universität wien

# MASTERARBEIT | MASTER'S THESIS

Titel | Title

Understanding Social Reward: A Systematic Review of Experimental Human Studies


verfasst von | submitted by

Isidora Bojkovska B.Sc.


angestrebter akademischer Grad | in partial fulfilment of the requirements for the degree of

Master of Science (MSc)

Wien | Vienna, 2025

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| Studienkennzahl lt. Studienblatt \| Degree programme code as it appears on the student record sheet: | UA 066 013 |
| Studienrichtung lt. Studienblatt \| Degree programme as it appears on the student record sheet: | Masterstudium Joint-Degree Middle European interdisc. master prog. in Cognitive Science |
| Betreut von \| Supervisor: | Assoz. Prof. Giorgia Silani Privatdoz. PhD |

**Abstrakt**

Soziale Belohnung ist die Grundlage menschlicher sozialer Kompetenz und umfasst positive Erfahrungen aus der Interaktion mit anderen. Dennoch fehlt es in der aktuellen Literatur zur sozialen Belohnung an einem Konsens darüber, wie das Konzept operationalisiert werden kann. Um diese Lücke zu schließen, wurde in dieser systematischen Übersichtsarbeit ein datengesteuerter Ansatz verwendet, um einen umfassenden Überblick über die Operationalisierung, den Vergleich und die Messung sozialer Belohnung in experimentellen Studien mit Menschen zu geben. Die Hauptbefunde der Untersuchung zeigen, dass dekontextualisierte soziale Belohnungen, Leistungsfeedback und Feedback zur eigenen Person häufiger verwendet werden als kontextualisierte soziale Belohnungen und Status. Diese sozialen Belohnungen werden in neuartigen, visuellen, bildschirmgestützten und versuchsbasierten Formaten präsentiert. In der Literatur stand vor allem im Fokus, wie soziale Belohnung im Gehirn verarbeitet wird und wie sie die Aufgabenleistung (d. h. Genauigkeit und Reaktionszeiten) bei der Zielerkennung und anderen kognitiven Aufgaben beeinflusst. Die soziale Spezifität wurde ermittelt, indem soziale Belohnungen mit ihren nicht-belohnenden (neutrales Gesicht) und/oder nicht-sozialen Gegenstücken (textuelles Feedback zur Leistung) sowie mit nicht-sozialen monetären Belohnungen verglichen wurden. Es gibt nur begrenzte Daten zu Vertrautheit, interaktiven sozialen Belohnungen (z. B. soziale Interaktion, soziale Nähe, gemeinsame Aufmerksamkeit), nicht-monetären, nicht-sozialen Belohnungen und dazu, wie soziale Belohnungen komplexe soziale Verhaltensweisen wie prosoziales Handeln und Status beeinflussen. Basierend auf diesen Erkenntnissen und Einschränkungen schlägt die systematische Übersichtsarbeit ein dreistufiges hierarchisches Modell zur Operationalisierung sozialer Belohnungen vor, das auf den Forschungsfragen, die auf jeder Ebene behandelt werden sollen, und den dafür verfügbaren Messmethoden basiert. Die drei Ebenen sind wie folgt umrissen: i) wie soziale Reize auf neuronaler und Verhaltensebene verarbeitet werden; ii) wie Menschen mit anderen interagieren und Beziehungen zu ihnen aufbauen; iii) wie soziale Belohnung komplexere soziale Verhaltensweisen und Phänomene wie prosoziales Handeln und Status fördert. Am Ende diskutiert die systematische Übersichtsarbeit einige Implikationen für die Kognitionswissenschaft und schlägt zukünftige Forschungsrichtungen vor.

**Abstract**

Social reward is the cornerstone of human social competence, encompassing positive experiences from interactions with others. Nonetheless, the current social reward literature lacks consensus on how to operationalize the concept. To address this gap, this systematic review employed a data-driven approach to provide a comprehensive overview of social reward operationalization, comparison, and measurement in human experimental studies. The main findings of the review indicate that decontextualized social rewards, feedback on performance and feedback about the self are more frequently used than contextualized social rewards and status. These social rewards are presented in novel, visual, screen-based, and trial-based formats. The literature was mostly interested in how social reward was processed in the brain and how it motivated task performance (i.e., accuracy and response times) in target detection and other cognitive tasks. Social specificity was determined by comparing social reward to its non-rewarding (neutral face) and/or non-social counterparts (textual feedback on performance), as well as to non-social monetary rewards. There is limited data on familiarity, interactive social rewards (i.e., social interaction, social closeness, joint attention), non-social rewards other than monetary ones, and how social reward drives complex social behaviors such as prosocial actions and status. Based on these findings and limitations, the systematic review proposes a three-level hierarchical model for social reward operationalization based on the research questions to be addressed at each level and the measures available to study them. The three levels are outlined as follows: i) how social stimuli are processed at the neural and behavioral levels; ii) how humans interact with and relate to others; iii) how social reward drives more complex social behaviors and phenomena such as prosocial actions and status. At the end, the systematic review discusses some implications for cognitive science and offers future directions for research.

# 1. Introduction

Social rewards broadly refer to positive experiences involving interactions with other people (Baez-Mendoza & Schultz, 2013; Fareri & Delgado, 2014; Bhanji & Delgado, 2014). These rewards encompass a wide range of phenomena, including attractive faces (Aharon et al., 2001), maternal or romantic love (Bartels & Zeki, 2004), positive social feedback (Meshi et al., 2013), and reputation enhancement (Izuma et al., 2008), among others. The pursuit of social rewards fosters adaptive social behaviors such as attachment and cooperation that support the survival and reproduction of the human species (Adolphs, 2003; Atzil et al., 2018).

Understanding social reward is, therefore, essential for comprehending social cognition and the factors that contribute to overall social competence (Fareri & Delgado, 2014). For instance, the pursuit of social reward has been linked to several important developmental milestones. Between 9 and 12 months of age, infants begin to exhibit joint attention, the ability to share focus on an object or event with their caregiver (Schilbach et al., 2010). Between the ages of 3 and 5, joint attention serves as a precursor to more complex social cognitive skills, such as theory of mind, which involves understanding the thoughts and intentions of others (Alkire et al., 2013).

These milestones are acquired through the active pursuit of social rewards, such as praise, smiles, and attention from caregivers, which enable infants and children to form close social bonds with others later in life (Hughes & Leekam, 2003). Conversely, disruptions in social reward processing can diminish social motivation, leading to a reduced interest in social interaction and bond formation (McCarthy et al., 2015; Barkus, 2021). For example, a child with impaired social reward processing may be less responsive to a caregiver's smiles or attempts to engage in joint attention. In turn, this may lead to decreased motivation for social interaction and close bond formation over time. Therefore, diminished social motivation and interest contribute to a state of social anhedonia, which is observed across various psychopathologies, including autism spectrum disorders (ASD), schizophrenia, and mood disorders (MD) (Barkus & Badcock, 2019; Aldridge-Waddon et al., 2020).

Given these considerations, the advent of neuroimaging methodology caused a surge in social reward research interest during the early 2000s (Aharon et al., 2001). To date, researchers continue to investigate the driving mechanisms of social reward's neural and behavioral processing in order to understand more complex phenomena tied to this concept such as social cognition, its aforementioned developmental milestones and how these help humans navigate their social environments (Lockwood et al., 2020; Grimm et al., 2021). Moreover, understanding the driving mechanisms of social reward promises to elucidate how its impaired processing may contribute to various psychopathologies, thus paving the way for more effective treatments (Kohls et al., 2012; Zald & Treadway, 2017; Aldridge-Waddon et al., 2020).

Taking this into account, previous review efforts have recognized the heterogeneous and multi-faceted nature of social reward as a concept (Matyjek et al., 2020b). For instance, the reception of praise from a teacher is qualitatively different from the experience of romantic love from a partner. Similarly, receiving a smile from an acquaintance is more transient than receiving an embrace from a close friend. Despite the fundamental importance of social reward and the growing interest in the field, there remains a staggering lack of consensus on how to operationalize it.

A meta-analysis by Clements and colleagues (2018) found mixed results pertaining to the neural processing of social reward among populations with ASD. In contrast to the social motivation hypothesis (Chevallier et al., 2012) which predicts aberrant neural processing of social reward in ASD populations, this meta-analysis found atypical processing of both social and non-social rewards. The authors attributed some of this variability to the heterogeneity of social stimuli used across studies (Clements et al., 2018). Thus, this meta-analysis demonstrates how a lack of consistency in a concept's definition can result in further inconsistencies in interpreting the corresponding findings.

To address this issue, the current systematic review adopted a data-driven approach to provide a comprehensive overview of the operationalizations, comparisons, and measures used for social reward in human experimental research. In turn, the resulting overview aims to offer guidance for future studies in the field. The data-driven approach identified several key social reward operationalization themes, which were grouped into one of five contextualization categories inspired by Tamir and Hughes's (2018) dual-model framework.

