is not data-driven, and investigations of different less prototypical love terms could augment and/or complicate our results.

We suggest that "love" may be viewed theoretically as an open, "fuzzy", yet continuous experience category of potentially inexhaustible subtypes, held together by varying degrees of similarity of positively valenced emotional feeling (in harmony with Cowen & Keltner, 2017).

The generalizability of our results is limited by the demographics of the sample (Finns, mostly women, mostly young adults). For example, that "love of nature" was among the most frequently felt types of love may reflect the fact that Finland is one of the most forested countries in the world and unbuilt natural environments are both easily accessible and commonly visited by many Finns. The frequency of how often our participants have experienced some other types of love is likely underrepresented in our sample (e.g., parental love), and limits the strength of the conclusions that can be drawn. Although self-reported bodily sensations related to more established emotion concepts, such as joy and anger, have been shown to be quite consistent across many cultures (Volynets et al., 2020), it would be surprising if linguistic, cultural and demographic factors would not affect our results (Brooks et al., 2016; Jackson et al., 2019). Also, due to the convenience sampling and lack of monetary compensation for the participants, the data might be overrepresented with participants who find the study topic interesting. Although the split-sample analyses suggest that we have captured stable patterns at a group level, there also likely exists considerable individual variability in the feelings people associate with different types of love. For example, the concept of "love for God" might be practically non-existent for a non-religious person but elicit strong feelings in a religious person (see Fig. S11). A natural continuation of our study is to investigate individual differences more closely and collect data from different cultures and demographic groups.

For the multidisciplinary understanding of love the contribution of our study is two-fold. For philosophers and other humanist disciplines concerned with love, our study offers important empirical data on similarities and differences between the love types these disciplines have historically considered significant. For the science of love, our

results indicate that there is important variation between different love types, and it is therefore a conceptual oversimplification to discuss love as if it were a single, discrete emotion or feeling state. The context and object of love have influence on the feeling of love in question. Further behavioral and neuroscientific research may shed light on to what extent different types of love share similar neural activation patterns (Ortigue et al., 2010; Saarimäki et al., 2018), and what the relationship is between these patterns and the similarity of feelings associated with different types of love.

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Data availability statement

Because of ethical restrictions, we cannot share the individual level data openly. However, we can grant access to the data with a data transfer agreement between the involved institutions. Analysis code and group-level data can be found from: https://github.com/mtavast/Body-Maps-of-Love.

Informed consent

Before the experiments, the participants received general information about the study and were asked to provide an informed consent.

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