Defining Social Reward: A Systematic Review of Human and Animal Studies

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A Systematic Review of Human and Animal Studies

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Abstract

Social rewards are strong drivers of behavior and fundamental to well-being, yet there is a lack of consensus regarding what actually defines a reward as "social." Because a systematic overview of existing social reward operationalizations is currently absent, a review of the literature seems necessary to advance toward a unified framework and to better guide research and theory. To bridge this gap, we preregistered and conducted the first comprehensive systematic review of human and animal experimental studies that used the term "social reward", and charted existing operationalizations, revealing the implicit and explicit definitions used in the field. Stimulus characteristics and measures of social reward were extracted from a total of 384 studies encompassing 42,118 participants and subjects. We provide detailed summaries of these elements, stratified by species (human/animal) and study type (behavioral, brain imaging, pharmacological, and physiological). Two main aspects were found to account for most of the difference in operationalizations: the sensory richness of a stimulus (intimacy) and engagement in social interaction (i.e., the synchronous observation and action between at least two individuals; viz. immediacy). Drawing insights from second-person neuroscience approaches and theoretical models in the field of human-computer interaction, we propose that human and animal research can greatly benefit from considering these properties, as they have important theoretical and practical consequences for human and translational research, with far-reaching implications for neighboring research fields such as those pertaining to social media and the development of artificial intelligence.

Keywords: social reward, translational research, systematic review, animal, human

Public Significance Statement

Although social rewards are important for survival and wellbeing across many species, their specifics and neural bases remain poorly understood, possibly due to inconsistencies in how the concept is defined and measured within and across disciplines. This systematic review attempts to describe with an unpreceded level of detail the definitions of social rewards used in human as well as animal research. It shows that human studies rely heavily on unimodal (visual) stimuli and animal studies instead use sensory-rich real-life interactions. Such discrepancy may lead to problems in comparability across fields and limited ecological validity of the results. We, therefore, encourage scholars to increase the levels of immediacy and sensory richness of social exchanges in human research. Doing so will help to advance human and translational research on social reward, ultimately paving the way for a better understanding of what makes us “social.”

Defining Social Reward: A Systematic Review of Human and Animal Studies

Receiving a smile or a compliment or sharing a personal story with a friend are examples of social rewards. We are motivated to seek them out; they make us feel good, and they can reinforce our future behavior. Social rewards have been broadly defined as “rewards that appear in social context” (Báez-Mendoza & Schultz, 2013, p. 3) and “positive experiences (i.e., outcomes or interactions that we seek out) which involve other people” (Bhanji & Delgado, 2014, p. 4). Similar to non-social rewards such as food (Schultz, 2015), social rewards are extremely relevant for well-being, as demonstrated, for example, by mammals’ dependence on social contact for survival, growth, and reproduction (Atzil et al., 2018; Dunbar, 2016) and by the existence of a homeostatic system devoted to regulating our social needs (Matthews & Tye, 2019). Despite being a widely used concept that is relevant to understanding basic aspects of our sociality and deviations therefrom, the scientific community has not yet reached (or even actively pursued) a consensus on how to precisely define and operationalize the term social reward. Whereas we have a better understanding of the specificity of other natural rewards (e.g., fat or sugar make food more rewarding), the characterization of *social* in “social reward” remains vague. This poses a significant obstacle to investigating social reward in humans and across different species. Moreover, translational research is fundamental in bridging the gap between our understanding of fundamental neural processes and their practical applications in the real world. Indeed, animal models can be used as a tool for addressing causal hypotheses that are not easily accessible through measurement techniques employed in human studies. Eventually, this allows us to develop more targeted mechanistic interventions in human research, leading to advancements that ultimately enhance our overall well-being. Nonetheless, if there are fundamental differences in the definitions and operationalizations of concepts within and across species, this will hinder the possibility of effective translation between them. Although the ecological profile of social rewards may differ more across species than that of other natural rewards (e.g., food), some key aspects of social interactions, such as physical closeness (Loseth et al., 2014), or interpersonal synchrony (Feldman, 2016), are shared across mammals, and translational research on social reward relies on these shared functionalities. Therefore, through this systematic review, we aim to present the most comprehensive overview of what is referred to as “social reward” in both human and animal research, and ideally foster a consensus within the field regarding the fundamental characteristics that define a reward as “social.”

Challenges for Translational Research on Social Reward

Unlike for other species, social reward in human research can be seen as an umbrella term covering a very broad range of stimuli. For example, smiles (Lin, Adolphs, et al., 2012), attractive faces (Spreckelmeyer, Rademacher, Paulus, & Gruender, 2013), signals of social approval (Izuma et al., 2008), or interpersonal sharing (Soutschek et al., 2016) have all been commonly used to demonstrate the rewarding value of social signals. In this tradition, the rewarding value has been operationalized at the neurobiological level as increased activity of the mesocorticolimbic circuit and especially the striatum (Bhanji & Delgado, 2014), and at the behavioral level as the willingness to pay, or to engage in various forms of effort, to gain access to these rewards (Izuma, 2015). A similar operationalization of social reward is often used in research with non-human primates, for example by measuring their willingness to sacrifice food to obtain a social reward and the primate’s brain activity during reward consumption (Báez-Mendoza & Schultz, 2013). In contrast, studies in rodents have defined social reward quite differently, for instance through behaviors such as play, grooming, and huddling (Trezza et al., 2010), and typically operationalize it using a set of highly standardized social learning paradigms including place conditioning, operant lever-pressing tasks, and T-maze paradigms (Trezza, Campolongo, et al., 2011).

Although interspecies social differences inevitably result in different operationalizations of social reward, some differences in operationalizations can create challenges when attempting to generalize underlying shared brain mechanisms involved in social reward processing. For example, we know that passive observation and social interaction result in very different patterns of brain activity – a finding that marked the beginning of a paradigmatic shift and the development of a ”second-person” neuroscience

(Schilbach et al., 2013). Similarly, recent evidence shows that symbolic and experiential rewards are valued differently in decision-making processes, suggesting different underlying brain representations (Garcia et al., 2023). Both of these findings are directly relevant for translation of social reward paradigms across species, and especially when creating social reward stimuli. Although it is true that both stimuli and measures are exclusive to and utilized depending on the particular species under study (for example, measures that require verbal communication are specific to research with humans and more invasive observations are used in animals; Der-Avakian et al., 2015), disparities in operationalizations persist even when behavioral tasks are used to investigate the same reward concept across species (Pool et al., 2016). The development of paradigms that are more comparable across species has been suggested as a main approach to advance translational research (Prounis & Ophir, 2020). This points to the necessity to compare and identify key differences and overlaps in social reward operationalization across species, both in terms of measures and stimulus characteristics, in order to advance the translational efforts on the topic.

To date, published reviews have discussed the translatability of brain activity acquisition techniques in the context of social reward research (Grimm et al., 2021). Similarly, researchers have discussed the translatability of experimental paradigms employed to investigate general reward concepts, such as motivation, reward evaluation, reward learning, “wanting,” and “liking” (Der-Avakian et al., 2015; Pool et al., 2016). Still, the comparability of operationalizations of social reward across different species is not adequately addressed in the existing literature. Notably, the development of unifying conceptual definitions and operationalizations of social reward across species constitutes a crucial aspect that warrants further attention.

Existing Conceptual Definitions of Social Reward

Although a comprehensive systematic literature review is currently lacking, there have been a number of efforts to delineate the defining dimensions of social rewards in humans. Drawing on brain research into social cognition across species, Baez-Mendoza and Schulz (2013) proposed two main dimensions of social reward that can be formulated as responses to the questions “who acts?” and “who receives?” For instance, when observing rewarding images, an individual both acts and receives; when receiving a gift, the other person acts and the individual receives, and when sharing money with someone, the individual acts and the other person receives (Báez-Mendoza & Schultz, 2013).

Tamir and Hughes (2018) suggested two main approaches to study social reward in humans. The first is to *decontextualize* social cues to discover “basic building blocks” of social motivation, that is, stimuli that are rewarding in their own right, with no or minimal context. Examples of such stimuli are smiling faces, social presence, or one-way information sharing. The second is to *recontextualize* social cues to understand the key contextual factors that determine reward value (e.g., social closeness of a partner or being observed by others while doing good deeds). According to the authors, studying contextual factors helps provide an understanding of the ultimate goals of social reward seeking (i.e., why we seek social contact), which can be linked to evolutionary theories (Tamir & Hughes, 2018).

Finally, a multidimensional approach by Matyjek et al. (2020) proposes that social and non-social rewards in human research differ along eight dimensions: primacy, temporal proximity, duration, familiarity, source, tangibility, naturalness, and magnitude. The authors argue that these dimensions can be used to better match social rewards to other rewarding stimuli such as money or food. Being shared between different reward types, these dimensions still do not address the question of what *social* means in the context of “social rewards,” and thus they cannot provide guidance on defining their specificity. For instance, there is no agreement on what constitutes a primary and what a secondary social reward. According to some authors, although acquired early in life, social rewards are not primary but rather constitute secondary rewards that fulfill basic needs such as the need for food or shelter (Atzil et al., 2018; Dunbar, 2016). Other authors claim that some social rewards are stimuli we are biologically predisposed to prefer, such as happy faces (Farroni et al., 2007; Reid et al., 2017) and touch (Della Longa et al., 2021), and could thus be considered as primary. With respect to contextual factors, the research to date is likewise marked by opposing views. Some researchers argue that social rewards must exist in the (at least minimal) context of social interaction, that is, that intention and direction from the reward sender to the receiver is a prerequisite for social reward (Krach et al., 2010; Matyjek, Meliss, et al., 2020), and others believe that some basic stimuli, prioritized in bottom-up processing (e.g., Hornstein et al., 2016; Pfabigan & Han, 2019), can hold rewarding value in the absence of a real social interaction context (Tamir & Hughes, 2018).

Present Study

Whereas existing discussions provide some guidance for navigating the field of social reward research, a systematic review of existing experimental operationalizations of the term “social reward” is currently lacking. Such a review is essential in order to classify and synthesize the existing operationalizations of social reward and to provide a guiding resource for researchers studying social reward experimentally. Moreover, it will also allow for a better understanding of the challenges in social reward research faced by the growing fields of translational and comparative research. Rather than using a working definition of the latent concepts (that may encompass various terms), this review focuses on the term “social reward” itself, aiming to show how different authors in the field operationally define it. We believe that assessing how the term is used in the field is an important stepping stone toward creating a shared framework of the latent concept that partially overlaps with other, related terms such as “social value” or “social incentive.” Some might argue that focusing on a single term, such as “social reward,” comes at the expense of giving a less comprehensive overview of the field. For example, studies similar to the ones included in this review might not explicitly mention the term “social reward” or they might use related (or, as some might argue, synonymous) terms (e.g., “social incentive,” “social reinforcement”). As a consequence, groups of authors and research traditions that consistently use these terms (and not “social reward”) do not figure in our sample. The aim of our study is to give a systematic overview of the literature that was created within a research tradition based on the term social reward. Within supplements (see Supplement 1; S1), we show through bibliometric analysis that (a) this body of research is indeed quite distinct from other bodies of literature that use (seemingly) related terms, and (b) that focusing on social reward as a focal keyword is the most appropriate from a translational perspective (animals, humans). We further discuss the ramifications and limitations of this approach as well as results from this bibliometric analysis transparently within the Limitation section.

In this preregistered systematic review (https://osf.io/nbd4y), we aimed to address three main questions:

1. What operational definitions (in terms of measures and stimuli) of social reward exist in experimental studies in humans and animals?
2. How do existing operationalizations differ between studies in humans and animals?
3. Which higher-order categories or dimensions can be extracted to organize the different types of social rewards within and across species?

To answer these questions, we charted operational definitions of social rewards, in terms of *measures* and *stimuli*, from 384 experimental human and non-human animal journal articles (henceforth referred to as human and animal studies) published through May 18, 2022. We coded the measures of social reward and the measurement techniques used, social reward stimuli, stimulus contents, and stimulus characteristics, enabling a comparison of existing social reward measures and stimuli within and between animal and human studies.

Method

Transparency and Openness

Our systematic review protocol was preregistered prospectively on the Open Science Framework (OSF; https://osf.io/nbd4y) before starting the literature search (2020, October 8), was amended prior to performing an update of the literature search (2022, May 18; https://osf.io/m498f), and was amended again during the manuscript revision (2024, February 5; (https://osf.io/q89nb). All deviations from the preregistration have been reported in the preregistration amendments and in the section Data Items and Transformation. There were no further deviations from the preregistration and its amendments. We adhered to the PRISMA (Page et al., 2021) and PRISMA-P (Moher et al., 2015) guidelines for conceptualizing, conducting, and reporting systematic reviews and systematic review protocols. All coding materials (a coding manual and a codebook), datasets, R syntax (R Core Team, 2023), and metadata to reproduce tables and figures reported in text and supplements are openly available (https://osf.io/cnhf4/).

Eligibility Criteria

Studies were included if they (a) were published in a peer-reviewed journal (irrespective of publication or data collection year) or as preprints on selected scientific preprint servers, (b) were written in English, (c) reported one or several experiments with human participants or animal subjects, and (d) referred to at least one stimulus or measure as “social reward” anywhere in the text. Other types of publications (e.g., theses and book chapters) as well as studies using only non-experimental methods (e.g., reviews, surveys, interventions, interviews) were excluded. As the main goal of this review is to scope operational definitions of the specific term “social reward” and avoid making assumptions about a latent shared concept that may be represented by similar terms (e.g., “social incentive,” “social value,” or “social reinforcement”), this criterion excluded studies that refer to their stimuli or measures by any other similar term. Studies that mention “social reward,” but do not do so in reference to their experimental paradigms, were also excluded. To gain an impression of how this body of literature overlaps or is distinct from bodies of literature using similar terms, see a bibliometric analysis of articles captured by our search term, as well as the related terms “social reinforcement” and “social incentive” (S1, Table S1, and Figures S1-S3). The results of this analysis are discussed in the Limitations section.

Originally, studies with human participants were included if at least part of the sample were healthy participants and adults or young adults (≥18 years old). During article revision, inclusion criteria were broadened to clinical samples and children/adolescents (<18 years old) and additional studies were introduced in the review. This change was amended in the preregistration (see Transparency and Openness section).

Information Sources and Search Strategy

A search for published journal articles was performed on *PubMed*, *Scopus*, and *Web of Science*[1], due to their broad coverage of the biomedical and social science literature as well as their suitability for systematic review searches (Gusenbauer & Haddaway, 2020). Additionally, preprints were searched on preprint servers for life sciences (*bioRxiv*), and psychology (*PsyArXiv*). All databases were searched on two dates, 2020, October 8 (covering the period from database inception until 2020, October 8) and, to update the first search, on 2022, May 18 (covering the period from 2020, October 9 until 2022, May 18). No database-specific filters (e.g., languages) or limits were set. Our literature search thus includes publications up to 2022, May 18.