Within each contextualization group, comparisons and measures of social reward were reviewed to identify prevalent trends and potential limitations. Based on the identified social reward themes, comparison patterns, and measurement trends, a *three-level hierarchical framework* was proposed to guide the operationalization of social reward according to the research questions being addressed and the methods available for investigation.

## 1.1 Challenges in Understanding Social Reward

Most of our current social reward data comes from comparisons with non-social monetary rewards, with the social nature of social reward considered the key difference between the two types of reward (Fareri & Delgado, 2014; Bhanji & Delgado, 2014). As a result, researchers have sought to determine whether social and nonsocial rewards produce similar outcomes in terms of neural activity and behavior (Baez-Mendoza & Schultz, 2013). For instance, neuroscientific research has established that social and nonsocial rewards produce "liking" or a subjective experience of pleasure when consumed (Schultz, 1998; Berridge & Robinson, 1998; Loseth et al., 2014). Similarly, both reward types can evoke "wanting" or the active pursuit of rewards in the presence of relevant reward-related cues (Berridge & Robinson, 1998; Loseth et al., 2014). In terms of behavior, both social and nonsocial rewards are expected to elicit approach behaviors toward the stimuli that are psychologically "liked" and "wanted" (Grimm et al., 2021).

At the neural level, both reward types have been shown to evoke activity in the dopamine-mediated mesolimbic circuits of the brain (Schultz, 1997; Berridge & Robinson, 1998; Aharon et al., 2001; Insel, 2003; Beloate & Coolen, 2017). In particular, some reviewers have implicated the striatum as a general-purpose subcortical brain region that integrates social information into broader non-social cognitive functions, such as perception, motor control, decision-making, learning, and memory (Baez-Mendoza & Schultz, 2013). Based on these findings, many reviewers have characterized social reward as similar to non-social reward, but occurring within a social context (Baez-Mendoza & Schultz, 2013; Fareri & Delgado, 2014; Bhanji & Delgado, 2014).

However, several challenges arise when social reward is defined by its similarities to non-social reward and is conceptually reduced to its social nature as the defining characteristic. Firstly, social rewards are more heterogeneous and multi-faceted than other rewards (Matyjek et al., 2020b). Secondly, the value of social rewards is more context-dependent than that of other rewards (Tamir & Hughes, 2018). Thirdly, social rewards have an inherently interactive nature, allowing them to be both received from and given to others (Baez-Mendoza & Schultz, 2013). Each of these aspects is discussed in more detail in the subsections below.

### 1.1.1 The Heterogeneity and Multi-facedness of Social Reward

The multifaceted nature of social reward is evident in its variability across factors like primacy, tangibility, and duration, depending on the specific operationalization used. For instance, sex is considered to be a primary social reward since it satisfies a fundamental human need for reproduction (Daniel & Pollman, 2014). However, a social media "like", in the form of a "thumbs-up" icon, acquires its value through associations with approval and validation from those who give it. Therefore, social media "likes" are better characterized as secondary social rewards (Sherman et al., 2018). In comparison, food satisfies a fundamental need for survival and remains a primary reward regardless of the exact type of food being consumed (Alonso-Alonso et al., 2015). Similarly, money is a secondary reward, as it serves to acquire primary rewards like food, regardless of the context in which it is earned (Delgado et al., 2006).

With regard to tangibility, social rewards have a mostly intangible quality to them since they stem from interactions with other people (Matyjek et al., 2020b). For instance, the smile of an acquaintance or praise from a teacher lasts only a few seconds before fading away. However, social rewards like affective touch or a caring embrace from a friend have a more tangible quality. Similarly, social reward can attain a more enduring quality once a social goal has been achieved (Tamir & Hughes, 2018). For instance, the bond formed with a new friend does not dissipate once the friend leaves the room. Similarly, the acquisition of status within a group, whether through being well-liked by peers or demonstrating superior skills, can persist over time (Xu et al., 2022).

On the other hand, non-social rewards like food and money are more tangible and less transient than social rewards, regardless of the exact definition used. As such, Matyjek and colleagues (2020b) have noted that when researchers compare social and non-social rewards within the same cognitive tasks, they may also be juxtaposing primary, intangible, and transient rewards with those that are secondary, tangible, and enduring. In addition, non-social monetary rewards can be physically obtained at the end of experiments upon task completion. On the other hand, the rewarding effects of social rewards like smiling faces are limited to the specific trial within the task at hand. Therefore, it may be the greater tangibility and reduced transience of non-social rewards, rather than the inherent sociality of social rewards, that underlie the improved task performance observed in certain populations under non-social conditions in some studies (e.g., Clements et al., 2018).

In addition to the three dimensions discussed above, the specific social reward operationalization employed directly affects the multi-modal and interactive nature of the concept (Di Paolo & De Jaegher, 2012). For instance, images of close others or social media “likes” are represented in a more static form, offering limited opportunities for interaction. In contrast, social rewards such as in-person praise or face-to-face conversations possess overtly multi-modal and directly interactive qualities. In contrast, non-social rewards do not provide opportunities for interaction.

However, non-social rewards can still gain a social and interactive quality when experienced in a social context. For example, eating a cake alone illustrates the consumption of a non-social reward, whereas sharing food with friends turns the experience of dining into a social one. Similarly, receiving a paycheck is a non-social reward, but sharing part of that money with someone else transforms the act into prosocial behavior, giving it a socially rewarding quality. Therefore, unlike the clear distinctions often drawn between social and non-social rewards (Lockwood et al., 2020; Matyjek et al., 2020b), real-world experiences suggest a continuum rather than a strict dichotomy between the two reward types.

In light of these considerations, it becomes evident that social reward is not a uniform concept. Moreover, conceptualizing social reward as a subclass of rewards in general, but delivered in a social context can cause misleading interpretations of study findings (Matyjek et al., 2020b). It can also be difficult to generalize said findings to real-word settings. In particular, several dimensions besides sociality add value to social rewards as a construct. These may include but are not limited to the primacy, duration, tangibility, and interactive nature offered by the exact definition being used (Di Paolo & De Jaegher, 2012; Matyjek et al., 2020b). Therefore, a systematic overview is warranted to better understand the heterogeneity and multifaceted nature of how this concept can be defined, as well as the implications of those definitions.

### 1.1.2 The Contextualization of Social Reward

Another challenge in social reward operationalization emerges from its sensitivity to context. The dual-model framework proposed by Tamir and Hughes (2018) presents two distinct yet complementary approaches to studying social reward. In that sense, decontextualizing social rewards involves removing basic social “building blocks” (e.g., smiling faces, social presence) from their typical environments to understand how they drive social behaviors. On the other hand, recontextualizing social rewards subjects them to motivational factors and reintroduces them to their typical environmental contexts. Thus, the authors make the claim that the value of various basic social ingredients changes depending on context and it influences the likelihood to pursue various behaviors such as cooperation or reputational management.

Therefore, ultimate social goals such as connection, bonding, and status are achieved through the pursuit of proximal social rewards like smiles (Aharon et al., 2001) or praise (Spreckelmeyer et al., 2009). These basic social ingredients maintain their rewarding value even in minimalist or inconsequential contexts, as evidenced by the reward-related brain activity and approach behaviors they elicit (e.g., for effects of smiling faces see O'Doherty et al., 2003; Leotti & Delgado, 2011; Spreckelmeyer et al., 2013; Tamir et al., 2015). Therefore, it can be inferred that the value of these stimuli stems from prior positive experiences with the stimuli (Burke et al., 2010; Hackel et al., 2015). For instance, people learn that smiling individuals are more likely to validate and accept them. However, once the minimalist stimuli are recontextualized, the likelihood to achieve a certain social goal changes based on context (Tamir & Hughes, 2018).

For example, the smiling face of a friend is experienced as socially rewarding when collaborating with them (Danvers & Shiota, 2018), but not when competing against them (Fareri & Delgado, 2013). In comparison, besides its negative valence, the frowning face of a friend acquires a social reward value in competitive settings (Sugimoto et al., 2021). Similarly, faces of in-group members are perceived as more rewarding than those of out-group members, as in-group members are seen as more similar to the participants (Chang et al., 2011). Therefore, the definition of what constitutes a social reward may vary depending on the context, as different contexts influence the likelihood of helping participants achieve their social goals.

The value of social rewards is further shaped by the familiarity of the social stimuli or social partners involved. In that regard, close others have been shown to be more motivationally salient as social targets than distant others (Hughes & Beer, 2012; Ratner et al., 2014; Hughes et al., 2018). Moreover, face familiarity has also been shown to modulate the local field potentials in the temporal lobe (Baez-Mendoza & Hoffman, 2009). Humans are also more likely to exhibit positive social behaviors toward familiar individuals compared to unfamiliar ones (Hughes & Zaki, 2015).

There are several potential reasons for the heightened valuation of familiar social rewards. Firstly, people tend to have more prior experiences and positive associations with familiar individuals (Reis et al., 2011). Secondly, familiarity enhances the accuracy of interaction outcome predictions generated through theory of mind (Fareri et al., 2015; Hackel et al., 2017; Hughes et al., 2018). Thus, given the difference in valuation between familiar and unfamiliar social rewards, this distinction represents another important factor to consider when operationalizing the concept.

Finally, social reward valuation can be affected by the immediate environment in which the reward is delivered or where the interaction takes place. The main reason for this is that the immediate environment determines the costliness of the action needed to be taken in order to acquire a certain reward (Gibson, 1977). For instance, excessive self-disclosure on social media can facilitate social networking and reputation management (Tamir & Mitchell, 2012; Schlosser, 2020). However, this same behavior can be perceived negatively by its recipients during in-person encounters where turn-taking in conversation is more appreciated (Bruss & Hill, 2010). Thus, self-disclosure must take a slightly different form to maintain its socially rewarding value in online spaces compared to offline contexts (Towner et al., 2022). Moreover, excessive self-disclosure becomes costlier in offline contexts, as it reduces the likelihood of a positive interaction outcome.

Being embedded in a social environment also causes people to determine the value of social rewards according to given norms and expectations (Izuma, 2017). In particular, the idea of social embeddedness argues that people's behavior is deeply influenced by their social networks, relationships, and communities (Granovetter, 1985). Therefore, people compare their own rewards and achievements to those of others (Fliessbach et al., 2007). For example, research has shown that reward signals in the striatum are sensitive to comparisons of reward status and outcomes relative to those of others (Dvash et al., 2010), and that these signals increase when an individual gains a reward larger than that of someone else (Bault et al., 2011). The ventral striatum was also active when losing less than someone else (Fliessbach et al., 2007) or when punishing others for perceived norm violations (Gabay et al., 2018). Therefore, social embeddedness should be taken into account when generalizing controlled findings to real-world contexts, as it can influence social reward processing in a variety of ways.

Overall, the context-dependency of social reward significantly contributes to its heterogeneity as a concept and distinguishes it from non-social reward. In particular, the social reward value of the definition used is shaped by the immediate context (e.g., cooperation vs. competition), familiarity of the social stimuli or partner, and the immediate interaction environment. Each of these factors has an influence on the likelihood that a given social goal such as connection or reputation management will be achieved (Tamir & Hughes, 2018).

The value of social reward and the generalization of controlled findings to real-world contexts are further influenced by social embeddedness, which also affects social reward processing in several ways (Fliessbach et al., 2007; Izuma, 2017). Therefore, a systematic investigation of social reward operationalization will elucidate the extent to which contextualization is accounted for in current definitions, further unraveling its heterogeneity and complexity, as well as the implications for findings.

### 1.1.3 Interactive Social Rewards

Social interaction is an integral part of everyday human communication. Therefore, social reward in the form of smiles or positive feedback is most frequently experienced in the context of multi-modal, face-to-face social interactions (Hamilton & Holler, 2023). However, the manner in which social reward is operationalized in a given study directly influences the opportunities for interaction provided by the chosen social stimulus or interaction partner (Di Paolo & De Jaegher, 2012).

For instance, as previously discussed, static images of loved ones offer limited to non-existent opportunities for interaction. This is in stark contrast with the experience of actively construing social reward during an in-person interaction with another individual (Vrticka, 2012). Therefore, additional features of in-person interactions, beyond the identity of the interaction partner and the immediate context or environment, might further contribute to the emergence of its rewarding properties.

In particular, prior research has shown that coordinated turn-taking during verbal communication leads to increased inter-brain synchrony and the subjective experience of pleasure during interaction (Kelsen et al., 2022; Kendrick et al., 2023). Similarly, the positive outcome of social interaction depends on several non-verbal exchanges between the interacting partners such as smiling (Foucault Welles et al., 2022), mimicry (Seibt et al., 2015), mutual gaze (Thepsoonthorn et al., 2016), gestures (Hadley et al., 2022) and posture (Hamilton & Holler, 2023). It can be inferred that the emergence of social reward during interactions relies on a combination of verbal and non-verbal exchanges between partners. However, this relationship has yet to be empirically tested.

Given the verbal and non-verbal signaling during in-person interactions, theory of mind gains increasing relevance in social reward value derivation as the interacting partners constantly infer the perceived beliefs and intentions of each other (Krach et al., 2010). In combination with the non-verbal cues, the emergence of social reward becomes subject to the establishment of overall synchrony and attunement between all interacting partners (Hamilton & Holler, 2023). For instance, Di Paolo and De Jaegher (2012) suggested investigating transitions during interactions, such as coordination breakdowns and recoveries, to establish the presence of social reward. According to them, once perturbations are introduced into the interaction, smoother recoveries signal greater subjective pleasure and reward, whereas difficulties in recovery suggest lesser pleasure and reward.

Reconceptualizing social reward as an actively constructed, reciprocal process between two interacting individuals opens up interesting avenues for research. These avenues go beyond the neural and behavioral markers that social rewards share with non-social ones to include verbal (Kelsen et al., 2022), non-verbal (Hadley et al., 2022) and dynamic properties of the interaction process itself (Di Paolo & De Jaegher, 2012). Thus, the generalization of controlled research findings to real-world environments might require a re-conceptualization of social reward extending beyond its shared properties with non-social reward.

In contrast, the pronounced emphasis on neural and behavioral properties shared between social and non-social rewards might have systematically overlooked those that are unique to social reward, especially during in-person interactions (for a review of neuroscientific conceptualizations and findings, see Baez-Mendoza & Schultz, 2013). As such, systematically reviewing how social reward was operationalized in the literature will also help clarify whether the most prevalent approaches have led to gaps in our understanding of the concept and its underlying mechanisms.

Overall, the arguments offered in the previous three sub-sections regarding the challenges in defining social reward indicate its complexity as a multifaceted, context-dependent, and interactive concept. To reiterate, the primary aim of this systematic review is to address these issues by identifying the most prevalent operationalizations of social reward in the human experimental literature to facilitate the interpretation of relevant findings and to inform future research designs. Therefore, in the Discussion section (see sub-sections 4.1.2 and 4.2.3), the review also addresses the extent to which the interactive nature of social reward was accounted for in the definitions used across studies.

**1.2 Challenges in Comparing Social Rewards**

It was already discussed that most of the current data on social reward comes from comparing it to non-social monetary rewards (for a review, see Fehr & Camerer, 2007). Therefore, research has largely emphasized the similarities between the two types of rewards, focusing on outcome measures such as neural activity and behavior (Lockwood et al., 2020). In addition to these outcome similarities, it can be argued that researchers have tailored their social reward operationalizations to align with those of the comparison stimuli.

For instance, monetary rewards are often represented as images of banknotes or coins (for examples of research paradigms, see Knutson, 2000; Kohls et al., 2009). Therefore, researchers often align social rewards with this comparison condition by operationalizing them in a similarly static format, such as an image of a smiling individual (e.g., Leotti & Delgado, 2011; Spreckelmeyer et al., 2013; Tamir et al., 2015) or a written statement conveying self-relevant praise (Korn et al., 2012; Meshi et al., 2013; Hughes et al., 2018). In contrast, comparing the effects of social rewards during social interactions to the reception of monetary rewards within the same task presents greater challenges.

As a result, these research practices might have led to an overestimation of the similarities between social and non-social rewards. It was already discussed how the sharp distinction between social and non-social rewards causes the sociality of social reward to become its main defining characteristic (Matyjek et al., 2020b). In turn, this conflates all other dimensions such as primacy, tangibility, and duration which might be different than those of the comparison stimuli to be conflated with the social nature of social reward. In addition, it was discussed how non-social rewards, such as having dinner, can acquire a social nature themselves when delivered in a social context (e.g., dining with friends). This suggests a continuous rather than a dichotomous distinction between social and non-social rewards. However, it can be difficult to address these nuances when sociality is taken to be the main differentiating characteristic between the two reward types.

Secondly, most reviewers argue that reinforcement learning and predictive coding are shared valuation algorithms for social and non-social rewards (Fareri & Delgado, 2014; Bhanji & Delgado, 2014). However, there might be additional cognitive abilities that are recruited in the valuation of social reward specifically. The predictive coding framework posits that humans guide their decisions and actions toward outcomes that are likely to be positive based on prediction errors (Bhanji & Delgado, 2014). In particular, prediction errors represent the difference between outcomes that are expected and those that are actually obtained (Schultz, 2016). Accurate predictions yield lesser differences and increase the likelihood of reward pursuit in the future through greater reward valuation and reinforcement learning (Bhanji & Delgado, 2014; Schultz, 2016).

At the neural level, this framework is further complemented by the dopamine (DA) prediction hypothesis. According to the DA hypothesis, predictive error processing is encoded by DA release in the mesolimbic circuits of the brain (Schultz, 1998). In particular, enhanced dopamine release signals better-than-expected outcomes while dampened dopamine release signals worse-than-expected outcomes (Schultz, 1998; 2016). However, some reviewers have argued that social reward valuation recruits additional neurotransmitter systems including oxytocin which have been linked to social bonding and trust (Krach et al., 2010; Preston, 2017).