As we were specifically interested in deriving definitions of the term social reward from the current literature, we only reviewed articles in which the authors claimed to have studied social rewards, irrespective of the authors' definition. Thus, our search strategy had only one keyword "social reward," that had to appear in the topic fields (title, keywords, or abstract). Variations of the keyword, such as "social rewards," "socially rewarding," and "prosocial rewards" were included through the use of database-specific truncation symbols (e.g., "*social* reward*"; for a full list of search strings per database, see S2).

Study Selection and Data Collection Process

Records were deduplicated using EndNote (Bramer et al., 2016) and unique records entered the selection process. We opted for a standard two-stage selection process with an initial title and abstract screening followed by an assessment of full texts (Page et al., 2021). In the first selection stage, titles and abstracts of the records retrieved from the first search (i.e., 2020, October 8) were screened by two independent raters consisting of AS and IB or one of them with a trained research assistant. Titles and abstracts of the records retrieved from the second search (i.e., 2020, May 18) were screened by AS and AK. In the second

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[1] All databases the University of Vienna library was subscribed to on the date of search, including *Web of Science Core Collection*, *BIOSIS Citation Index*, *BIOSIS Previews*, *Current Contents Connect*, *Chinese Science Citation Database*, *Data Citation Index*, *Derwent Innovations Index*, *Inspec*, *KCI-Korean Journal Database*, *MEDLINE*, *Russian Science Citation Index*, *SciELO Citation Index*, and *Zoological Record.*

stage, two raters (AS and IB for the first search and AS and AK for the second search) reviewed full texts and provided reasons for rejection based on the aforementioned criteria (1 – 6; see S3 for more details on study selection). During the article revision, the rejected abstracts and full texts were screened by the first author for inclusion of studies performed on children, adolescents and clinical samples.

All studies eligible for inclusion retrieved from the first search, which make up 61% of all studies coded in this review, were coded by two pairs of independent raters, consisting of AS and a trained research assistant, and IB and AK, between 2021, February 20 and 2021, August 18. Interrater agreement was calculated using percentages of agreement and Cohen's Kappa on a sample of 24 studies coded by AS and IB before proceeding to code the remaining studies and was deemed sufficiently high (Cohen's κ: $M = 0.73$, range [0.29,1], percentage agreement: $M = 84.02$, range [50, 100]; see S4 for more details on interrater agreement). Studies included from the second search were coded by AK and validated by AS between 2022, June 17 and 2022, September 9. No automation tools were used during the data collection process. We originally excluded 92 studies that were included during manuscript revision and were coded by pairs of independent raters between 2024, January 29 and 2024, March 4, following the same coding procedure from the original search. Interrater agreement was calculated on a sample of 25 studies by AS and AK (Cohen's κ: $M =0.49$, range [0, 1], agreement: $M = 91.71\%$, range [66.67, 100]). See S4 for more details on the data collection procedure for all stages. The manuals used in study selection and data collection is available on the study's OSF page (https://osf.io/8gz9e).

Data Items and Transformations

The main aim of the present review was to chart existing operationalizations and definitions of the term social reward and their use in different experimental settings. Therefore, the focus was on characteristics of social reward stimuli and measures of social reward. All collected items were categorized into three groups: (a) study and population characteristics, (b) measures collected in these paradigms (including direct measures of social reward processes, such as motivation to acquire or reward learning), and (c) social reward and control stimuli used in experimental paradigms. A list and descriptions of all recorded variables can be found in our openly available codebook (https://osf.io/wqvab).

Several variables were recoded and/or grouped post-data collection (see Amendment to study preregistration; https://osf.io/m498f), as these transformations allowed for a more effective representation of the data. Transformations are reported together with the respective data items, and further details are available in the supplements (S5). Data items for which information was missing were marked as “not stated” for all variables. In the data synthesis, these fields were treated as missing values and were not considered for summary statistics. The same applied for items marked as “not applicable” for a given stimulus/measure.

Study and Population Characteristics

We recorded the country of data collection and whether the study also included a clinical sample (model of clinical disorder for animal studies) and/or a child/adolescent sample (yes/no). Characteristics of the study sample were also recorded, including species, race/ethnicity (for studies with human participants), age, gender (proportion of female participants), and sample size. Type of each study was recorded using data-driven categorization that was decided upon by consensus after piloting the coding sheet and included the following types: behavioral, brain imaging, brain physiology, peripheral physiology, pharmacology, genetics, and lesion. Importantly, with the exception of behavioral studies, studies including multiple methodologies could belong to more than one category (e.g., a study that used both pharmacological manipulation and brain imaging was categorized as both). After data collection, we reduced the number of categories to four: behavioral, brain imaging, pharmacology, and physiology. Both brain imaging and pharmacology encompass some brain physiology studies, depending on whether the brain was pharmacologically manipulated or whether markers of brain activation were recorded. The categories genetics and lesion studies were excluded, as there were very few corresponding studies, and given that these studies belonged to at least one more category. See S5 for descriptions of each study type. We chose these four categories because they represent the main fields that investigate social reward, namely experimental psychology (behavior and self-report measures), neuroscience (brain imaging), psychopharmacology (pharmacological manipulations), and psychophysiology (measures of peripheral physiology). Given the lack of shared conceptual definition of the term social reward, we expected operationalizations to differ depending on fields and different methodologies they use. Moreover, previous reviews on measuring reward across species argued that using different measurements shapes translatability of the reward concept that is measured (Der-Avakian et al., 2015). Therefore, we considered the methodology used to study social reward as one of the key variables. We always present our data stratified by study type, and sometimes also by more specific measurement techniques described in the next subsection.

If a study included more than one independent experiment with independent samples, we coded only the experiments that included at least one stimulus or measure that was directly referred to as "social reward." Only samples from coded experiments were then counted into sample information reported in results. Within each study, unique tasks or paradigms including social rewards were coded only once (i.e., if more than one experiment included the same task, this task was coded once). Task names and short descriptions were recorded for these tasks. Stimuli and measured items were nested under the respective tasks.

Measures of Social Reward

All measures collected within tasks that contained social rewards were recorded. Items for each measure included the measure name (e.g., liking, preference, motivation, attentional bias), whether the concept was stated in the study authors' or raters' words, its content (e.g., rating, accuracy, response time), whether it was a direct measure of social reward, whether it was statistically tested by contrasting a social and a non-social condition, and whether it was statistically tested by contrasting a reward and a non-reward condition. If a measured concept was not clearly stated by the authors, raters used task description and the context of the whole article to code the measured concept item. A measure was defined as a *direct measure of social reward* if the measured concept was identified as part of the social reward definition, anywhere in the text. Examples include reward liking, motivation to obtain reward, approach behaviors, brain activity during reward consumption/anticipation, or learning of reward value. Remaining measures were categorized as indirect if the effect of social reward was tested but the measure was not an aspect of social reward (e.g., cognitive control, trust, or prosocial behavior) and as uncategorized if the effect of social reward was not tested (e.g., amount of food consumed, or choices concerning monetary rewards). Indirect and uncategorized measures, as well as information on which statistical tests were performed for each measure, are not discussed in the Results section and can be found in the open data files.

Direct measures of social reward (hereafter referred to as “measures of social reward”) were grouped into a reduced number of themes (see S6 for details on theme extraction). The themes were hierarchically organized into three categories: anticipation phase, delivery phase, and learning measures. Anticipation phase themes refer to measures relating to the anticipation of social reward, including (in alphabetical order) behavioral measures (accuracy/reaction time, approach behavior, effort, and payment for reward), brain activity, eye movement, facial movement, peripheral physiological responses, and self-report measures (ratings). Delivery phase themes refer to measures relating to delivery of social reward, including behavioral measures (amount of reward and social interaction behaviors), brain activity, eye movement, facial movement, peripheral physiological responses, and self-report measures (ratings). Learning themes refer to measures of social reward learning, including brain activity, conditioned preference, discrimination learning, operant/instrumental learning, Pavlovian learning, and reinforcement (associative) learning (see openly available codebook for definitions of each theme; https://osf.io/wqvab).

Social Reward Stimuli

Social reward stimuli were defined as any stimulus the authors referred to as “social reward” anywhere in the text. Wherever possible, we retained the authors’ own words describing the social reward stimuli. If this was not possible, the name of the social reward was instead assigned by the rater (and recorded as such). This was the case when text contained a statement that “social reward” was measured and/or manipulated in the given study but there was no direct reference to a stimulus as “social reward.” In these cases, positive social stimuli in the task in which “social reward” was manipulated and/or measured were coded as social reward stimuli (e.g., "social interaction" in Hung et al., 2017 or "happy faces" in Radke et al., 2016). We also recorded contents of social reward stimuli or what they consisted of (e.g., image, text, access to a conspecific animal).

Social reward stimuli and their contents were synthesized into a reduced number of themes (see S6 for details on theme extraction). The final list of social reward stimulus themes included (in alphabetical order): affective sound, affective touch, biological motion, body, face, feedback on performance, feedback on self, gestures of approval, humor, joint attention, observing other (without interaction), physical closeness, play, prosocial actions, sexual stimulus, smile, social closeness, social interaction, social support, and status. The list of social reward content themes included: action, conspecific, image, movie, smell, sound, spoken word, text, and touch (see openly available codebook for definitions of each theme).

In addition to the definition and contents of the social reward stimuli, we recorded a list of social reward characteristics that we considered relevant for the operationalization of the concept, partially drawing on previous dimensional approaches to social reward (Báez-Mendoza & Schultz, 2013; Matyjek, Meliss, et al., 2020). The reward characteristics included (a) familiarity (whether reward content is novel or familiar; for humans, familiar was split into two categories: close person and acquaintance); (b) sensory modality[2] (visual, auditory, tactile, olfactory, multimodal, or not applicable); (c) tangibility (in presence, on screen, abstract); (d) direction (whether the reward was received or given by participants); (e) duration (length of reward presentation); (f) unit of reward presentation (e.g., trial, session, task); (g) number of reward presentations; (h) announcement (whether the reward was announced); (i) delivery time (whether the reward was delivered immediately, delayed, or

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[2] Notably, taste never appeared in the operationalization of social rewards.

never; if delayed, length of delay); (j) number of manipulated levels of reward magnitude; and (k) short descriptions of reward levels (if more than one). The variable sensory modality was re-coded into several binary variables based on whether or not the reward includes a certain modality: visual, auditory, tactile, olfactory, and no sensory modality (see S5 for more details). Some of the variables were deemed redundant (i.e., unit of reward presentations, number of reward presentations, announcement, and levels of magnitude) and were not used in the final analysis (see S5 for justification); these variables can be found in the openly available data files. In the final stage of data synthesis, a higher order variable stimulus category was extracted based on social reward theme codes with four exclusive categories: observation, 1-way exchange (received), 1-way exchange (given), 2-way exchange, and imagined/abstract (see S6 on details on extraction and definitions of variable levels). This variable was coded by the first author and validated by a senior author GS.

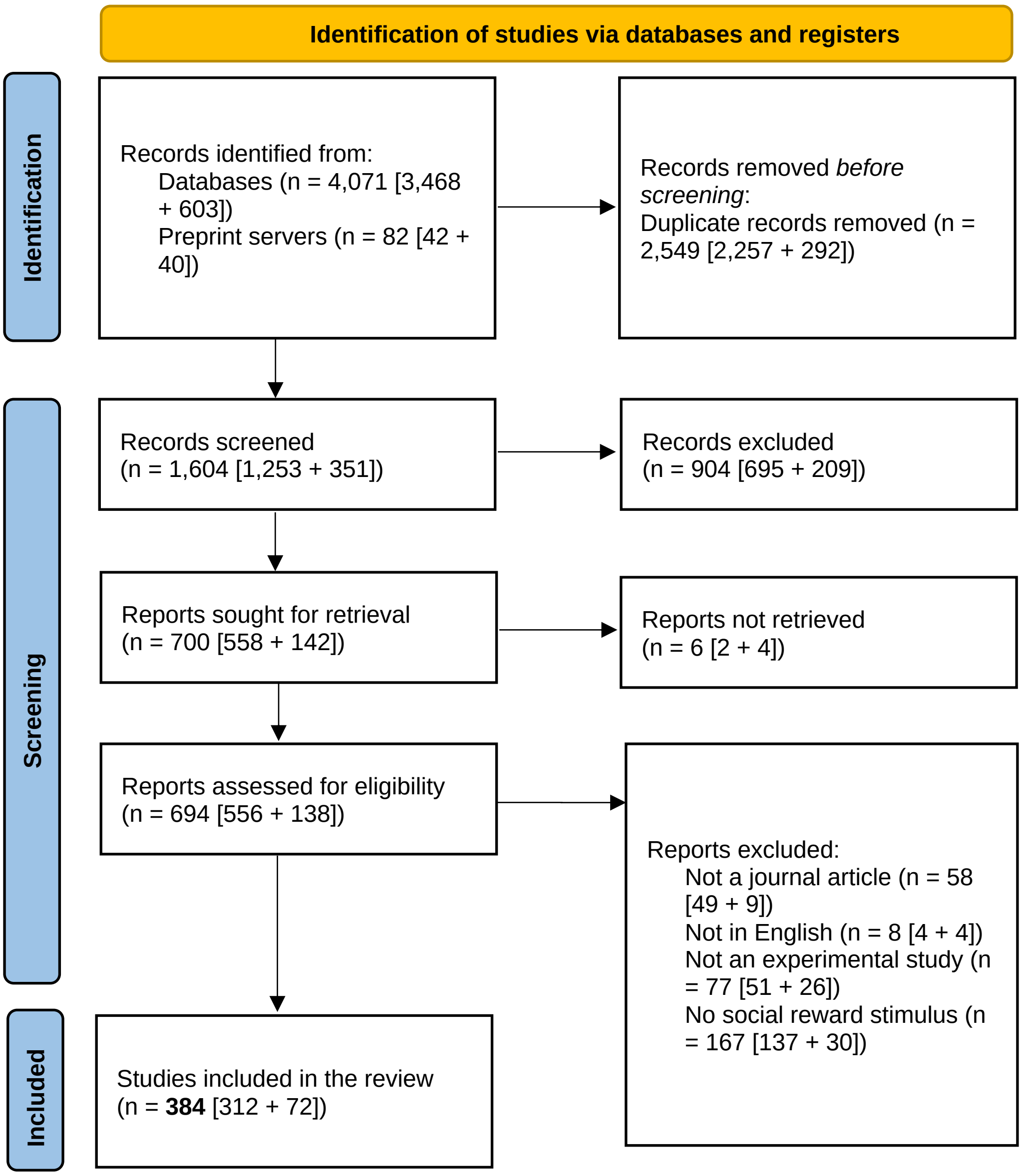
We also recorded control stimuli in all tasks that included social reward stimuli (see S7 for details on coded characteristics and themes). As these data are beyond the scope of the present manuscript, the results are reported in the supplements (see Figure S5 and Figure S6).