Moreover, the previous sub-section argued that in-person interactions engage various verbal and non-verbal signals, increasing the relevance of accurately inferring the intentions and beliefs of others, thus recruiting theory of mind in the process of social reward value derivation (Krach et al., 2010; Kelsen et al., 2022; Hamilton & Holler, 2023). This suggests that the mechanisms underlying social reward valuation are notably more complex than those for non-social rewards.

Therefore, aligning the operationalization of social reward to match the one of its comparison stimuli, while overemphasizing the shared properties and valuation algorithms between the two reward types, might have led researchers to overlook the importance of socially specialized cognitive abilities and neurotransmitter systems in the process of value derivation for social reward (Krach et al., 2010; Lockwood et al., 2020). As such, a secondary aim of this systematic review is to provide an overview of the comparison stimuli used for the study of social reward to assess how the chosen comparisons might have shaped social reward operationalization and influenced the interpretation of findings.

### 1.3 Social Reward Operationalization and Measurement

The operationalization of social reward across human experimental studies might have been affected by the range of measurements that were available to researchers. In that sense, individual and multi-person measurements capture different outcome variables, requiring different approaches to social reward operationalization (Hadley et al., 2022). For instance, previous social reward reviewers placed emphasis on neuroimaging studies, hinting at the prevalence of this measure for studying social reward (Baez-Mendoza & Schultz, 2013; Fareri & Delgado, 2014; Bhanji & Delgado, 2014). However, other authors have also worked on the validation of self-report measures (Foulkes et al., 2014) and more recent reviewers argue for the implementation of multi-person measurements (Caruana et al., 2017b; Hadley et al., 2022).

In particular, neuroimaging studies capture various aspects of individual brain activity upon social reward anticipation and delivery with methods such as functional magnetic resonance imaging (fMRI) or electroencephalography (EEG) (Baez-Mendoza & Schultz, 2013; Fareri & Delgado, 2014; Bhanji & Delgado, 2014; Grimm et al., 2021). In these studies, social reward images or text are presented as outcomes for successful trial performance in various cognitive or learning tasks (van Atteveldt et al., 2018; Tamir & Hughes, 2018). Therefore, besides brain activity, neuroimaging studies are also interested in behavioral outcomes such as accuracy and response times as indicators of motivation for social reward (e.g., Clithero et al., 2011; Delmonte et al., 2012; Lin et al., 2012; Bedi et al., 2018; Schwartz et al., 2019).

As such, these studies are likely to emphasize the positive external qualities of the social stimuli used, such as facial attractiveness (Aharon et al., 2001) and positive emotional expressions (Rademacher et al., 2010). However, some studies also include interpersonal factors into their definitions, incorporating social feedback, social validation, reputational recognition and cooperation[1] as their social rewards (Rilling et al., 2002; Izuma et al., 2008; Spreckelmeyer et al., 2009).

In comparison, behavioral studies focus on the abstract and subjective effects of social reward that are expected to arise from various social situations (Foulkes et al., 2014). Therefore, these studies use self-report questionnaires in which participants

[1] Refers to cooperation in neuro-economic games such as the Prisoner's Dilemma Game, in which participants choose between cooperation and betrayal, with the outcomes revealing choices made either for the purpose of self-interest or mutual benefit.

numerically rate various subjective aspects of the social reward experience. While there is a lack of consensus in the field on this matter too, a prominent exploratory analysis by Foulkes and colleagues (2014) identified the following social situations as the most likely to elicit social reward: being admired and validated, engaging in social gatherings with or without active participation in them, sexual attraction, romantic engagement, and prosocial interactions. The authors further argue that individuals high on anti-sociality may experience social reward from causing discomfort or distress in others.

Therefore, neuroimaging and self-report methodologies may have influenced the operationalization of social reward in different manners. Namely, the research design of neuroimaging studies required more concrete, stimulus-based definitions of social reward like smiling faces or self-relevant feedback (Lin et al., 2012; Schwartz et al., 2019). On the other hand, behavioral self-report measurements focused on the subjective experience of pleasure expected to arise from various complex, everyday social situations (Foulkes et al., 2014). In either case, social reward was limited either to a received, static stimulus or to an imagined, subjective evaluation of an abstract scenario. Both neuroimaging and self-report measurements aimed to capture how individuals processed different aspects of social reward.

On the other hand, more recent reviewers emphasize the importance of multi-person methodologies for future social reward research (Hadley et al., 2022; Hamilton & Holler, 2023). The implementation of multi-person methodologies was first advocated for by Schilbach and colleagues (2013) who argued in favor of a second person perspective in social neuroscience. The authors claimed that single-person methodology, such as the neuroimaging and self-report methods discussed above, could not adequately capture the dynamic and interactive nature of real-world social interactions.

Given that social reward is inherent to successful real-world social interactions, the same line of reasoning can be extended to social reward research too. In particular, single-brain neuroimaging and behavioral measurements are not able to capture both the non-verbal cues as well as the dynamic and reciprocal properties of in-person social interactions (Hadley et al., 2022). Therefore, recent reviewers propose methods such as hyperscanning and multi-person motion-capture software to successfully capture the neural and behavioral effects of social reward from more than a single person at a time (Hamilton & Holler, 2023).

In turn, the application of these multi-person methodologies might expand the conceptualization of social reward to include phenomena which can only be defined within the context of in-person social interactions. Previous reviewers have suggested that these may include joint attention (Caruana et al., 2017b), non-verbal synchronization (Yun et al., 2012), and the effects of physical co-presence (Hamilton & Lind, 2016). The social reward effects captured by multi-person methodologies can be further complemented by embodied measurements such as eye tracking, facial movement, and physiological activity to elucidate how social reward may physically manifest in the body (Fridlund, 1991; Krishnan-Barman & Hamilton, 2019).

Given these considerations, there is a possibility that the prevalence of certain social reward operationalizations was chosen based on their alignment with the methodologies available to study the concept, such as individual neuroimaging and self-report measures (Baez-Mendoza & Schultz, 2013; Foulkes et al., 2014). As such, the increased implementation of multi-person measurements in future studies may broaden current conceptualizations of social reward to facilitate the generalization of controlled research findings to real-world environments (Krakauer et al., 2017).

In light of this, another aim of the current systematic review is to provide an overview of the most common measures implemented in the study of social reward in human experimental studies. In turn, this overview aims to identify how the prevalence of certain measurements may have influenced the prevalence of specific operationalizations, shaping research findings and our overall understanding of social reward as a concept.

### 1.4 The Importance of Social Reward for Cognitive Science

Social cognition is an important research topic across several cognitive science disciplines. Given that social reward can be taken as a central driving factor behind social cognition (Adolphs, 2003), most of the disciplines investigate this concept to facilitate their research understanding of social cognition too. For example, psychologists and neuroscientists strive to understand how social reward, in the form of various social stimuli and events, is processed at the perceptual, cognitive, neural, and behavioral level (Baez-Mendoza & Schultz, 2013; Tamir & Hughes, 2018). In turn, artificial intelligence research utilizes some of these findings to build effective computational models with improved predictions about social behavior and decision-making across different forms of context (Feldman Hall & Nassar, 2021).

In comparison, anthropologists investigate the role of social reward in various cultural and social processes, including social norms, practices and influences from the environment (Bender & Beller, 2011). Therefore, it can be inferred that an enhanced research understanding of the multifaceted nature of social reward can facilitate various inter-disciplinary insights into concepts such as joint attention (Caruana et al., 2017b), theory of mind (Rusch et al., 2020), empathy (Ferguson et al., 2020), and social learning (Clark-Elford et al., 2014). Thus, an improved understanding of these social processes will yield a better understanding of the driving factors behind human social competence and facilitate the development of sophisticated computational models (FeldmanHall & Nassar, 2021), improving research understanding and predictions about human social behavior.

While the interest in social reward is shared by most cognitive science disciplines, each field might operationalize the concept differently, compromising the interpretation of inter-disciplinary findings. Thus, this systematic review adopts a targeted approach by examining social reward operationalization in psychological and neuroscientific human experimental studies. The resulting social reward operationalization overview aims to enhance interdisciplinary communication and improve alignment with the remaining cognitive science disciplines.

In addition, social reward might be conceptualized differently even within the same field depending on the dominant cognitive science framework driving its interpretation. For example, within the traditional cognitivist approach, social reward would be understood as an externally observable stimulus or event (Fodor, 1983). The framework postulates that subjective value is assigned to said stimuli or events based on internal evaluation which in turn favors certain future behaviors over others. In that sense, when a student receives social praise from a teacher, they are likely to assign positive subjective value to it. In turn, this increases the likelihood of repeating the behaviors that resulted in this social praise, such as studying to perform well on an exam, to obtain similar reinforcement.

In comparison, as previously discussed, the predictive coding approach postulates that social reward emerges when there is a small discrepancy between the predicted and actual social outcome (Friston, 2005). Similarly to the traditional cognitivist approach, these predictions are based on sensations received from external social stimuli or events and are updated in the case of positive or negative discrepancies (Schultz, 1998). For example, in the previous scenario, the student expects to receive social praise from the teacher if he performs well on the exam. When the anticipated praise is received, or if it surpasses expectations, the subjective feeling of reward is generated. This activates the brain's mesolimbic dopamine system, reinforcing the expectation that performing well on an exam will lead to praise in similar future contexts (Schultz, 2016). Thus, both of these cognitive approaches conceptualize social reward as an externally observed social stimulus or event that is internally and mentally evaluated.