Risk of Bias Assessment

We did not undertake a quality, risk of bias, publication bias, or certainty assessment, as the focus of our review was on definitions and operationalizations of social reward regardless of study quality, rather than on statistical effects and effect strength.

Figure 1

PRISMA Flow Chart



Note. The first number in square brackets in each box refers to studies from the first search, published until 2020, October 8, and the second number refers to studies from the second search, published between 2020, October 9 and 2022, May 18.

Results

Study Selection

Our study selection process is depicted in Figure 1. The first literature search (2020, October 8) yielded 3,468 articles retrieved via database searches (*PubMed* = 549, *Scopus* = 923, *Web of Science* = 1996) and 42 from preprint servers (*bioRxiv* = 22, *PsyArXiv* = 20).

After deduplication, we screened titles, abstracts, and keywords of 1,253 articles and assessed full texts of 556 of these studies for eligibility. The final number of studies included from the first search is 312. In the second literature search (2022, May 18), 603 records were identified from the databases (*PubMed* = 125, *Scopus* = 258, *Web of Science* = 220) and 40 from the preprint servers (*bioRxiv* = 11, *PsyArXiv* = 29). Titles, abstracts, and keywords of 351 articles were screened both for inclusion criteria and dates of publication, and of these, 138 full texts were assessed for eligibility. The final number of studies included from the second search is 72. Thus, a total of 384 publications were included in our review.

Study and Population Characteristics

The majority of studies included human samples (72%, 276 studies). Of these, the majority were brain imaging studies (56% of human studies) and the majority of animal studies were pharmacological (57% of animal studies; see Table 1). Of the studies performed in animal samples, most encompassed rodent species (79% of animal studies), dogs represented 7%, non-human primates 6%, and fish 6% of animal studies (see Table S2 for details on study samples). Throughout this article, human studies will be compared to all animal studies grouped across species.

With regards to human samples, the majority of studies were performed in North America (41%; 36% in the United States) or Europe (30%; see S8 and Figure S4 A). From the 28% of human studies that reported ethnicity, an average of 57% (SD = 27.92) of study samples identified as white. These results overall point to an overreliance on WEIRD samples (Western, Educated, Industrialized, Rich, and Democratic, Henrich et al., 2010) in human social reward research.

Table 1

Distribution of Study Types in Humans and Animals

Study type	% human studies (number of studies)	% animal studies (number of studies)
Behavioral	34 (94)	27 (29)
Brain imaging	56 (154)	35 (38)
Pharmacological	7 (20)	57 (62)
Physiological	9 (25)	8 (9)
Total number of studies	276	108

Operationalization of Social Rewards in Animals and Humans

To address our first research question, we outline existing measures of social reward, social reward stimuli, and their characteristics in humans and animals. For a full list of stimuli and measures, see the open data (https://osf.io/cnhf4; see “README.txt” for guidance). Results on control stimuli used for comparisons with social rewards are reported in the supplements (Figure S5 and Figure S6). As operationalizations of social reward are mainly defined by the methods available to measure them in different species, we first introduce measures of social reward, followed by an analysis of the social reward stimuli.

Measures of Social Reward

In human studies, most measures of social reward were collected in the reward delivery phase (in 68% of studies), followed by measures during reward anticipation (49%), and reward learning measures were the least frequent (14%)[3]. In animal studies, most measures were collected in the delivery phase (in 65% of studies), closely followed by learning measures (56%), and anticipation measures were the least frequent (32%).

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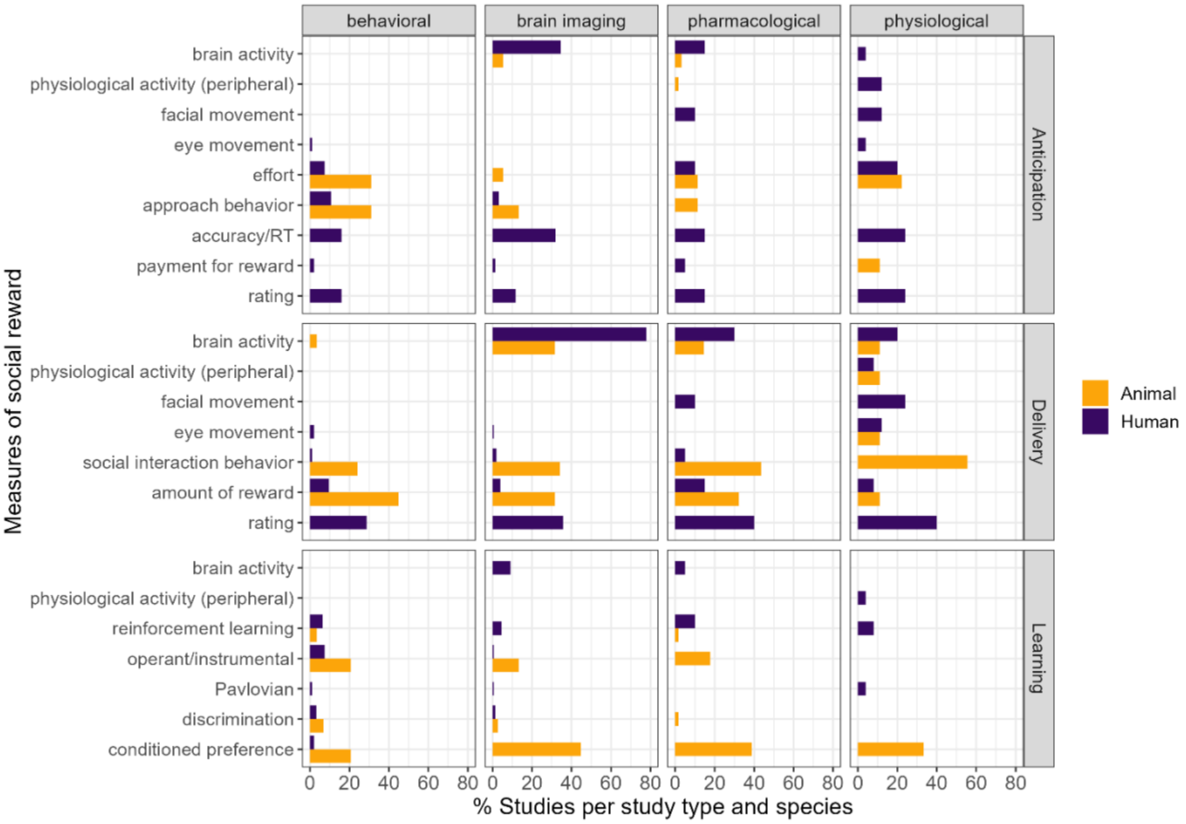
[3] Each measure was categorized as one measure theme, and each study could contain multiple measures. In text and figures, results are always expressed as percentages of studies that had at least one measure belonging to a certain measure theme. For example, if a study had an anticipation brain activity measure, an anticipation effort measure, and a delivery rating measure, this study was counted once in % of studies with anticipation measures and once in % of studies with delivery measures. When reporting specific measure themes within anticipation and delivery, the study was counted once for each theme (i.e., once for brain activity, once for effort, and once for rating).

Figure 2

Measures of Social Reward Across Study Types, Reward Phase, and Species (Human/Animal)



Note. Measures of social reward organized into a reduced number of themes and separated into three aspects of social reward: anticipation, delivery, and learning. Bars show percentages of studies per study type and species with each measure theme (e.g., top bar in brain imaging column represents % of human brain imaging studies that collected a brain activity measure during reward anticipation). In animal studies, the theme "payment for reward" refers to exchange of another reward for social reward (e.g., juice for pictures of conspecifics). RT = reaction time.

Anticipation. The most frequent measures during reward anticipation in humans were accuracy/reaction time (e.g., in target detection tasks) in 25% of studies, brain activity in 20% (of which 74% used functional magnetic resonance imaging (fMRI) and 26% electroencephalography (EEG)), and subjective ratings (e.g., motivation, wanting, or anticipated enjoyment) in 14%. Effort, approach behavior, payment for reward, facial movement, peripheral physiological activity, and eye movement were present in less than 10% of studies each. Of the animal studies, 17% measured effort, 16% measured approach behavior, and less than 5% measured brain activity and payment for reward (i.e., sacrificing another reward type for social reward; see Figure 2 and Table S3).

Delivery. In human studies, the most common measure during the delivery phase was brain activity (44% of human studies, of which 75% employed fMRI, 23% EEG, and 2% functional near-infrared spectroscopy (fNIRS)), followed by subjective ratings (e.g., valence, liking, or closeness; 34%). Amount of reward consumed, facial movements, eye movements, and social interaction behaviors (e.g., smiling behavior) were collected in less than 10% of studies each. In animals, 35% of the studies measured amount of reward consumed and social interaction behaviors each (e.g., grooming, play, or mating behaviors), and 13% brain activity. Eye movements and peripheral physiological activity were present in one study each.

Learning. Of the human studies, 6% used associative reinforcement learning, 5% used brain activity measures of learning (of which 79% comprised fMRI and 21% EEG), 3% instrumental learning, 2% discrimination learning, and 1% Pavlovian learning. By contrast, 34% of the animal studies used measures of conditioned (place) preference, 16% instrumental learning, 4% discrimination learning, and 2% associative reinforcement learning.

See Figure 2 and Table S3 for an overview for further stratification by study type for anticipation, delivery, and learning themes. For examples of tasks in which these measures were applied, as well as specific measures belonging to the themes, see the open data files on the study's OSF page (https://osf.io/cnhf4; see "README.txt" for guidance). For an overview of prevalence of indirect and uncategorized measures, see Table S3, and for respective examples, see open data files.

Social Reward Stimuli

Social Reward Themes. The most common themes in human studies were feedback on performance (51% of human studies[4]), face (49%), smile (39%), feedback on

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[4] Each stimulus was coded as one or more social reward themes and as one or more content themes. In text and figures, results are always expressed as percentages of studies that had at least one reward with a certain characteristic and/or theme. For example, if a study had a face picture and a body picture as social rewards, this study is counted once in the percentage of studies with the theme face and once in the percentage of studies with the theme body. If a study had two familiar

self (22%), social interaction (17%), gestures of approval (13%), status (8%), social closeness (7%), and prosocial actions (5%). The remaining social reward themes represented less than 5% of human studies each (see Figure 3A and Table S4). Ordered from most to least frequent, social reward content themes in human studies were image (photos, icons, or drawings; 59% of human studies), text (words, statements, or numbers; 24%), spoken word (words of approval or encouragement; 13%), movie (videos or animations; 10%), action (sharing, giving, donating, or gifting; 9%), conspecific (physically present other person; 8%), sound, and touch (each <5%; see Figure 3B and Table S5). See Figure 3C and D, Table S4, and Table S5 for further stratification by study type.

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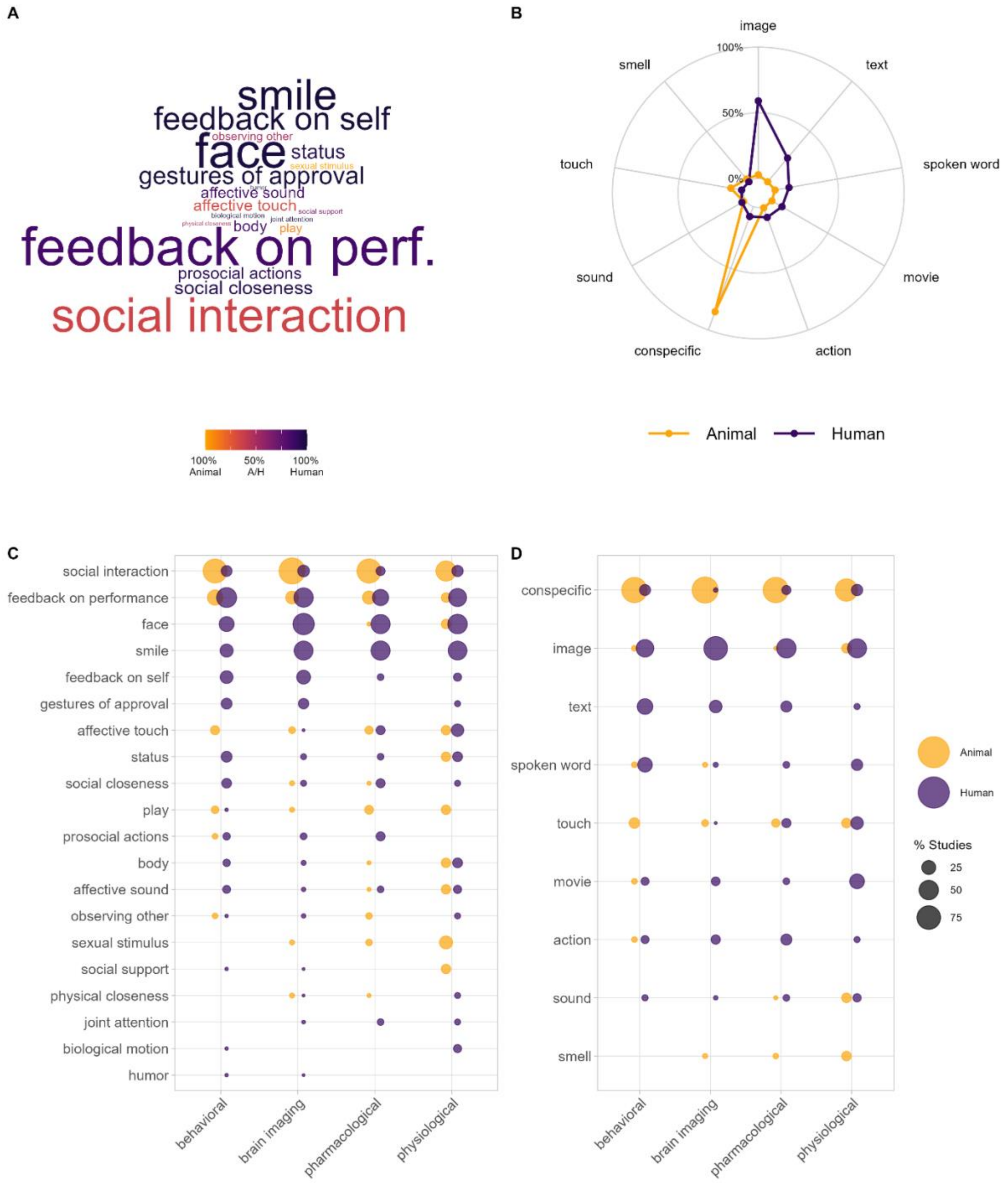
social rewards and one novel reward (e.g., in three separate experiments), this study is counted once in the percentage of studies with familiar stimuli and once in the percentage of studies with novel stimuli.

Figure 3

Social Reward Themes (A and C) and Social Reward Content Themes (B and D)



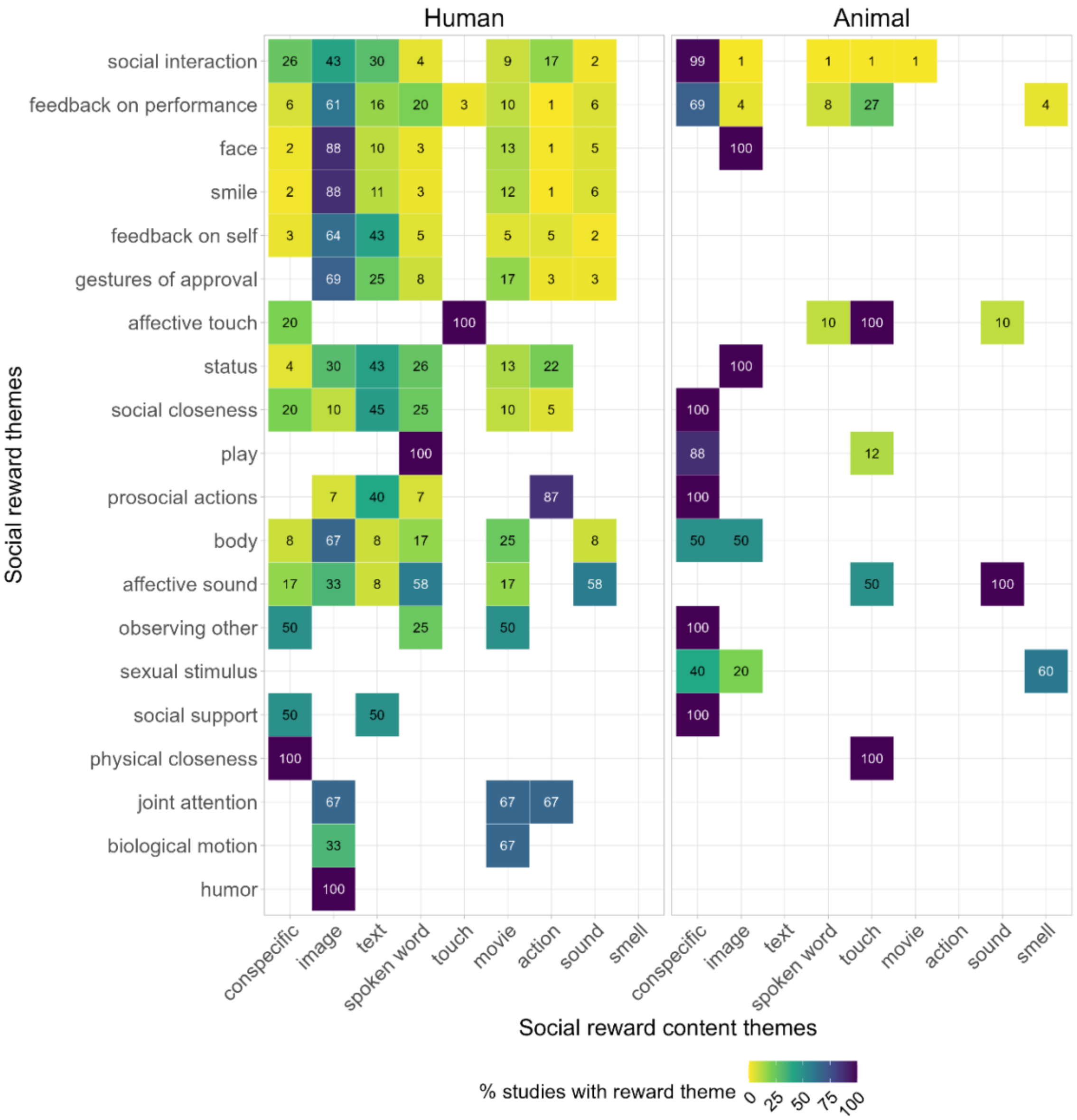
Note. Social reward themes and their content themes were extracted, respectively, from the names of the stimuli used in publications and the contents of which these stimuli were made (see S5 for theme extraction procedure). The figure represents: absolute frequencies of **social reward themes** and distribution across human vs. animal studies (A), percentages of human/animal studies across social reward **content themes** (B), percentages of studies per study type and species across **social reward themes** (C), and percentages of studies per study type and species across social reward **content themes** (D). Social reward themes in C and D were ordered by unweighted frequency of studies that contained them across humans and animals. For full tables with percentages, see Table S4 for A and C and Table S5 for B and D.

When looking at social reward stimuli and their contents together (see Figure 4), the social reward themes face, smile, and gesture of approval were usually represented by images (69-88% of studies with the themes; e.g., images of smiling faces or social media-like icons), but sometimes also represented by movies (12-17% of studies with the themes; e.g., videos of a person showing thumbs-up or animations of a smiling avatar), or accompanied by text (10-25% of studies with the themes, e.g., image of one's selfie together with the number of likes). Most of the stimuli with the themes feedback on performance and/or feedback on self were represented by images (61% and 64%, respectively, mainly smiling faces and thumbs-up signs). Feedback on self was sometimes also delivered as written text (43% of studies with the theme, e.g., statements of praise, agreement, or personal validation) and feedback on performance as spoken word (20%, e.g., experimenter voicing "Good!" or "Well done!"). Less frequently, they included movies, sound, or touch (see Figure 4 for all combinations of social reward stimuli and their contents). Social interaction was either mediated via images (43% of studies with theme) and/or text (30%), or it included physically present person(s) (26%). See Figure S7B for an overview of co-occurrence of social reward themes in human studies.

In animal studies, the most common themes were social interaction (80% of animal studies) and feedback on performance (24%), and the less frequent themes were affective touch (9%), and play (7%; see Figure 3A and Table S4). The most frequent content theme was conspecific (85%). Affective touch was social reward in 10% of studies. The themes image, smell, sound, spoken word, and movie were each present in less than 10% of studies (see Figure 3B and Table S5). Almost all social rewards consisting of a social interaction used one or more conspecifics as contents (99% of studies with this theme; see Figure 4). Feedback on performance also included conspecific in the majority of rewards with this theme (69%), less frequently touch (27%), and the least frequently spoken word, image, or smell (4-8%). Play included conspecific in 88% of the studies with this theme and touch by a human experimenter in 13%. Affective touch, in addition to touch, sometimes included sound and/or spoken word or sound (10% each).

Figure 4

Studies With Each Social Reward Theme Distributed Across Social Reward Content Themes in Humans (Left) and in Animals (Right)



Social reward themes	Human									Animal								
	conspecific	image	text	spoken word	touch	movie	action	sound	smell	conspecific	image	text	spoken word	touch	movie	action	sound	smell
social interaction	26	43	30	4		9	17	2		99	1		1	1	1			
feedback on performance	6	61	16	20	3	10	1	6		69	4		8	27				4
face	2	88	10	3		13	1	5			100							
smile	2	88	11	3		12	1	6										
feedback on self	3	64	43	5		5	5	2										
gestures of approval		69	25	8		17	3	3										
affective touch	20				100								10	100			10	
status	4	30	43	26		13	22				100							
social closeness	20	10	45	25		10	5			100								
play				100						88				12				
prosocial actions		7	40	7			87			100								
body	8	67	8	17		25		8		50	50							
affective sound	17	33	8	58		17		58						50			100	
observing other	50			25		50				100								
sexual stimulus										40	20							60
social support	50		50							100								
physical closeness	100													100				
joint attention		67				67	67											
biological motion		33				67												
humor		100																

Note. In each row, colors depict percentages of studies with a given social reward theme (e.g., first row and first column on the right represents % of animal studies with the theme social interaction that had conspecific as a content). Social reward themes and social reward content themes are ordered from highest to lowest overall frequency (across human and animal studies). Numbers in the tiles represent respective percentages. It should be noted that stimuli could have more than one theme and/or content theme. For example, a static image of a baby face may be presented together with baby laughter sounds.

Social Reward Characteristics. In human studies, the majority of social rewards included only the visual modality (71%, see Figure 5A for sensory modalities included in social rewards and Table S6 for unique combinations of modalities) and were delivered on screen (79%; see Figure 5D). Most of the rewards delivered in the presence of another person (15% of human studies) included all modalities except for tactile[5] (11% of human studies), whereas some included only one modality (4% auditory, 2% tactile). Rewards coded as having no modality (12%) were abstract and/or consisted of an action. Most of the rewards were novel (in 76% of studies; see Figure 5C), whereas some included acquaintances (18%) and close persons (10%). The average length of stimuli in human studies was 1.27 minutes (median 0.03 min, standard deviation 8.43 min, range from 0.0003 min to 93 min, see Figure 5B), and the majority lasted between 1s and 10s (58%, see Figure 5B). Most of the social rewards were delivered immediately (54%), many were delivered with a delay (in 45% of studies), and some rewards, usually abstract or imagined, were never delivered (6%; see Figure 5E). For delayed rewards in human studies, the average delay was 92.61 min (median 0.06 min, standard deviation 965.48 min, range from 0.004 min to 10,080 min). See Figure S7A for an overview of social reward characteristics for each social reward theme in human studies.

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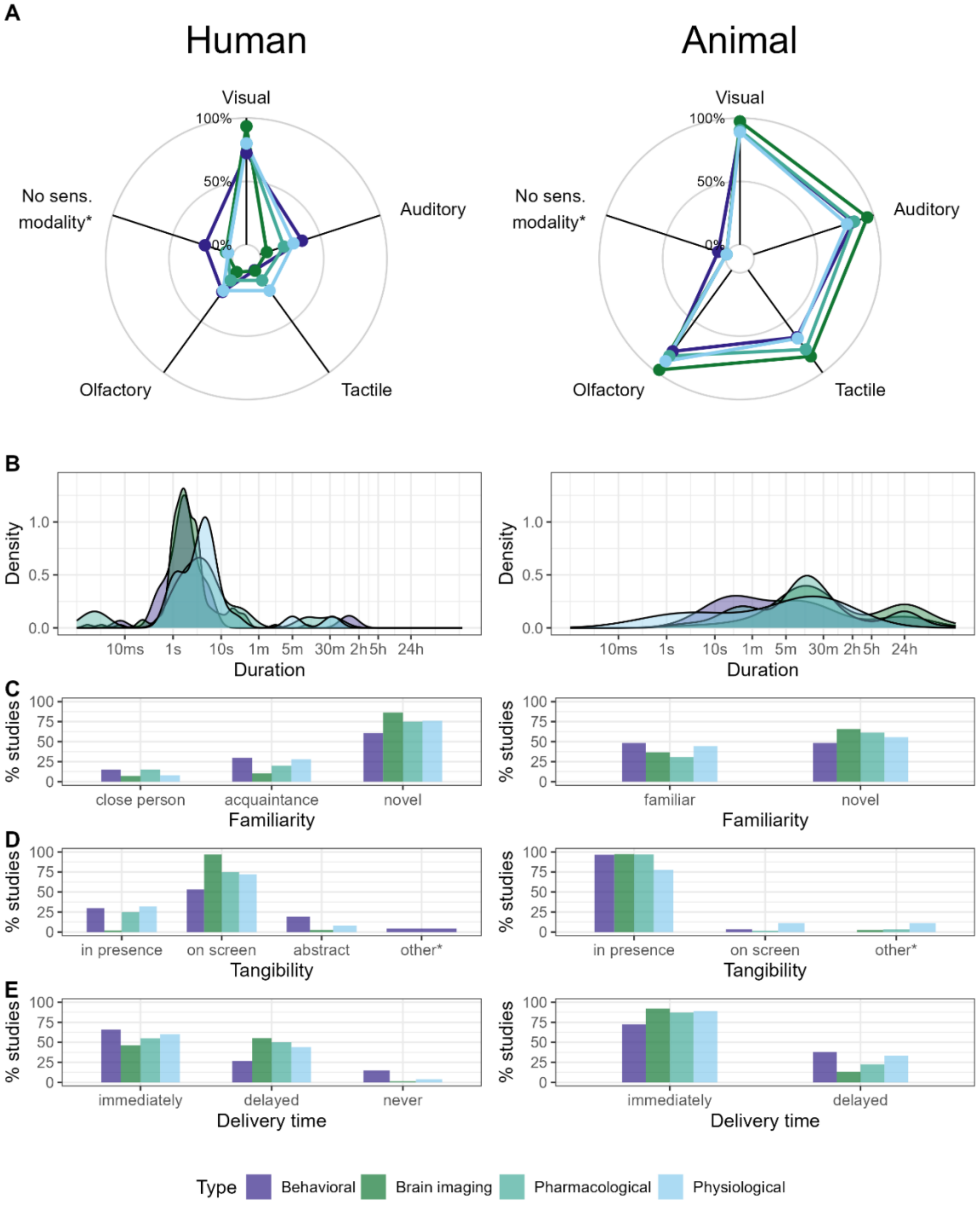
[5] Gustatory modality was not coded, see Method.

Figure 5

Overview of Social Reward Characteristics (A-E) for Humans (Left) and Animals (Right) Stratified by Study Type (Colors)



Note. Social reward characteristics: sensory modalities involved (A), duration (B), familiarity (C), tangibility (D), and delivery time (E). Percentages represent percentage of studies of a given species and study type. * Label “No sensory modality” refers to abstract rewards (e.g., hypothetical scenarios, a memory about a loved one) or situations in which social reward is an action of giving (e.g., sharing money with an opponent, donation to charity). For full table with percentages and percentages stratified only by species, see Table S6.

In most animal studies, social rewards included all modalities (70%; see Figure 5A and Table S6) and were delivered in the presence of another conspecific or a human (95%; see Figure 5D). In some animal studies, rewards were presented in all modalities but the tactile modality (15%) or only in one modality (17% of studies). Novel rewards were more common (57%) than familiar ones (38%; see Figure 5C) in animal studies. The average length of stimuli in animal studies was 344.62 min (median 10min, standard deviation 1,362.08 min, range from 0.01 min to 14,400 min; see Figure 5B) and stimuli were usually presented immediately (83%; see Figure 5E). Regarding animal social rewards that were delivered with a delay, the average delay was 16.94 minutes (median 0.17 min, standard deviation 70.64 min, range from 0.003 min to 300 min). See Figure 5 for further stratification by study type and Table S6 for full table with percentages (stratified by species only and by species and study type).

Higher-Order Grouping of Social Reward Stimuli

We grouped social reward stimuli into four larger groups that reflect the extent to which social interaction was involved in the operationalization of social reward, as this is one of the main characteristics that differentiated stimuli in human and animal studies. The categories rely on previous conceptualizations of social reward dimensions (i.e., “who acts” and “who receives”; Báez-Mendoza & Schultz, 2013), and “decontextualization” and “recontextualization” of social rewards (Tamir & Hughes, 2018). Social rewards included either no social exchange (passive observation), received one-way social exchange, given one-way social exchange, or two-way social exchange. As social rewards in animal studies were by far more homogenous in their characteristics, the categorization of animal stimuli is only briefly outlined for the purpose of comparison with human studies, whereas human stimuli are covered in more detail.