In contrast, embodied approaches to cognition conceptualize social reward as an experience grounded in the body, emerging from its interaction with the social environment rather than from internal mental evaluation (Barsalou, 2008). Thus, an embodied approach accounts for the role of non-verbal signals in social reward valuation and manifestation. As previously discussed, these non-verbal signals include facial expressions, gestures, and posture (Hamilton & Holler, 2023). In turn, they signal social reward in the body through the emergence of arousal and warmth, enabling physiological measurements to capture its presence (Cacioppo & Berntson, 2005).

Therefore, operationalizing social reward in embodied terms is more likely to emphasize in-person, interaction concepts such as joint attention (Caruana et al., 2017b), affective touch (Sailer & Leknes, 2022), mimicry (Chartrand & van Baaren, 2009), and other forms of non-verbal synchronization. In addition, an embodied approach is more likely to incorporate the role of bodily sensations, such as autonomic arousal (Proges, 2003), physical proximity (Feldman, 2012), and tactile comfort (Gallace & Spence, 2010) in social reward valuation. Thus, the value of social reward in these instances becomes derived from the subjective bodily experiences rather than from internal evaluations based on the external attributes of social stimuli or events.

Building upon this, an enactive approach to cognition postulates the coupling of social perception and action to give rise to social reward and behavior (De Jaegher & Di Paolo, 2007). Thus, social rewards are co-created in real-time when two or more individuals interact with one another in a dynamic and reciprocal manner. According to this framework, social rewards are an integral part of the collective ongoing enactment of social reality. Therefore, this approach is most likely to operationalize the concept in terms of full-scale social interactions and to consider outcomes measures like the synchronization of smiles or recoveries in verbal and non-verbal coordination during perturbations (Di Paolo & De Jaegher, 2012).

For example, according to this framework, social reward can emerge in a group setting where friends are conversing and laughing with each other. In this setting, a positive feedback loop is formed among all participants due to the mutual enjoyment of the interaction. Perturbations can be introduced in the form of misunderstandings or interruptions. According to the enactive framework, these can be restored at varied paces through verbal expressions like "Oh, I meant to say…" in combination with reciprocal, non-verbal gestures like smiles or nods. Thus, social reward becomes constituted in the experience of conversing and laughing together and becomes co-constructed through the embodied, interactive engagement of each individual with other members of the group (Varela et al., 1991).

In light of these considerations, social reward operationalization and measurement can vary significantly depending on the exact cognitive science framework guiding a given research design. Thus, understanding how social reward is defined and measured within psychology and neuroscience promises to identify the most prevalent cognitive science frameworks in its operationalization and to uncover potential research gaps emerging from these trends.

### 1.5 Research Questions and Aims

In general, social rewards constitute positive experiences with other people. Therefore, understanding social reward is crucial for elucidating the driving mechanisms of social cognition, behavior, and competence (Adolphs, 2003). However, to date, there is a lack of consensus in the human experimental literature regarding the operationalization of social reward. The main contributing factor to this is that most of our knowledge about social reward comes from comparing it to non-social rewards (Lockwood et al., 2020; Matyjek et al., 2020b). This approach overlooks the multi-faceted (Matyjek et al., 2020b), context-dependent (Tamir & Hughes, 2018), and interactive nature of social reward (Baez-Mendoza & Schultz, 2013) and might have compromised the interpretation of findings in the field.

In addition, the operationalization of social reward might have been shaped by the type of comparison stimuli and measures available for its study. Therefore, this systematic review adopted a data-driven approach to provide a comprehensive overview of social reward themes, comparisons, and measures employed in the human experimental literature. The extracted themes, comparisons, and measures were further grouped into one of five possible contextualization categories according to Tamir and Hughes' (2018) dual-model framework.

The identified trends and potential research gaps were narratively synthesized in the Discussion section of the paper. Based on the findings, a three-level hierarchical framework for social reward operationalization was proposed to guide future research designs according to the type of research questions being addressed and the methods available to study them. The systematic review concludes by discussing the implications of the identified trends and proposed hierarchical framework for cognitive science as a whole.

## 2. Methods

The methodology of this systematic review closely follows the approach outlined in Stijovic and colleagues (2024). To maintain clarity and conciseness, only the methodological aspects relevant to the current research questions are presented below. For details on the complete methodological approach, please refer to Stijovic and colleagues (2024).

### 2.1 Eligibility criteria

Studies were included if they were (1) published as articles in a peer-reviewed journal or as preprints on selected scientific preprint servers, (2) written in English and (3) reported on one or more experiments with (4) human participants. Theses and book chapters were excluded. Studies using non-experimental methods such as reviews, surveys, interventions, or interviews were also excluded. In terms of sample characteristics, at least one of the comparison groups has to contain a (5) healthy population or a (6) young adult population (≥ 18 years old). Studies with exclusively human or adolescent/child populations were excluded. Finally, authors had to (7) refer to at least one stimulus or measure as "social reward" anywhere in the text to be included for review.

### 2.2 Information sources

Published journal articles were retrieved from PubMed, Web of Science, and Scopus due to their extensive coverage of biomedical and social science literature. Additionally, life science preprints were sourced from bioRxiv and psychology preprints were sourced from PsyArXiv. The initial literature search was performed on October 8$^{th}$, 2020, and covered the period from each database's inception until the search date. This search was updated on May 18$^{th}$, 2022 with a subsequent literature search which covered the period from October 9$^{th}$, 2020 until May 18$^{th}$, 2022.

### 2.3 Search strategy

To maintain neutrality and avoid personal bias on the raters' part regarding what constitutes a social reward, the only keyword used in the search strategy was “social reward”. For a study to be considered for inclusion, this term had to appear in the title, abstract, or keywords. Variations of the keyword such as “social rewards”, “socially rewarding”, and “prosocial rewards” were included through data-base specific truncation symbols (e.g., social reward* for Web of Science).

Following de-duplication with Endnote, a total of 1,253 articles were identified during the first search and 351 articles were identified during a second search. All of these articles included both human and animal populations as data on animal studies were filtered out at a later step. Exact numbers of hits per database are reproduced from Stijovic and colleagues (2024) in the Appendix.

### 2.4 Selection process

A two-stage selection process was implemented for both literature searches. In the first stage, two pairs of independent raters screened all titles and abstracts for eligibility. All eligible studies proceeded to the second stage for a full-text screening. In cases of indecision or disagreement between the raters, studies were also advanced to the second stage. Based on the full-text screening, articles were either accepted or rejected for inclusion, with reasons for rejection provided according to the aforementioned criteria. Persisting disagreement over inclusion were resolved by the senior authors of Stijovic and colleagues (2024). Finally, data on animal studies were filtered out by the author of this systematic review, IB, once data collection concluded.

### 2.5 Data collection process

The initial phase involved rigorous training on a subset of 17 human and animal studies to standardize the data extraction process and minimize disparities between raters. Most of the final dataset, 80.83%, comprises studies retrieved from the initial literature search conducted on October 8$^{th}$, 2020. Two pairs of independent raters performed the data extraction process for these studies between February 20$^{th}$, 2021, and August 18$^{th}$, 2021. Inter-rater agreement was assessed for 24 human and animal studies from the initial literature search. Cohen’s Kappa was calculated for all variables, except those incorporating free-text entries. Cohen’s Kappa demonstrated a satisfactory level of agreement with a mean value of 0.74 (range [0.29, 1]) and percentage agreement of 84.02% (range [50, 100]).

The remaining studies of this initial literature search were split between the two pairs of independent raters. Data was extracted in MS Word tables due to its compatibility with free-entry items (for an example, see section A2 in the Appendix). Weekly discussions were held for each pair to address potential coding discrepancies in batches of 5-10 studies and to develop unified coding sheets. These unified sheets were later transposed into MS Excel to align with the presentation format.

The same two-stage procedure was followed for all studies from the second literature search on May 18th, 2022. Data extraction was conducted between June 17th, 2022, and September 9th, 2022, by two of the authors from Stijovic and colleagues (2024) and was validated by the first author of that paper. No automation tools were used for either subset during data extraction.

**2.6 Data items**

All data items that were extracted per study fell into the following four categories: (1) general information; (2) sample characteristics; (3) social reward dimensions; (4) comparison stimuli; and (5) measures. Some of the extracted variables were subject to further data transformation during data processing. In addition, some initially collected data items were excluded from further analysis to enhance the effectiveness of data representation and to minimize redundancy (for details, see the corresponding sections below).  Missing data were also excluded from subsequent analysis.