Animal Studies

A large majority of animal studies included social interactions with a conspecific or a human (82%) that were categorized as two-way social exchanges. In some studies (11%), rewards were passively observed (e.g., seeing conspecifics through blinded glass, images of conspecifics, or olfactory stimuli) or received in a one-way social exchange (when delivered as feedback on performance; 8%). Animal studies included a given one-way social exchange in 2% of the studies (exhibiting aggressive behavior and helping behavior).

Human Studies: No Social Exchange (Passive Observation)

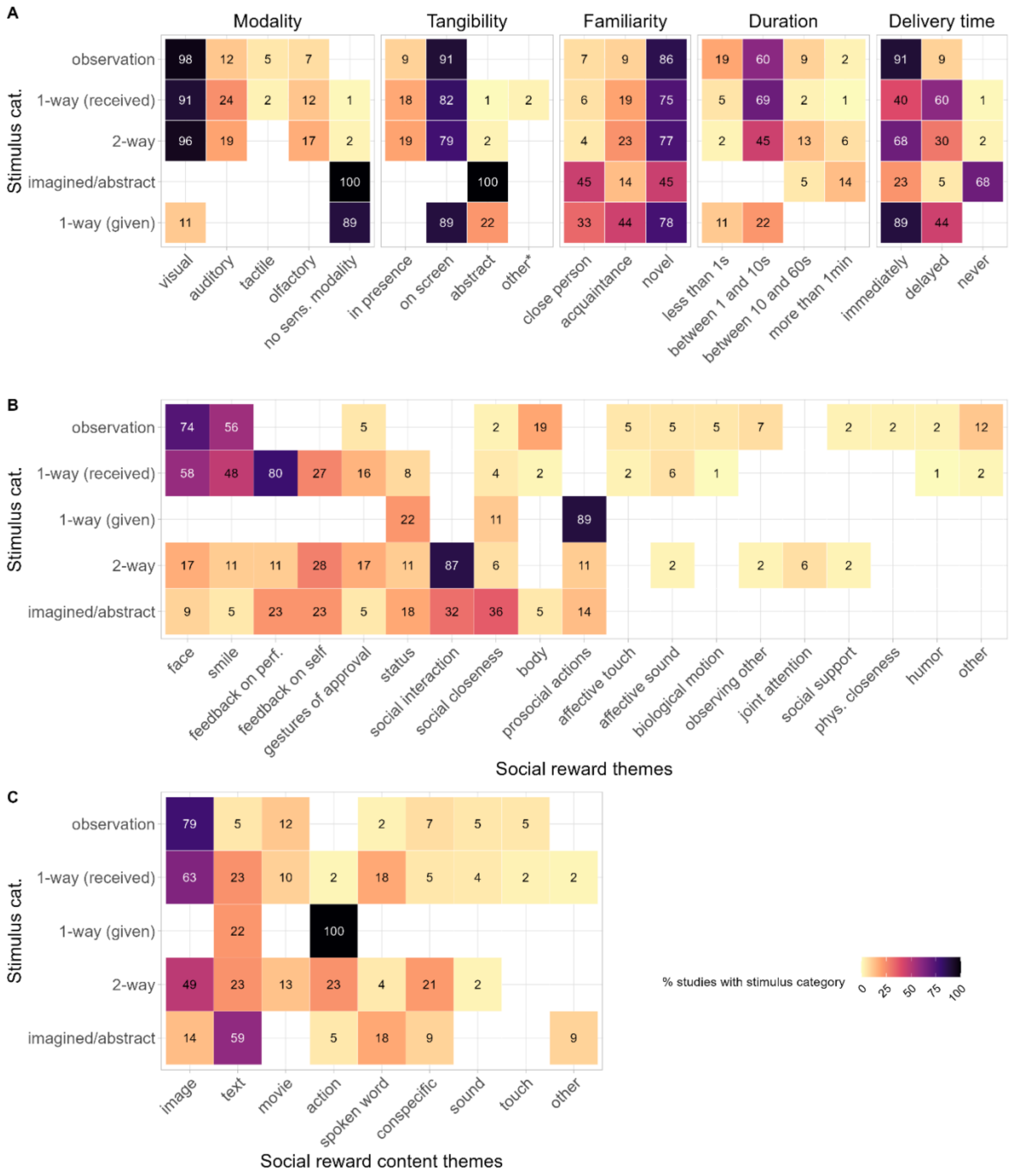
A proportion of human studies (16%) used stimuli that were presented without contingency to participants' responses and were not integrated into real or hypothetical social exchange. In these studies, participants both acted (i.e., perceived) and received, and stimuli represented "decontextualized" basic elements of social interaction. This group is dominated by the most common social reward themes, such as face (74% of studies in this group), smile (56%), and body (19%). Some of the less frequent themes were observing others without interaction, biological motion, affective touch, affective sound, approval gestures (see Figure 6B). In terms of their contents, they usually consisted of images (79%), movies (12%), or physically present others (7%; see Figure 6C). Almost all stimuli included visual modality (98%), and the majority were delivered on screen (91%), novel (86%), less than 10 s long (79%), and delivered immediately (91%; see Figure 6A).

Human Studies: Received One-way Social Exchange

The largest share of stimuli in human studies included one-way social exchange, in which social reward was received by participants (60% of studies) as one or more of the following: feedback on performance (80% of studies in this group), feedback on self (27%), and status (8%). These stimuli assume that an imagined (or real) person acts and the participant receives. The context of social interaction is minimal ("decontextualization"), whereas the inclusion of status and reputation also taps into long-term social goals ("recontextualization"). This group often included face (58%), smile (48%), or gestures of approval (17%), and less frequently, themes such as affective sound, affective touch, body,

Figure 6

Higher-Order Stimulus Categories in Humans Across Social Reward Characteristics (a), Social Reward Themes (B), and Social Reward Content Themes (C)



Note. Colors represent percentages of studies with a given stimulus category in humans that have each characteristic and theme. Numbers in the tiles represent respective percentages.

or social closeness (see Figure 6B). Feedback was commonly delivered as images (63%), text (23%), spoken word (18%), or movies (10%), and less commonly included conspecific, sound, or touch (see Figure 6C). Similar to the group that includes passive observation, these stimuli were mainly visual (91%), delivered on screen (83%), novel (75%), less than 10s long (74%), and delivered with a delay (60%; see Figure 6A).

Human Studies: Given One-way Social Exchange

In several studies (3%), social rewards were defined as an act of giving, in which the participant gives and an imagined (or real) person receives. Similarly to the previous category, these rewards include minimal context of social interaction (“decontextualization”), but sometimes also incorporating social goals such as status (“recontextualization”). The reward included prosocial actions in 89% of studies from this group (e.g., donations), status in 22% (informing others about one’s success), and social closeness in 11% (see Figure 6B). The content of these rewards was always action (see Figure 6C), most often incorporated in on-screen paradigms (89%), included novel individuals (78%), was delivered immediately (89%), and reward duration was often not given or not applicable (see Figure 6A).

Human Studies: Two-Way Social Exchange

Some studies operationalized social rewards through two-way social exchange (17%), which included any form of back-and-forth exchange between the participant and another person (imagined or real). These rewards included reciprocal giving and receiving between the participant and an imagined (or real) other person and were thus less decontextualized. Ultimate social goals, such as building social connectedness or status, could be included. Studies with such stimuli usually included the theme social interaction (87%) or joint attention (6%). Sometimes they also involved the feedback themes (11-28%), faces (17%), approval gestures (17%), smiles (11%), and prosocial actions (11%; see Figure 6B). Common social reward content themes include images (49%), text (23%), action (23%), conspecific (i.e., physically present person(s); 21%), and movies (13%; see Figure 6C). Although different modalities and tangibility levels were more represented than in other groups (19% included presence of others), visual modality and on-screen paradigms dominated this group (96% and 79% respectively), as did novel individuals (77%). In most of the studies, stimulus length was not reported, and rewards were delivered immediately (68%; see Figure 6A).

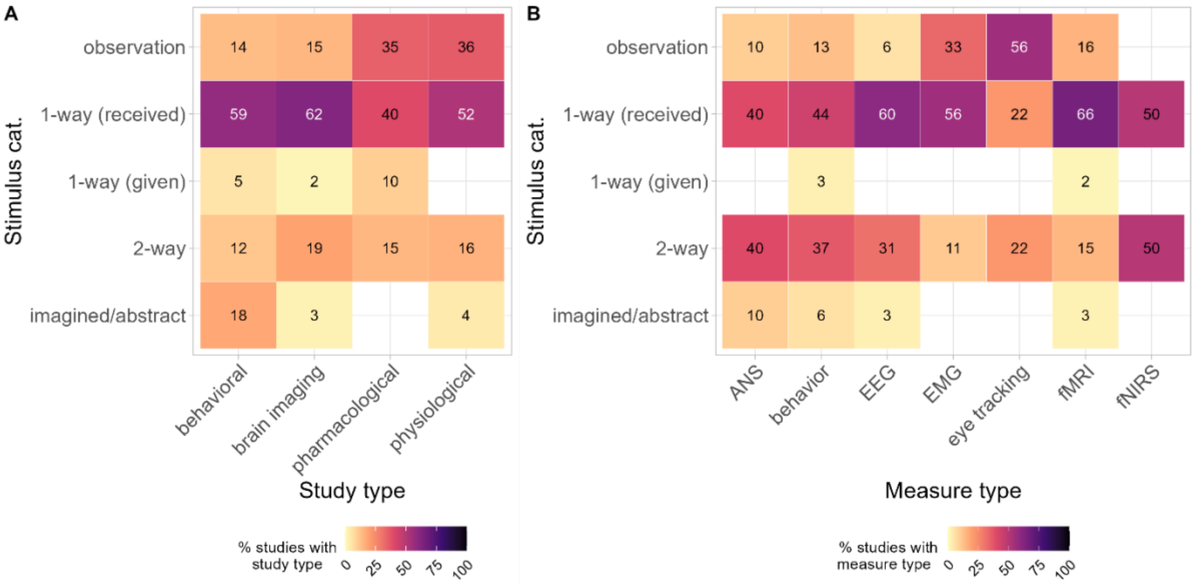
A considerable number of human studies (8%) included abstract rewards in which neither social exchange nor passive observation took place and are thus considered as a separate category that overlaps with the level of tangibility variable “abstract.” Interestingly, this group of studies had the highest prevalence of the theme social closeness out of all groups (36%), whereas imagined social interaction was the second most common theme (32%; see Figure 6B). Therefore, these stimuli often tapped into long-term social goals such as social connectedness, although participants neither acted nor received a real social reward.

Social Reward Stimuli in Humans Across Study Types and Measurement Techniques

After exploring social reward measures and stimuli separately, we also looked at how stimuli and their characteristics related to the methodology used to study social rewards in humans. We report the prevalence of different social reward themes, social content themes, and higher-order stimulus groups in different study types (behavioral, brain imaging, pharmacological, and physiological) and different types of measures (fMRI, EEG, and fNIRS for brain imaging, electromyography (EMG), eye tracking and measures of the autonomic nervous system (ANS) for physiological study types, and behavioral measures for all study types). For an overview of the prevalence of specific measure themes (listed in Figure 2) for each social reward theme, see Figure S8.

Figure 7

Higher-Order Stimulus Categories Among Different Study Types and Measurement Techniques

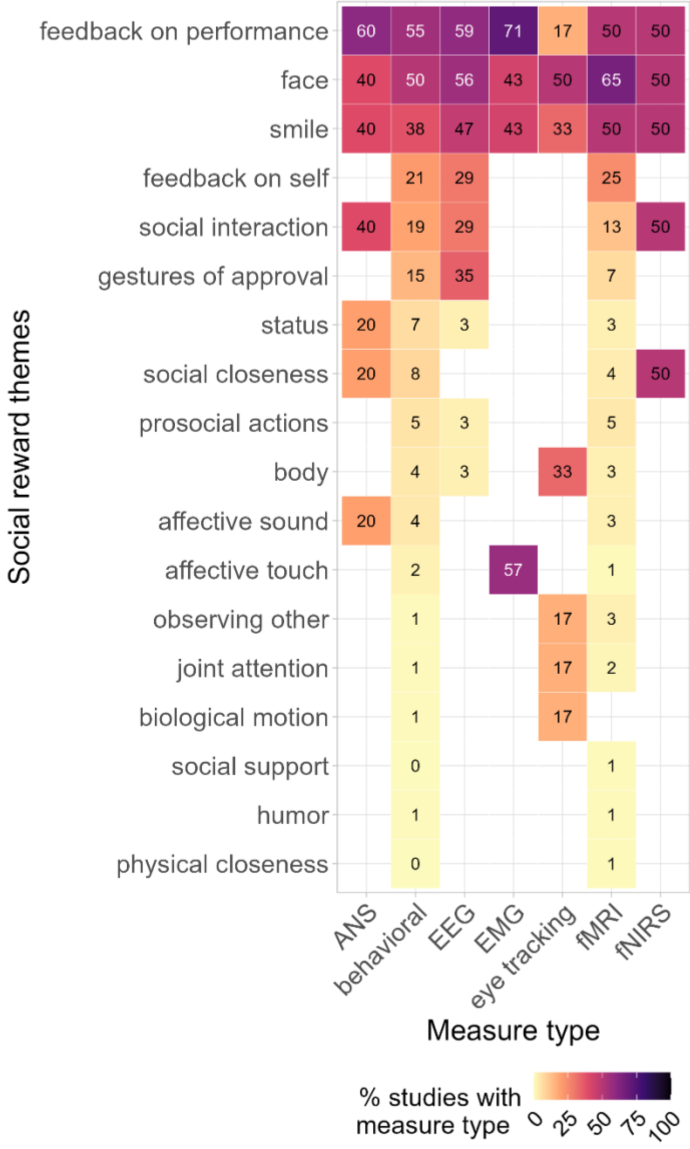


Note. Colors represent percentages of studies of each study type that included each higher-order stimulus group (A) and percentages of studies using each measurement technique that included each higher-order stimulus group (B). Numbers in the tiles represent respective percentages.

The most frequent study type in social reward research in humans was brain imaging (see Table 1). Of these studies, 73% used fMRI, 22% used EEG, and 1% used fNIRS to measure social reward-related activity (the rest did not have direct measures of social reward). Most of the social reward stimuli in brain imaging studies were classified as received one-way social exchange (62%), followed by two-way social interactions in on-screen paradigms (19%), and passive observation of social reward stimuli (15%; see Figure 7A). Faces were the most dominant theme in brain imaging studies (62% of studies), followed by feedback on performance (51%), smile (49%), feedback on self (25%), and gestures of approval (75%; see Figure 3C). In addition to faces and smiles, brain imaging studies also had the highest prevalence of social interaction (18%) among all study types. Stimuli were mostly represented by images (75%) and sometimes text (20%; see Figure 3D). With regard to individual brain imaging techniques, the most prevalent themes in fMRI studies were face (65% of fMRI studies), feedback performance (50%), smile (50%), and feedback on self (25%) albeit with a large variety of social reward themes appearing in a smaller number of studies each (e.g., social interaction, social closeness, or joint attention;

Figure 8

Techniques Used to Study Social Reward in Humans Across Social Reward Themes.



Note. Colors represent percentages of studies that used each measurement technique (here, measure type) to measure aspects of social reward in humans. For example, top cell in the column fMRI refers to the % of studies that measured social reward-related activity using fMRI and included faces as social reward stimuli. ANS measures include heart rate, electrodermal activity, and salivary cortisol. Behavioral measures of social reward refer to all study types, fMRI, EEG, and fNIRS to brain imaging studies, and ANS, eye tracking, and EMG refer to physiological studies. Numbers in the tiles represent respective percentages.

see Figure 8). Although feedback on performance, faces, and smiles were also the most common themes among EEG studies (59%, 56%, and 47% of EEG studies, respectively), gestures of approval had the highest representation among all measurement techniques (35%; see Figure 8). Two fNIRS studies included either social interaction or feedback on performance, smiling face, and social closeness.

Among the behavioral studies, received one-way social exchanges were the most common group of stimuli (55%, see Figure 7A). Feedback on performance (54%), face (29%), smile (22.34%), and feedback on self (21%) were the most common reward themes (see Figure 3C and Table S4), and images (40%), text (32%), and spoken word (28%) the most common content themes (see Figure 3D and Table S5). Nevertheless, behavioral studies also showed a higher variability in social reward themes (see Figure 3C) and social reward characteristics than did brain imaging studies (e.g., in sensory modality and familiarity; see Figure 5A and 5C). Of all study types, behavioral studies had the highest representation of social closeness (11.7%) and status (14.89%; see Figure 3C), but also of imagined/abstract social rewards (18%; see Figure 7B) that often included social closeness.

Most of the social reward stimuli in pharmacological studies were received one-way social exchanges (40%) or passively observed (35%), and the proportion of a given one-way social exchange was higher than in other study types (10%; see Figure 7A). These studies also frequently included the social reward themes face, smile, and feedback on performance (50%, 50%, and 35%, respectively; see Figure 3C), and the social reward content theme image (50%; see Figure 3D). However, compared to other study types, they had a relatively high representation of the themes of social closeness (10%) and prosocial actions (10%; see Figure 3C). Moreover, stimuli in pharmacological studies were most likely to include a close person (15%, see Figure 5C).

In physiological studies, measures of ANS activity (heart rate, electrodermal activity, and salivary cortisol), eye tracking, and EMG were used to measure social reward-related activity. Although, most physiological studies included one-way exchanges (52%) like other study types, they also had the highest prevalence of passive observation from all study types (36%; see Figure 7A). Whereas face, smile, and feedback on performance were the most common themes (52%, 48%, and 44%, respectively), physiological studies also had the highest representation of the less frequent themes, such as affective touch (20%), body (12%), biological motion (8%), and observing others without interaction; 4%; see Figure 3C). Physiological studies were the most likely to include a social reward delivered in presence

(32%, see Figure 5C). With respect to specific measurement techniques, ANS studies had the highest representation of status and affective sound from all measurement techniques (20% of ANS studies each) and, after fNIRS studies, the highest representation of social interaction (40% of ANS studies; see Figure 8). Studies with eye tracking predominantly included passive observation (67% of eye tracking studies, see Figure 7B), often with smiling faces but also complex visual stimuli such as full body images, biological motion, or observation in real life (see Figure 8). They also had the highest prevalence of joint attention, categorized as a two-way social exchange (17%, see Figure 7B). Studies including EMG showed the highest representation of affective touch stimuli (57% of studies using this technique), followed by images or videos of smiling faces (43%; see Figure 8).

Discussion

Given the lack of consensus regarding appropriate methods and concepts to study social rewards within and across species, we conducted a systematic review to chart existing operationalizations of the term social reward in experimental studies in humans and non-human animals. In the following discussion of our results, we first compare operationalizations of social reward between humans and animals and highlight implications for future translational research. Second, we propose two dimensions along which existing social rewards in human studies can be organized and that we find relevant for establishing specificity of social rewards and increasing the comparability of social reward stimuli across species. These dimensions are *immediacy*, that is the level to which operationalizations of social reward include a synchronous social interaction, and *intimacy*, that is the level to which sensory properties of social reward stimuli are close to real life (e.g., multisensory integration and physical presence).

Comparison of Social Reward Measures and Stimuli in Animal and Human Studies

Measures of Social Reward

The operationalization of social reward is mainly defined by what we are able to measure in different species and how we are able to do so. On the one hand, human studies rely on brain activity measures (mainly focused on reward-related brain regions; see Figure

2) and subjective ratings (e.g., of motivation, pleasure, valence, arousal, wanting, or liking; see Figure 2). On the other hand, animal studies operationalize social reward through learned preferences and observed social interaction behaviors (e.g., play behaviors, huddling, grooming, etc.; see Figure 2). A tendency to operationalize social reward in animals as (learned) behavior rather than as a stimulus explains the overrepresentation of behavioral learning measures and the underrepresentation of brain activity measures in animal studies (see Limitations). Our results indicate that some cross-species similarities exist in the measures of the anticipation and learning of social rewards – this is in line with the conclusions reached by a previous review on reward paradigms used in translational clinical research (Der-Avakian et al., 2015). Behavioral measures such as effort, approach behavior, or choice of social reward over alternative reward types have predominantly been employed in animal studies, but they have also been utilized in human participants (see Figure 2). Effort is operationalized in human studies as the number of key presses (e.g., Fussner, Mancini, et al., 2018) or the force exerted on a hand-grip device (e.g., Korb, Goetzendorfer, et al., 2020), which is comparable to effort measures used in the animal literature, such as the number of lever presses (e.g., L. Martin et al., 2014) or the degree of difficulty in overcoming physical obstacles (e.g., Bai et al., 2017). Approach behavior is frequently operationalized in humans as the selection of one reward over another stimulus (Soutschek et al., 2017), which is similar to the methodology employed in animal paradigms (e.g., discrete choice paradigms; Venniro et al., 2018). Some human studies have measured social reward motivation through monetary exchange, whereas exchanging food for social rewards is the preferred method in some primate studies (e.g., K. K. Watson et al., 2009, 2010). When it comes to learning measures (see Figure 2), certain human studies employing associative reinforcement learning and conditioning paradigms align closely with the reinforcement, discrimination learning, and conditioning paradigms employed in animal research (e.g., Haffey et al., 2013; Thompson & Westwater, 2017). Learning paradigms that are highly comparable across species have also been previously implemented for other reward types (e.g., food rewards, Pool et al., 2015). Nevertheless, learning measures were

by far a more frequent type of measure in animals than in humans (see Figure 2). As a result, comparing findings on social reward learning between humans and animals might prove challenging in most cases. Exploring the use of learning tasks in humans that are comparable to those employed in animal studies may be a promising pathway for advancing translational research in this domain.

There are also several differences between the measures used in the animal and human literature. Accuracy and reaction time are the most common behavioral measures during the anticipation phase in human studies (see Figure 2), as shown by the prevalence of paradigms in which social rewards take the form of feedback for simple motor or cognitive tasks (e.g., social incentive delay tasks (target detection), reinforcement learning tasks, attention tasks, and cognitive control tasks). However, these measures are not always intended as sensitive behavioral markers of reward anticipation per se, because sometimes, task difficulty is dynamically controlled in order to keep the proportion of accurate trials fixed (Dichter et al., 2012; Goerlich, Votinov, Lammertz, Winkler, Spreckelmeyer, Habel, Gruender, et al., 2017). Most human studies rely on brain activity and ratings (see Figure 2), whereas effort and approach behavior—the two most common measures in animal studies—are used less frequently (Korb, Massaccesi, Gartus, Lundstrm, et al., 2020; Matyjek et al., 2021). In human studies, participants typically provide subjective ratings of their experience of stimuli they have just observed (e.g., valence, arousal, closeness, liking, trust, and attractiveness), but in animal studies, social behaviors (e.g., grooming, nose contact, play behaviors, mating behaviors, exploratory behaviors, and huddling) are coded during social interaction (see Figure 2). Importantly, subjective ratings in humans can be considered as comparable to measures of conditioned preference in animals (e.g., of a place or a neutral stimulus) rather than to measures related to the reward delivery, whereas physiological measures such as facial EMG and eye tracking are used less commonly (see Figure 2). In terms of social interaction behaviors in humans, there are only two observational studies that coded reciprocated smiles during free interactions (Fairbairn, Sayette, Aalen, et al., 2015; Fairbairn, Sayette, Amole, et al., 2015). Given recent recommendations to develop more ethologically relevant paradigms in humans as a way to advance translational research (Prounis & Ophir, 2020), future studies should therefore strive to employ more observational paradigms.

Social Reward Stimuli

Having different phylogenetic histories and ecosystems, social interactions and thus social rewards widely differ between species. Nevertheless, although perfectly parallel operationalizations of social reward stimuli across species are not possible, some fundamental differences we observed may pose several concerns for translational studies, depending on the aspect under investigation (e.g., reward learning, “wanting,” or “liking”). The relevance of each difference depends on the questions and physiological mechanisms that researchers are aiming to investigate (not all differences will be relevant for all studies). In the following, we organize these differences around several discussion topics potentially relevant for translational research.

Observation vs. Interaction. One of the main differences is that most human rewards involve observation of unimodal sensory stimuli whereas most animal rewards involve dynamic interactions including observation of multimodal sensory stimuli and social actions (see Figure3 A-B, Figure 4, and Figure 5A). Human and animal rewards can also be similar in this regard, for example in human studies that involve real-life interactions (e.g., Philipp-Muller & MacDonald, 2017) and in the rare animal studies (e.g. with primates) that involve the presentation of pictures of faces (e.g., K. K. Watson et al., 2009). Humans, as a highly social species, are willing to work or pay for simple visual cues representing social stimuli, and such stimuli also activate reward-related brain regions (see Izuma, 2015 for a review). Nonetheless, authors hold opposing views on whether smiling faces can be considered rewarding even in the absence of any direct contingency with participants’ responses (Krach et al., 2010; Matyjek, Meliss, et al., 2020) or without additional salient characteristics such as attractiveness or closeness (Izuma, 2015). Our results show that the majority of animal studies rely on free social interactions between conspecifics (see Figure 3A-B and Figure 4), but unimodal social cues can be used as valid stimuli in some non-human species, such as primates and dogs (Boch et al., 2021; Munuera et al., 2018). Evidence from second-person human neuroscience approaches suggests that various aspects of the processing of our social world differ between mere observation and actual interaction (see Redcay & Schilbach, 2019 for a review). Therefore, matching social rewards across species on this characteristic may be crucial for some translational and comparative studies.

Symbolic vs. Experiential. Human social rewards often involve symbols such as gestures of approval (thumbs-up, 'likes'), words, or various elements of abstract games (e.g., winning points for another person), whereas rewards in animal studies are purely experiential (e.g., nose pokes, sniffing, grooming, huddling; see Figure 5A-B). Recent evidence shows that when individuals make choices between experiential and symbolic stimuli, their evaluation of the two options differs significantly, suggesting that the common currency hypothesis of a shared evaluation mechanism for all types of rewards does not hold when comparing experiential and symbolic rewards (Garcia et al., 2023). If the objective of translational research is to compare the mechanisms underlying the estimation of social reward value, it is crucial to strive to match experiential value between human and animal rewards.

Involvement of Higher-order Social Cognitive Processes. Social interactions between humans involve a higher level of cognitive complexity compared to most other species, because they require the use of higher cognitive abilities such as theory of mind, mentalizing, and joint attention—though it is worth noting that some non-human primates may exhibit partial exceptions to this observation (Krupenye et al., 2016). Social interactions are ubiquitous in everyday life, and some authors argue that theory of mind is a crucial factor for humans to derive rewarding value from these interactions (Krach et al., 2010; Matyjek, Meliss, et al., 2020). Therefore, experimental manipulations that make participants believe that another person is present in space and time are an effective means to increase the ecological validity of unimodal stimuli such as images or text (Alkire et al., 2018; Chakrabarti, 2013). For example, participants might be led to believe that their task responses will be assessed by a committee (Izuma et al., 2010b) or that a cooperation game partner is sitting in an adjacent room (Gromann, Shergill, de Haan, et al., 2014). Importantly, when participants believe that they are interacting with a real person rather than with a computer, they report greater enjoyment (Weibel et al., 2008) and show increased activation in reward-related brain regions (Pfeiffer et al., 2014). Yet, it is crucial to account for, and where necessary adapt, the cognitive complexity of social reward stimuli when comparing humans to species that lack the same cognitive abilities.

Transient vs. Long-lasting. This dimension is relevant for human-animal comparisons, in addition to social/non-social reward comparisons (Matyjek, Meliss, et al., 2020). Rewards such as smiling faces, feedback on motor performance, joint attention, or affective touch may be considered transient, that is, their effect is not likely to last for a long time after stimulus presentation. By contrast, some stimuli are designed to activate long-lasting social goals (called ultimate goals of social interactions by Tamir and Hughes, 2018) such as building or maintaining social connections (e.g., closeness building, Tchalova & MacDonald, 2020), status (e.g., downward comparison with others, Oikawa et al., 2012), or positive self-image (e.g., receiving ‘likes’ for one’s selfies on social media, Rosenthal-von der Puetten et al., 2019). In addition to being abstract and involving concepts that do not apply to most species, the timeline on which such rewards operate might render them less comparable to animal rewards. In some cases, however, animal rewards can also include relationship building (see later discussion on affiliative vs. reproductive rewards).

Primary vs. Secondary. Although social contact has long been recognized as a fundamental need and proposed as being regulated by a dedicated homeostatic system (Matthews & Tye, 2019), there has been little discussion regarding the primacy of social rewards (i.e. for which some sort of biological preparedness is expected). The fact that infants show a prioritization of certain stimuli such as faces (Farroni et al., 2007) or touch (Della Longa et al., 2021) shortly after birth has been taken as evidence that these are primary rewards. Furthermore, in addition to activating the mesocorticolimbic circuit, certain social rewards also recruit additional basic social-specific neural pathways, such as C-fibers specialized in affective social touch in primates and humans (Olausson et al., 2010). A meta-analysis of brain imaging studies in humans found that primary rewards (food and erotic stimuli) and a secondary reward (money) have partially different neural representations, with primary rewards leading to greater activation in the anterior insula (Sescousse et al., 2013). Because primary and secondary rewards may tap into partly different brain systems and because secondary rewards are prominent in human research but rarely used in animal studies, it may be important to better define this dimension of social reward in order to fully understand its human and non-human neural basis.