**2.6.1 General Information and Sample Characteristics**

For each included study, general information on the country, year of publication, and study type was collected. During an initial pilot stage, the authors of Stijovic and colleagues (2024) utilized a data-driven approach to identify seven distinct study types. After data transformation[2], only four study types were retained in the final data set. These study types were behavioral, brain imaging, pharmacological, and physiological studies. Studies using multiple methodologies could be categorized under more than one study type. For example, a study using both fMRI and heart rate measurements would be categorized as both brain imaging and physiological. Lastly, it was recorded whether children, adolescent, or clinical samples were used as comparison.

[2] The excluded study types were comprised of brain physiology, genetic, and lesion studies. No human studies used brain physiology or lesion methods. For simplicity, one study using both genetic and brain imaging methods was classified as brain imaging.

Extracted sample characteristics included sample size, mean age, standard deviation, proportion of female participants, and ethnic composition. Information was provided separately for healthy adult, clinical, and adolescent/child samples. However, only data from healthy adult samples were analyzed. For studies with multiple experiments, sample information was collected only for those explicitly mentioning "social reward." In these cases, sample characteristics for the entire study were coded too, but only samples of experiments with social reward were considered for analysis.

### 2.6.2 Social Reward Tasks and Characteristics

Data was collected only for tasks explicitly involving social reward. If a study included multiple social reward tasks, data was collected separately for each. Tasks without a social reward were excluded from this review. Before gathering other data items, the task name was recorded, either as provided by the authors or assigned by reviewers if unspecified. A brief description was also noted to capture the timing between reward delivery and data collection (see Appendix for examples). The data items below describe all information gathered per social reward.

#### 2.6.2.1 Social Reward Concept and Content

Free-text entries captured the social reward concept and content as described by the study authors. The concept referred to specific stimuli regarded as social rewards, such as “happy face,” “social approval for good performance,” or “affective touch.” If authors did not explicitly address social reward, reviewers inferred it by interpreting positive social stimuli described as representation of reward (e.g., attending to the same stimulus as a friend (Ma et al., 2018) or receiving positive feedback in a task (Crawford et al., 2020)). On the other hand, social reward content captured how each study represented social rewards, using terms like “image”, “word”, “sound”, “video”, or “conversation”. For example, a “happy face” concept could be represented as an “image”, and “affective touch” as “gentle caresses”.

All extracted social reward concepts and contents were integrated into a smaller set of social reward themes (for theme extraction procedure, see A3 in Appendix). The extracted social reward themes were as follows (listed in alphabetical order): affective sound, affective touch, approval gestures, biological motion, body, face, feedback on performance, feedback on self, humor, joint attention, observing other (without interaction), physical closeness, prosocial actions, smile, social closeness, social interaction, social support, and status. The extracted social reward contents included (listed in alphabetical order): action, conspecific (another human), image, movie, sound, spoken word, text, and touch.

The data items below are partially based on previous reviews arguing for the multi-dimensionality of social rewards (Matyjek et al., 2020b). These data items capture various social reward dimensions including familiarity, sensory modality, tangibility, duration, and delivery time. Additional data items included magnitude, duration, and announcement, but were excluded from further analysis[3].

**2.6.2.2 Social Reward Dimensions**

Dimensions for each social reward, including familiarity, sensory modality, tangibility, duration, and delivery time, were extracted. In terms of familiarity, social rewards were classified as novel, acquaintance, or close person, according to participants' prior experience with them. Acquaintances included any stimuli with which participants had prior engagement before the task, such as the experimenter, other participants, or confederates.

With regard to sensory modality, social rewards could be visual, auditory, olfactory or multimodal[4]. For imagined or recalled social rewards, the modalities being imagined were recorded (e.g., multimodal, but imagined when participants recalled spending time with a close other). After data collection, the sensory modality variable was transformed into five binary variables: visual, auditory, tactile, olfactory, and no sensory modality. This transformation enabled a more precise classification of multimodal stimuli (e.g., whether visual and auditory or multiple senses were engaged). Sensory modality was complemented by a tangibility variable, indicating whether a social reward was delivered on screen, in person, or was abstract (e.g., imagined or recalled).

The duration of social reward was recorded in seconds. When delivered more than once, the unit of duration and the total number of units were recorded as well. Units of duration included entries such as “per trial”, “per block”, or “per experimental session”. The total number of units indicated the segments of the task with social reward delivery, excluding those without. For example, if a task had 60 trials but only 30 involved a social reward, only the 30 trials with social rewards were

[3] The main reasons for exclusion were to limit the review's scope and avoid redundancy with information captured by other retained variables. For example, direction indicated whether a reward was received or given by the participant, but this was sufficiently captured by sensory modality and tangibility variables. All given rewards lacked sensory modality and were abstract. Similarly, all announced variables were also delayed in delivery time.

[4] Social rewards were classified as multi-modal when several modalities were engaged, such as in the case of in person conversations.

recorded. However, the unit and number of reward presentations were excluded from further analysis after data collection, as this information was adequately represented by the duration variable.

Lastly, delivery time was classified as immediate, delayed, or never. A social reward delivered at the end of each trial without prior announcement was classified as immediate. If the reward was announced during the trial and delivered at the end, it was recorded as delayed, with the delivery time measured in seconds between the announcement and delivery. Social rewards that were announced but never delivered, as well as all imagined social rewards, were categorized as never.

### 2.6.3 Social Reward Contextualization

During data analysis, all social reward concept themes were categorized into one of five groups based on their contextual level, as outlined in the dual-model framework by Tamir and Hughes (2018). This categorization aimed to clarify how varying levels of interactivity, such as static smiling faces versus multimodal conversations, might systematically influence the tasks, dimensions, and measurements employed in social reward research.

The first group is comprised of decontextualized social reward themes that offer limited interaction opportunities and are generally inconsequential (De Paolo & De Jaegher, 2012; Tamir & Hughes, 2018). These include faces, smiles, approval gestures, affective sounds, body language, and biological motion. In contrast, contextualized social rewards could only be defined within the context of an interaction (Hobson, 2008). These include social interaction, social closeness, prosocial actions, affective touch, observing other (without interacting), joint attention, social support, physical closeness, and humor.

The third group focused on status, which emerged as the sole social reward theme representing an ultimate social goal (Tamir & Hughes, 2018). The last two groups each focused on a single social reward theme, feedback on performance and feedback about the self, since either category could be illustrated using operationalizations from the remaining three categories (e.g., a decontextualized smiling face, contextualized affective touch or status can all represent feedback on performance). Therefore, these two social reward themes represent distinct categories in their own right.

### 2.6.4 Comparison Stimuli

For a stimulus to be considered as a comparison to social reward, it had to meet one or both of the following criteria: 1) the stimulus was statistically contrasted with social reward, and/or 2) the stimulus was crucial for extracting a measure of social reward (e.g., the ratio of time spent with a social vs. a non-social stimulus). The concept and content for each stimulus were recorded, either as directly referenced by the authors or as inferred by reviewers from the text. Sometimes, social rewards were compared to no stimulus, making it difficult to distinguish between concept and content. Thus, only content was recorded. In addition, the valence of each comparison was recorded as positive, negative, or neutral, along with whether each comparison stimulus had rewarding and/or social properties.

The theme extraction procedure followed the same steps for both social rewards and comparison stimuli (for details, see A3 in the Appendix). The extracted themes for comparison stimuli were as follows (listed in alphabetical order): affective sound, affective touch, afraid (face), angry (face), biological motion, body, drug, face, feedback on performance, feedback on self, food, humor, joint attention, money, no stimulus, nonsocial other, observing (without interaction), physical closeness, prosocial actions, sad (face), smile, socially blurred, social closeness, social interaction, social support, and status. The extracted content themes were as follows (listed in alphabetical order): action, conspecific, empty space, image, movie, no stimulus, physical object, real food, real money, smell, sound, spoken word, text, and touch.

### 2.6.5 Measures of Social Reward

Social reward measures were recorded for each task involving social reward manipulation, along with relevant information about their concepts and content. The concept was either directly referenced by the authors or inferred by the reviewers from the text. Examples include: “preference for an item”, “incentive salience of an item”, and “attentional bias”.  In comparison, the content specified how each measure was quantified, such as using a 7-point Likert scale to assess preference for an item.

Each measure was further categorized as direct or indirect. Direct measures captured one of three reward components, including brain activity, subjective reward ratings, task accuracy, and reaction times during reward consumption or anticipation. Indirect measures captured phenomena influenced by social reward, but not directly related to it, such as cognitive control, memory, and driving performance.

Depending on the reward component measured, all direct measures of social reward were grouped into one of three categories: (1) anticipation, (2) consumption, and (3) learning. Theme extraction was performed in the same manner as for social rewards and comparison stimuli (for details, see A3 in Appendix). The extracted anticipation measure themes were: 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. The extracted consumption measure themes were: behavioral measures (amount of reward and social interaction behaviors), brain activity, eye movement, facial movement, peripheral physiological responses, and self-report measures. Finally, the extracted learning measure themes: brain activity, conditioned preference, discrimination, operant/instrumental, Pavlovian, and reinforcement (associative) learning.

The data analysis structure of each study was reviewed to see if measures were statistically contrasted with non-reward stimuli, like neutral stimuli, or non-social rewards, such as money, food, or drugs. To limit the review scope, these variables were excluded from further analysis.