Affiliative vs. Reproductive. Rather than a point of divergence, the distinction between affiliative and reproductive rewards exists in both humans and animals, although animal studies often mix the concepts of social and sexual rewards (the theme sexual stimuli was present only in the animal literature; see Figure 3A and C). Human studies sometimes involve manipulations and measures of attractiveness (Spreckelmeyer, Rademacher, Paulus, & Gruender, 2013), or include romantic partners (Gere et al., 2013). Sexual rewards such as erotic images (Creswell et al., 2013) or body odors (Habel et al., 2021) are still not usually considered as social rewards in the human literature, whereas sexual stimuli such as copulation partners and odors have been referred to as social rewards in rodents (Bell & Sisk, 2013; Bialy et al., 2014). Research suggests that affiliative and reproductive rewards involve at least partially separate systems (Matthews & Tye, 2019). Therefore, these two reward types should be clearly delineated in future research, both within and across species boundaries. Finally, within affiliative rewards, familiar stimuli were less frequent in human than in animal studies (see Figure 5C). As we know that familiarity is one of the contextual factors that can increase the salience of social stimuli in humans (Inagaki et al., 2020), more research might want to consider including close others in experimental paradigms.

Defining Dimensions of Social Reward

Achieving greater comparability of operationalizations of reward across species is a necessary step in the development of translational research (Der-Avakian et al., 2015; Prounis & Ophir, 2020). We argue that two dimensions are especially relevant because they account for most of the aforementioned points of divergence between human and animal social reward stimuli and because they help define the specificity of social rewards in contrast to other types of rewards. The first is the extent to which participants are involved in social exchange (*immediacy*), which is underlined by our higher-order categorization of social reward stimuli into four categories: no social exchange (observation), received one-way social exchange, given one-way social exchange, and two-way social exchange. Our findings demonstrate that social rewards in animal studies mostly involve two-way social exchange, and human studies mostly include received one-way social exchange. The second dimension (*intimacy*) underlines the differences between human and animal studies in terms of sensory richness – with animal studies mostly involving physically present conspecifics and multisensory integration, and human studies mostly using unimodal visual stimuli.

These dimensions of immediacy and intimacy also build on previous theoretical accounts on social reward (Báez-Mendoza & Schultz, 2013; Matyjek et al., 2020; Tamir & Hughes, 2018). We directly map the leading questions “who acts?” and “who receives?” posed by Báez-Mendoza and Schultz (2013) onto one-way social exchanges where participants act (i.e., given one-way exchanges), receive (i.e., received one-way exchanges), or observe. Importantly, we take this notion one step further to differentiate reciprocal exchange (where both participant and another person act and receive), agreeing with previous comments on the importance of social interaction in defining social reward (Krach et al., 2010; Matyjek et al., 2020). Tamir and Hughes (2018) outlined two approaches to study social reward, “decontextualization” and “recontextualization,” stressing both the importance of isolating key characteristics of reward out of naturalistic contexts and studying higher-order goals of social connectedness. We argue that our dimensional approach enhances both approaches by demonstrating that different levels of immediacy and intimacy can be incorporated in a wide variety of paradigms (e.g., minimal social exchange like joint attention, as opposed to social closeness induction through asking intimate questions).

The dimensions originate from the concept of *social presence* (Argyle & Dean, 1965; Wiener & Mehrabian, 1968), which can be defined as the salience of another person through a communication medium or the subjective feeling that another person is in one's immediate environment (Cummings & Wertz, 2023). Whereas many dimensions of social presence have been proposed (see Cummings & Wertz, 2023 for review), we focus on immediacy*,* the level to which interaction is synchronous (Grondin et al., 2019; Wiener & Mehrabian, 1968), and intimacy or medium richness*,* the capacity of a medium to relay verbal or non-verbal information (Grondin et al., 2019; Wiener & Mehrabian, 1968).[6] In choosing these dimensions, we were inspired by recent work suggesting that social presence and empathy may be well-applicable and relevant for differentiating affective physiological and neural responses to social situations (Petereit et al., 2022). Moreover, the concept of social presence is widely used in fields of human-computer interaction and telecommunications as a problem encountered when building different forms of artificial intelligence (Sciutti & Sandini, 2017) or computer-mediated interaction platforms (Grondin et al., 2019). The concept can also be useful for defining social reward stimuli, especially given that social rewards are operationalized in experimental environments where the presence of another person is, at least to some extent, artificial. It is also important to note that these dimensions can be used to define any social stimuli and not specifically social rewards. As the definition of social presence states, these dimensions define the salience of the presence of another person, irrespective of the valence. Previous reviews already focused on defining reward characteristics that are shared between social and other reward types (Matyjek et al., 2020). Nevertheless, social reward specificity is not well established yet. By defining characteristics of stimuli that are uniquely social, we argue that these dimensions may be especially important for future efforts in defining social rewards as a primary/basic need.

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[6] Intimacy sometimes also refers to emotional intimacy of communication (Argyle, 1965), but for our purpose will refer only to its meaning as medium richness (to which our variables familiarity and social closeness refer).

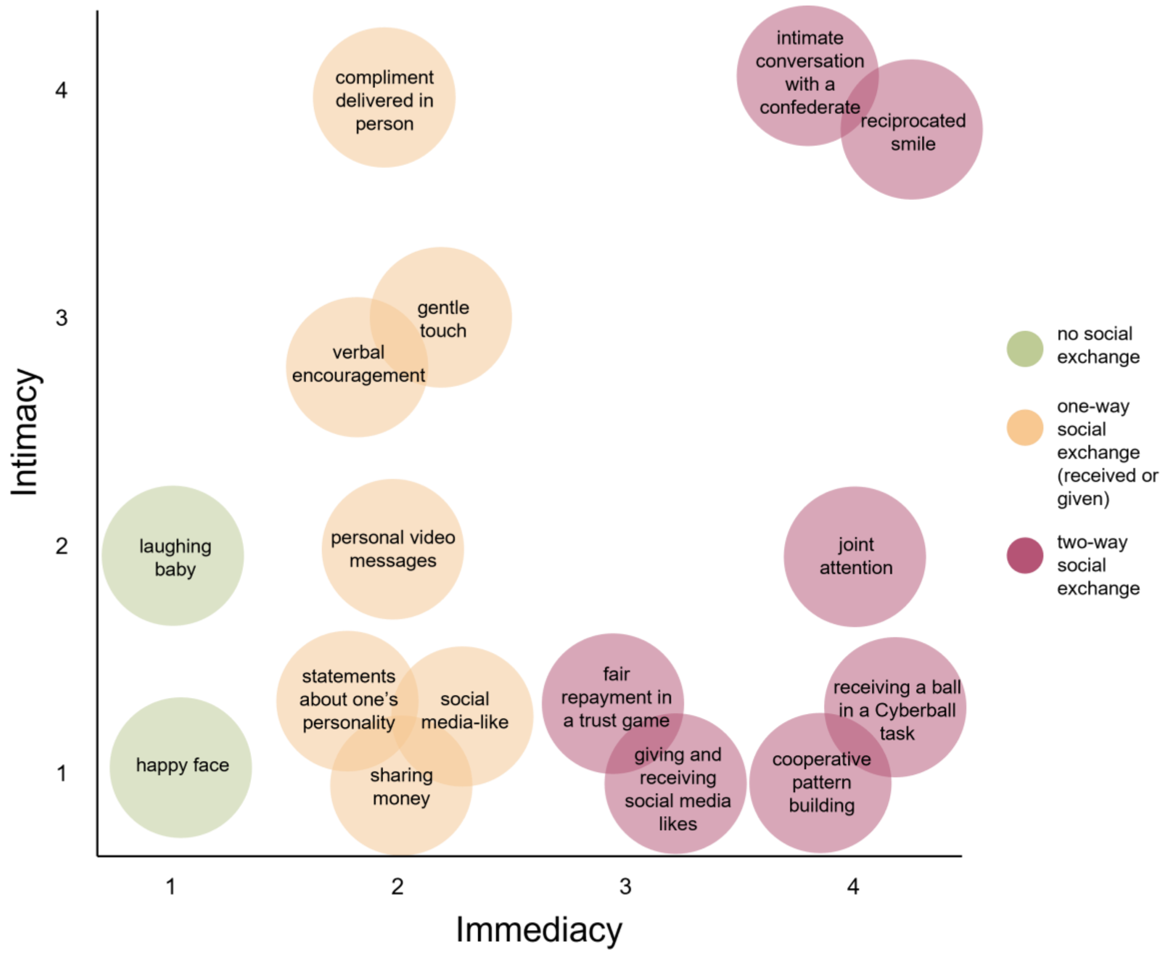
The closer the dynamics of interaction are to the dynamics of real-life communication between people, the greater the immediacy of a social reward (e.g., simultaneously texting as opposed to sending an email). The relevance of this dimension is supported by the research on interpersonal synchrony, which is described as the alignment of behavior of interacting individuals in a time-dependent manner and is argued to be the core characteristic of our social affiliation as a species (Shamay-Tsoory et al., 2019). Synchrony is a prerequisite for building closeness in babies, and it is enjoyable (Sabu et al., 2019) and it leads to greater feelings of connectedness in adulthood (Tarr et al., 2016). The importance of including real-life social interaction in neuroscience has been discussed in the context of a second-person neuroscience approach (Schilbach et al., 2013) and is supported by the finding that brain mechanisms involved in interactions are fundamentally different to those involved in observation only (see Redcay & Schilbach, 2019 for review). Still, the potential of second-person neuroscience for translational research has received little attention (Schilbach, 2016). Finally, previous reviews on social reward also stressed the importance of including more close-to-real-life interactions in human studies on social reward (Matyjek, Meliss, et al., 2020), also as a way to improve the translatability of animal studies (Prounis & Ophir, 2020).

The more information is received through a medium, for example through the integration of multiple sensory modalities (e.g., seeing a picture of a friend vs. holding their hand) and through observing dynamic as opposed to static stimuli (e.g., seeing a picture vs. a video), the greater the intimacy of a social reward. Indeed, as a social species, we are more prepared to receive social information that involves the integration of multiple senses (Scheller & Sui, 2022). Moreover, senses other than visual, such as touch (Taneja et al., 2019) and olfaction (Ravreby et al., 2022), are increasingly being recognized as primary pathways of social information processing. Nevertheless, our social world is increasingly being replaced by less sensory-rich and predominantly visual stimuli, such as video calls or social media, and we are only just beginning to understand how this affects our interpersonal interactions (Cañigueral et al., 2021; Orben & Przybylski, 2019). By manipulating the dimension of intimacy, we can gain insights into the distinctions between experiencing another person in physical proximity vs. encountering them remotely.

Stimuli previously categorized as not involving any social exchange (passive observation; see Figure 6) would be qualified with the lowest levels of immediacy and intimacy (see Figure 9 for examples). These stimuli often extract salient elements that are expected to retain their value when removed from the context of social interactions, such as smiles or biological motion. Increasing intimacy through sensory richness and naturalness may additionally increase their rewarding value, making them more experiential and thus comparable to animal rewards. For example, dynamic visual stimuli, as opposed to static ones, increase the activation of the mentalizing brain network that is usually involved in real-life interactions (Henry et al., 2021), and seeing live smiles on a screen induces more mimicry and more enjoyment than viewing prerecorded videos (Hsu et al., 2022). Some authors still argue that at least minimal contingency to participants' responses, or even an involvement of theory of mind, is necessary to extract rewarding value from social information in humans (Krach et al., 2010; Matyjek, Meliss, et al., 2020).

Figure 9

Examples of Social Rewards in Human Studies Mapped onto Immediacy and Intimacy Dimensions



Note. Levels of immediacy are defined as follows: 1 = observation without social exchange, 2 = one-way social exchange, 3 = infrequent two-way social exchange (single exchange in a trial), 4 = frequent two- or more-way social exchange (multiple exchanges in a trial); and levels of intimacy as follows: 1 = unimodal and delivered without presence of another person, 2 = multimodal and delivered without presence of another person, 3 = unimodal and delivered in presence of another person, 4 = multimodal and delivered in presence of another person. See https://osf.io/m4u3c for an interactive plot and details about the example stimuli.

Stimuli including one-way social exchange, in which rewards are either received (feedback on performance, self, or status, etc.; see Figure 6) or given (sharing, donating, etc.; see Figure 6), have higher immediacy as they usually include (an imagined) other person and can vary in intimacy (see Figure 9 for examples). Senders of feedback or receivers of gifts may be personified through task instructions, introduced in person during the task, or alternatively no information about the potential sender/receiver is provided. Including a cover story about another real person as part of an experimental task increases enjoyment and activation of reward-related brain regions (Alkire et al., 2018; Weibel et al., 2008) and is seen as a means to increase ecological validity (Chakrabarti, 2013). In terms of translational research, it is worth noting that such stimuli often involve symbols and higher-order social cognitive processes, which we previously discussed as a potential drawback when comparing animals and humans. With respect to intimacy, stimuli from this category were mostly characterized by the lowest intimacy level (see Figure 6 and Figure 9 for examples). In some studies, however, feedback stimuli also included touch (Korb, Goetzendorfer, Massaccesi, Sezen, et al., 2020; Massaccesi, Willeit, Quednow, Nater, Lamm, Mller, et al., 2022) or verbal feedback delivered in person (Lenaert et al., 2018; Ramirez-Marin & Shafa, 2018), demonstrating that one-way feedback paradigms can also involve higher intimacy (see Figure 6 and Figure 9).

Stimuli from the category of two-way social exchange (see Figure 6) are characterized by higher immediacy and can have both a low and a high level of intimacy (see Figure 9 for examples). Paradigms including face-to-face conversations (e.g., Fairbairn, Sayette, Amole, et al., 2015; Heerey & Crossley, 2013; Philipp-Muller & MacDonald, 2017) show the highest immediacy and on-screen paradigms can vary depending on how close the interaction dynamic is to real-life interaction (see Figure 9 for examples). A fast-paced game such as Cyberball (e.g., Beltzer et al., 2019; Niedeggen et al., 2014) or naturalistic tasks with joint attention (Preller, Herdener, Schilbach, Staempfli, et al., 2014; Soussignan et al., 2019) may be considered closer to real-life interactions as compared to slow-paced paradigms such as trust or prisoner’s dilemma games (Gromann, Shergill, de Haan, et al., 2014). There are several ways to bring artificial interactions closer to real life. For example, mutual engagement, behavioral alignment, and reciprocity (Redcay & Schilbach, 2019) can be used to extract the aspects of social interaction that are most relevant for translational research (e.g., avoiding symbolic and abstract elements of interaction). In online games, participants usually believed that one or more other players were physically present in a nearby room or were connected via the internet (e.g., Kawamichi et al., 2019; Weschke & Niedeggen, 2013). On other occasions, participants either met other players in person (D. Zhang et al., 2020) or received no information about the identities of co-players (Beltzer et al., 2019). Rewards from this group had the lowest intimacy when including only the visual modality and the highest when involving face-to-face interaction (see Figure 9 for examples). Nonetheless, some studies, which were not captured by our search criteria, involved individuals talking with another person through a screen during fMRI experiments (e.g., Redcay et al., 2010b), suggesting that relatively high intimacy can also be achieved with on-screen paradigms.

Our systematic review shows that depending on the focus of research, stimuli can be adapted in multiple ways to increase their ecological validity and their comparability to animal stimuli, for example, by increasing immediacy, intimacy, or both. Moreover, these dimensions can also be used in human studies to compare social rewards that differ in immediacy and intimacy. Finally, to create novel social reward stimuli that are compatible with the available measures of social reward processing, we can draw on knowledge from the field of human-computer interaction, which aims to create a sense of social presence in artificial environments, for example through haptic feedback technologies (Yarosh et al., 2022) or robotics (Sciutti & Sandini, 2017).

Social Reward Stimuli Seen Through Methodological Constraints

Although immediacy and intimacy of social rewards are independent from measurement techniques used to study them, the way they could be implemented in different subfields depends on the constraints posed by the methodology. Moreover, measurement techniques differ in their implications for translational research (Grimm et al., 2021). Finally, operationalizations of social reward often rely on convenience. In human studies, social reward is usually not defined in the same strict operational terms employed for animal research, for example through reward learning paradigms. Instead, the rewarding status of stimuli is often assumed, or justified by previous findings of correlated activation of reward-related circuits or participants' willingness to approach (Tamir & Hughes, 2018). Definitions of social reward thus often remain vague and implicit in human literature, and they rely more on the methodology used to study the concept. By structuring our discussion following the different methodologies used to study social reward, we attempt to provide awareness of the constraints posed and give an overview relevant for different fields (experimental psychology, neuroscience, psychopharmacology and psychophysiology).

The use of unimodal, static, and brief stimuli that can be delivered in artificial environments is beneficial for most experimental designs, but especially for brain imaging studies using fMRI or EEG (see Figure 7B and Figure 8). These techniques require highly constrained movement, many trials, and precise comparison with control conditions. Understandably, this particularly favors short and sensory unimodal stimuli that can be repeated and that are expected to induce reliable activity. Mobile EEG and fNIRS systems could help to overcome some of the physical constraints posed by classical brain imaging methods. These methods are still less popular in social reward research in human adults, as demonstrated by the fact that our sample contained only two studies using such a technique (Lertladaluck et al., 2020; D. Zhang et al., 2020). This explains why the category of brain imaging studies was dominated by stimuli with the lowest level of intimacy (see Figure 3C-D and Figure 5). It should be noted, that reward themes such as affective touch and physical presence have also been implemented in the fMRI environment (Zimmermann et al., 2019). We further found that a considerable number of fMRI studies operationalized social rewards as two-way social exchanges (see Figure 7) with paradigms such as trust (e.g., Gromann et al., 2014), cooperation (e.g., Decety et al., 2004), Cyberball games (e.g., Weschke & Niedeggen, 2013), or Island Getaway tasks (e.g., Gromann et al., 2014), which are all higher in immediacy and lower on the intimacy dimension (see Figure 9 for examples). In sum, brain imaging techniques are dominated by static visual stimuli, but some studies have demonstrated that it is possible to include more complex and interactive stimuli on a screen, and also to deliver rewards in the presence of another person.

Like brain imaging studies, pharmacological studies were also dominated by one-way exchanges (see Figure 7A). Many of them included social closeness (see Figure 3C and Figure 5C) such as sharing money with a friend (Soutschek et al., 2017), receiving messages from a close person (Inagaki, Ray, et al., 2016), closeness building (Tchalova & MacDonald, 2020), or seeing pictures of babies (Bhandari, van der Veen, et al., 2014).

Pharmacology was the most common study type in animal studies (see Table 1), and it should be noted that most of our current understanding of the neurochemistry of social reward processing comes from animal research. Consequently, there is a need for more human studies to adopt pharmacological approaches while employing operationalizations of social rewards that can be effectively compared across different species.

Behavioral studies allow for less prioritization of strict experimental control, have fewer physical constraints, and rely less on the use of standardized trial-based paradigms. Accordingly, behavioral studies had the highest variability in reward characteristics (see Figure 5) and often involved more ecologically valid stimuli (see Figure 3C), with stimuli such as interaction on a fake social media website (Hudd & Moscovitch, 2020), a personal conversation with a confederate (Philipp-Muller & MacDonald, 2017), a reciprocated smile during free interaction (Fairbairn, Sayette, Aalen, et al., 2015), or an imagined interaction with a family member (Seaman et al., 2023). Like behavioral studies, physiological studies also allow for more variability in stimulus characteristics (see Figure 5). Some stimuli used in physiological studies could be characterized as having higher ecological validity than most of the more commonly employed stimuli (see Figure 3C and 8). Even when using only the visual modality, they include movement and complexity closer to real life (biological motion; Williams et al., 2019) as well as observations in real life (Zimmermann et al., 2019), and some of them also incorporate physical presence (Massaccesi, Willeit, et al., 2021; Sutherland et al., 2022). The absence of physical constraints such as those posed by imaging techniques suggests that a combination of behavioral and physiological measures may be beneficial for exploring more real-life social rewards and possibly developing more ecologically valid paradigms.

A recent review on social reward circuitry in humans and animals highlighted the importance of brain imaging for translational research, focusing on the presence of homologous reward-related brain mechanisms including activations in midbrain reward regions and the amygdala (Grimm et al., 2021). In the present work, we found that brain imaging techniques, and especially fMRI, were the most commonly employed tools to study social reward processes in humans, which is promising given their high potential for translational insights. Imaging studies also achieved a higher standardization of the social reward stimuli and experimental paradigms, although ecological validity and comparability of reward stimuli to those from animal studies might be an issue. Another review suggested that incorporating more ethologically relevant and real-life paradigms in human studies would facilitate greater alignment between human and animal research on social rewards; it likewise underscored the importance of identifying homologous brain regions across species (Prounis & Ophir, 2020). Importantly, we found that most of the existing methodological approaches also show potential for adapting stimuli on the dimensions of immediacy and intimacy, which would help increase their ecological validity. Physiological and behavioral measures could be used to gain more insights into social reward operationalized through unconstrained real-life interactions, which could in turn be useful for building more ecologically valid stimuli that are applicable in more physically constrained environments.

Limitations and Future Directions

Despite our endeavor to provide the most extensive and complete up-to-date review on the topic, the article presents several limitations, which we address in the following. In our search strategy, we relied on “social reward” as the keyword, in order not to be biased by our own definitions of the concept. We acknowledge that this led us to miss some studies in which the authors intended to study rewarding properties of social stimuli. For instance, some of these studies simply did not use the term “social reward” or used it only as a secondary term, which did not appear in the topic fields of the respective articles (e.g., Aharon et al., 2001; Bartels & Zeki, 2004; Deaner et al., 2005; Gordon et al., 2013; Redcay et al., 2010; Tamir & Mitchell, 2012). Nevertheless, we deem our keyword-based search approach to be the least biased option in terms of capturing the (implicit, ill-defined) meaning of social reward in the field.

Although this review focuses specifically (and deliberately) on operational definitions of the term “social reward,” future reviews are needed to address the definition of the latent concept that is partially overlapping with terms such as “social incentive” and “social reinforcement." It is however important to note that this review gives a comprehensive overview of the use of this specific term and not of the entire field, which somewhat limits its scope. To understand the extent of this limitation and identify potentially relevant unrepresented studies, authors, and research traditions, we provide a bibliometric analysis of the articles captured by the related terms "social reinforcement" and "social incentive" (see S1, Table S1, and Figures S1-S3). We found that, although there was an overlap in journals and keywords between the three search strategies (23-36% of those captured by the terms "social reinforcement" and "social incentive" were also captured by the term "social reward"), there was less overlap in publications (2% and 8% of those captured by "social reinforcement" and "social incentive," respectively) and in authors (8% and 18%; see Figure S1). This suggests that, although these terms cover partially overlapping topics, authors tend to consistently use only one term in their publications. Moreover, our thematic analysis revealed relevant groups of authors and topics that our original search strategy missed (see Figure S3 and Table S1). For example, with regards to "social reinforcement" studies, our review does not represent neurophysiological experimental studies in animals by authors like J. B. Richards and S. Watanabe (Schatz et al., 2019; Watanabe, 2015; cluster "reward" in Table S1) or hyperscanning studies on cooperation by authors like M. Balconi and M. E. Vanutelli (Balconi et al., 2018; Balconi & Vanutelli, 2017; cluster "performance"). With regards to "social incentive," examples include relevant observation studies in vervet monkeys by T. J. M. Arseneau-Robar or E. Müller (Arseneau-Robar et al., 2016, 2018; cluster "performance") or experiments with priming and mimicry by J. W. Roberts, S. J. Bennett or S. J. Hayes (Roberts et al., 2016, 2018; cluster "behavior"). Notably, both terms "social reinforcement" and "social incentive" included a substantial body of applied studies in the areas of education, work, and public health (see Table S1), which are usually interventions rather than experiments, and thus do not fit our study inclusion criteria. Moreover, the term "social reinforcement," unlike other terms, was commonly used in the period between 1958 and 1990 (see Figure S2), and the representativeness of these studies for the field today may be questioned (see a later point in Limitations). Conversely, the term "social reward" has a higher representation of animal experimental studies (see keywords for the cluster "nucleus-accumbens" in Table S1), brain imaging (see clusters "behavior" and "nucleus-accumbens"), and less representation of applied studies (only cluster "performance") than other search terms. We conclude that the term "social reward" is the most relevant for translational science and experimental studies, both central to this review. Nevertheless, future search strategies could be extended even further to include specific stimulus names (like "face" or "social closeness") or other keywords ("social value" or "social utility") to gain a more detailed overview of the field.

With regards to the limitations of the underlying evidence from the studies we review, we found that most studies in humans were performed on WEIRD samples (Western, Educated, Industrialized, Rich, and Democratic; (Henrich et al., 2010), therefore not generalizable to the entire human population (see S8 and Figure S4). Such bias might have affected how operational definitions of social reward have been developed. We further point out that we reviewed only articles written in English, which introduced the mono-language bias (Johnson, 2021). This might have limited the representation of social reward definitions specific to some countries and cultures.

As our review focuses on current uses of the term in the academic community, we decided to focus on published literature and preprints. Future reviews may include unpublished records to test whether our conclusions generalize to "gray" literature and to potentially increase representation of overlooked (e.g., non-WEIRD) populations. Furthermore, this review includes no methodological quality assessments of coded studies. As this review includes no synthesis of study results, and as we aimed to chart a wide array of social reward definitions (irrespective of study quality), we argue that this decision was appropriate for the present study. However, future reviews could consider adding this step as a way to further strengthen generalizability.

When comparing operationalizations of social reward between animals and humans in our sample, it is important to point out that we averaged across many studies and many species. Had we focused on a comparison between humans and a specific species (e.g., primates) or on a more specific topic (e.g., anticipation measures), it would have been possible to provide a nuanced view on specific translational and comparative research topics. For example, we may have missed small groups of studies in animals and in humans that have very good comparability regarding measures or stimuli, or niche paradigms that match very well between humans and a species may have been underrepresented in our sample. Therefore, we encourage any reader who is interested in more fine-grained comparisons to access our open data (https://osf.io/cnhf4; see “README.txt” for guidance).

Furthermore, we found that the term “social reward” was used differently in human and in rodent studies—in rodents, it was often used as a synonym for conditioned preference or learned behaviors shaped by social interactions, and in humans, it always referred to a stimulus. One outcome of this is that we might have missed some rodent studies that measured social reward-related brain activity but had no reference to “social reward” in text. There is indeed a large body of rodent studies in which the activity of reward-related circuits during social interaction was measured and these studies are crucial for translational research on social reward (see Grimm et al., 2021 for review). It is worth noting that this limitation primarily affected our discussion on measures rather than on stimuli, as the stimuli used in animal studies on social reward were highly consistent across tasks, irrespective of whether they met our inclusion criteria.

Finally, we did not consider publication year or the influence that articles had in their respective fields (e.g., as measured by citation counts), instead focusing solely on frequencies of appearance. It is possible that social reward paradigms that were used more than fifty years ago have less relevance for researchers today. Moreover, some stimuli may have been represented in more studies because specific labs and authors have higher research outputs.

Conclusions

The concept of reward is key to understanding the motivational basis of our behavior, and social rewards, such as approval in humans or play in animals, have been shown to be essential for overall well-being (Matthews & Tye, 2019). Yet, there is no explicit consensus on the precise definition of social reward, leading to tremendous variability in its operationalizations. This disparity is observed not only within human research but also between human and animal studies. Although this variability may hinder the comparability of findings, there has been little discussion regarding the defining dimensions of social rewards, especially in the context of translational research. In this first systematic review on the topic, we charted existing measures of social rewards, social reward stimuli and their characteristics, compared them between animal and human research, and extracted higher-order categories and dimensions relevant for conceptualizing social reward across species. The greatest cross-species similarities in behavioral measures of social reward were observed during reward anticipation and learning, whereas measures observed during reward delivery were the least comparable. In animal studies, social reward stimuli typically included two-way social interactions and encompassed all sensory modalities. In human studies they predominantly revolved around visual cues only and consisted of feedback related to participants' performance or self-relevance.

Considering the differences in stimuli and building on previous literature, we identified several key points of divergence between social reward stimuli in animals and humans. These distinctions should be taken into consideration when translating findings from animal studies to humans. Factors such as observation vs. interaction, symbolic vs. experiential aspects, transient vs. long-lasting effects, primary vs. secondary rewards, and the degree of involvement of higher-order social cognition all contribute to these differences. To enhance the comparability to animal social rewards and improve ecological validity, we advise that human studies should include experiential, transient, and primary rewards, and incorporate social interaction and/or sensory-rich contexts. We argue that two main aspects account for most of these points, namely, (a) engagement in social interaction (i.e., synchronous observation) and action between at least two individuals (*immediacy*); and (b) presence of a conspecific and sensory richness (*intimacy*). By drawing insights from research employing second-person neuroscience approaches (Redcay & Schilbach, 2019), as well as theoretical models in the field of human-computer interaction (Cummings & Wertz, 2023), we propose that both human and animal research can greatly benefit from considering these emerging properties, which can also be adapted and integrated into the existing methodologies used to study social rewards.

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