### 2.7 Study Risk of Bias Assessment and Effect Measures

As the present systematic review focuses on qualitative outcome variables, the assessment of risk of bias and effect measures was not considered.

## 3. Results

### 3.1 Study Selection

The study selection procedure overlaps with the one described in Stijovic et al. (2024), with the exception of the very last step. The initial literature search that took place on October 8th, 2020 yielded 3,468 articles from the database search and an additional 42 articles from the preprint servers search (for details, see A1.1 in the Appendix). After de-duplication, 1,253 articles were screened for titles, abstracts, and keywords to determine their eligibility. Out of these, 443 articles survived into the next stage for a full text screening. Finally, 236 studies survived the full text screening to be included for review.

In a similar fashion, the second literature search that took place on May 18th, 2022 generated 603 articles from the database search and 40 articles from the preprint servers search (for details, see A1.2 in the Appendix). After de-duplication, the titles, abstracts, and keywords of 351 articles were screened to determine their eligibility and to check for dates of publication. Out of these, 117 articled survived into the second stage for full text screening. Finally, 56 studies from the second search survived the full text screening, bringing the total number of included articles thus far to 292.

Since the current systematic review exclusively concentrates on human literature, the review author conducted a final step to filter out studies with only human populations as samples. Consequently, a total of 188 studies survived this final step and were included for review. The study selection process is depicted in its entirety in the PRISMA flowchart in Figure 1.

**3.2 General Study Characteristics**

The included studies were published between 1962 and 2022. Interest in this topic especially surged between 2010 and 2022 ($M$ = 13.31, $SD$ = 6.58). The largest number of studies, 30 (15.96%), was published in 2020.

The majority of studies (27.13%, $n$ = 51) were published in the United States. This was followed by Germany (11.17%, $n$ = 21), the United Kingdom (10.11%, $n$ = 19), China (6.91%, $n$ = 13) , Canada (6.38%, $n$ = 12), and Japan (5.85%, $n$ = 11). The remaining studies accounted for less than 5% of all included studies (for details, see Table A4 in the Appendix).

In terms of study type, most of the included studies were brain imaging (55.32%, $n$ = 104) , followed by behavioral (31.91%, $n$ = 60), physiological (10.64%, $n$ = 20), and pharmacological (9.04%, $n$ = 17).

**3.3 Sample Characteristics**

The median sample size, reported for all included studies, is 44.5 participants (range: 1–2424). The mean age of the participants, reported in 175 (93.09%) of the included studies, is 26.07 years old (range: 17-67.88) and a mean standard deviation of 4.46 years old (range: 0.12-12.95). The mean proportion females, reported in 179 (95.21%) of the included studies, is 52.77% (range: 0-100).

In terms of sample ethnicity, reported in 48 (25.53%) of the included studies, 39 (20.74%) have a multi-ethnic sample population and 9 (4.79%) have an ethnically homogeneous sample. The proportion of adult healthy Caucasian participants across these samples is 56.3% (range: 0-100).

In terms of comparison groups, 28 (14.89%) of the included studies involve a clinical sample. Eight (4.26%) studies involve a non-adult sample (<18 years old). Finally, 1 study (0.53%) involves both a clinical and non-adult sample.

### 3.4 General Social Reward Trends: Operationalizations and Dimensions

Most included studies utilized decontextualized social rewards (53.72%, *n* = 101). This was followed by feedback on task performance (29.26%, *n* = 55), contextualized social rewards (27.13%, *n* = 51), feedback about the self (19.15%, *n* = 36), and status (10.11%, *n* = 19). For details on exact operationalizations and dimensions per category, see section 3.7.

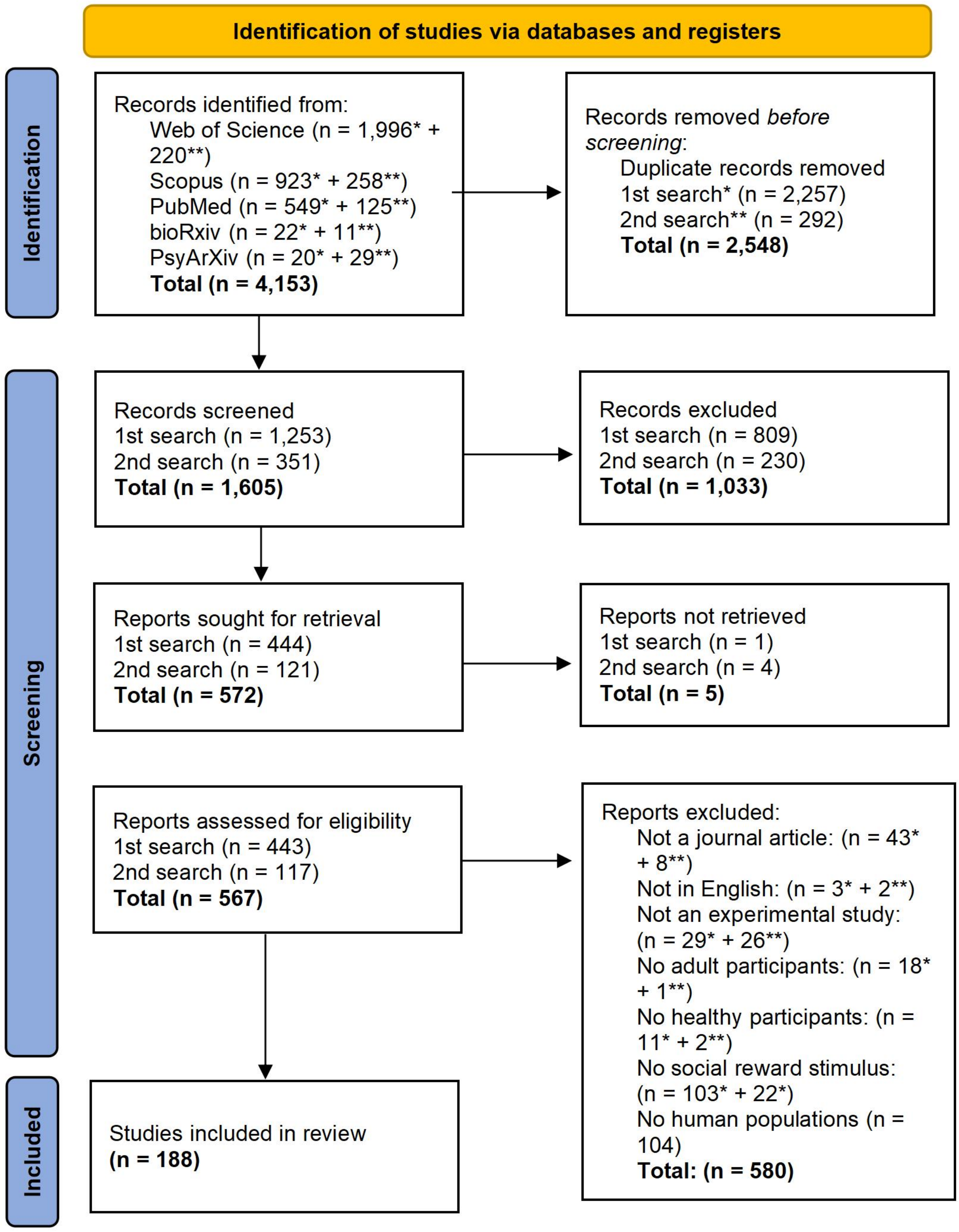
Regarding sensory modality, most social rewards were visual (70.21%, *n* = 132). The remaining studies had multimodal (7.98%, *n* = 15), auditory (4.79%, *n* = 9), and tactile (2.66%, *n* = 5) presentations. Visual presentations predominated in brain imaging studies (47.87%, *n* = 90) while multimodal presentations predominated in behavioral (4.26%, *n* = 8) and physiological studies (2.13%, *n* = 4). Some studies did not define a sensory modality (12.74%, *n* = 24). This was particularly true when social reward was defined as an action, such as a monetary donation (e.g., Burum et al., 2020; Mercadante & Tracy, 2021; Sparrow et al., 2021).

As such, most studies delivered their social rewards through a screen (79.25%, *n* = 149). The remaining studies delivered them in person (13.83%, *n* = 26) or in an abstract manner (9.57%, *n* = 18). Screen-based deliveries were prevalent in most brain imaging (52.66%, *n* = 99), behavioral (18.62%, *n* = 35), physiological (6.91%, *n* = 13), and pharmacological (6.38%, *n* = 12) studies. On the other hand, in person (7.98%, *n* = 15) and abstract (6.38%, *n* = 12) deliveries prevailed in behavioral studies. In this context, abstract presentations required participants to imagine the social reward in question, such as interacting with a close other (Seaman et al., 2021). Regardless of study type, most studies used novel social rewards (77.13%, *n* = 145). Some studies also used acquaintances (22.34%, *n* = 42) or close persons (6.91%, *n* = 13). Acquaintances such as the experimenter or confederates prevailed in behavioral (10.11%, *n* = 19) and physiological studies (3.19%, *n* = 6).

Regarding duration, over half of the included studies (53.19%, *n* = 100) had social rewards that lasted between 1s and 10s. In particular, most of these were brain imaging studies (42.55%, *n* = 80). The remaining studies had social rewards that lasted less than 1s (6.38%, *n* = 12), between 10s and 60s (5.32%, *n* = 10), or more than 1 min (3.72%, *n* = 7). However, a large portion of studies did not state duration (34.04%, *n* = 64) with most of these being behavioral (23.94%, *n* = 45). Overall, the median duration of social reward was 2s (range: 0.08s - 5580s) across studies. Duration variability was high across study types, with brain imaging studies being the least variable (SD = 1.01 min; range: 0.20s - 10 min) and behavioral studies being the most variable (SD = 22.58 min, range: 0.08s - 1.55h).

**Figure 1**

*Study Selection Process: PRISMA Flow Chart*

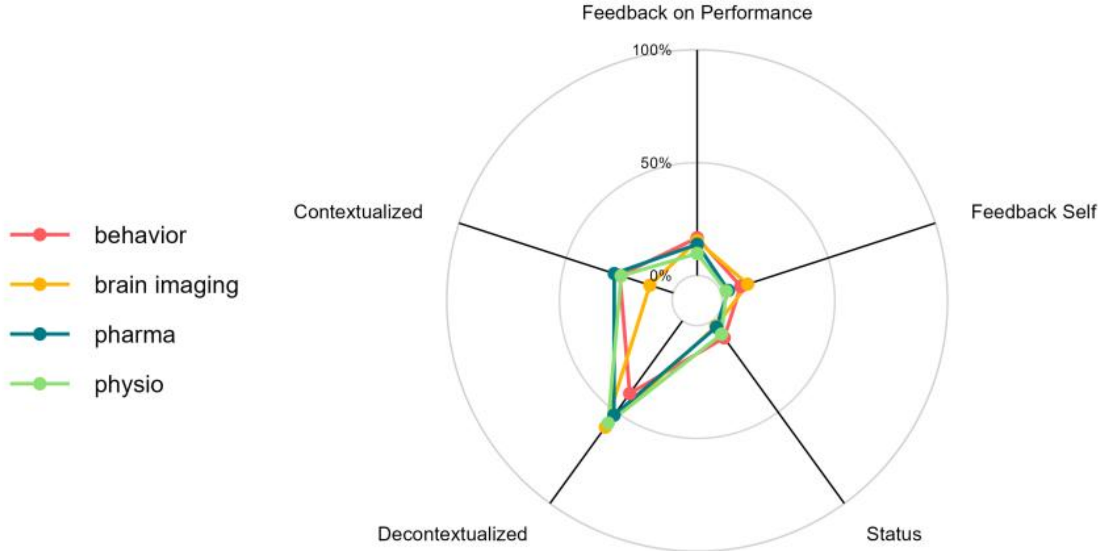



*Note.* * = studies retrieved from the 1st search (published up until 08.10.2020); ** = studies retrieved from the 2nd search (published between 09.10.2020 and 18.05.2022).

In terms of delay time, most studies had delayed (55.32%, *n* = 104) and immediate (46.28%, *n* = 87) deliveries. Some studies never delivered their social rewards (4.79%, *n* = 9). This occurred primarily in behavioral studies (3.19%, *n* = 6) that instructed participants to imagine social rewards (Seaman et al., 2021) or promised, but did not deliver, an actual reward (Hudd & Moscovitch, 2020). Otherwise, delayed deliveries were the most common in brain imaging (37.77%, *n* = 71) and immediate deliveries were the most common in behavioral studies (21.81%, *n* = 41). In studies that delayed their social rewards, the median delivery time was 3 seconds with high variability across studies (SD = 17.71h). For example, the quickest social reward was delivered within 0.25 seconds and the slowest social reward was delivered within 168 hours or 7 days. However, the median range across study types was 2.5s - 5.00s.

**Figure 2**

*The Contextualization of Social Reward Across Study Types*




*Note.* All represented values refer to the percentage of studies within a given study type that contextualized social reward in a given way. pharma = pharmacological; physio = physiological

### 3.5 General Trends in Comparison Stimuli of Social Reward

The most frequent comparison stimuli across all study types were faces (29.80%, *n* = 56). In terms of emotional valence, they were mostly angry (10.60%, *n* = 20) or sad (5.85%, *n* =11) facial expressions. Other common comparisons included money (25.50%, *n* = 48), feedback on performance (22.90%, *n* = 43), non-social other stimuli (17.60%, *n* = 33), no stimulus (13.30%, *n* = 25), feedback about the self (12.80%, *n* =

25), and status (5.32%, *n* = 10). In particular, faces, money, and feedback on performance predominated as comparison stimuli in brain imaging studies (52.66%, *n* = 99)[5]. In addition, faces were a frequent comparison in almost half of physiological (4.26%, *n* = 8) and pharmacological studies (3.72%, *n* = 7). On the other hand, the lack of a stimulus was a common comparison in behavioral studies (9.57%, *n* = 18).

Images were the most common representation for comparison stimuli (41.00%, *n* = 77) . They were most widely used in brain imaging studies (37.77%, *n* = 71). The remaining content was comprised of text (15.40%, *n* = 29), no stimulus (10.10%, *n* = 19), movies (7.45%, *n* = 14) or actions (4.79%, *n* = 9). Studies using money as a comparison often delivered real money at the end of the experiment (17.60%, *n* = 33). The remaining comparison stimuli and content were present in less than 4.26% of studies (for details, see Table A5 in the Appendix).

### 3.6 General Trends in Measures of Social Reward

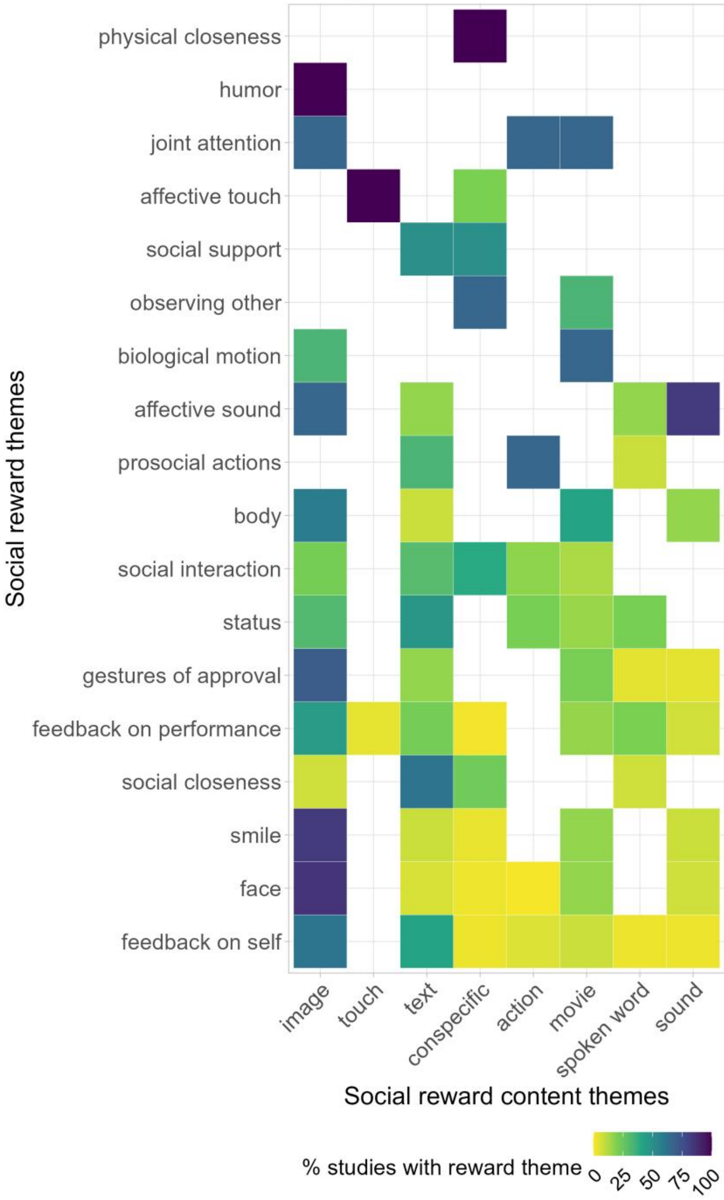
Most studies measures social reward directly (52.66%, *n* = 99) or used both direct and indirect measures (39.30%, *n* = 72). Fewer studies relied solely on indirect measures (7.45%, *n* = 14) or included no measures at all (1.60%, *n* = 3). Direct measures of social reward most often focused on consumption (69.15%, *n* = 130), followed by anticipation (52.13%, *n* = 98) and learning (12.23%, *n* = 23). Most studies measured multiple reward components (44.15%, *n* = 83), with a primary focus on both anticipation and consumption (31.91%, *n* = 83). Some studies also measured anticipation with learning (5.32%, *n* = 10) or consumption with learning (5.32%, *n* = 10), while the fewest studies included all three components (1.60%, *n* = 3).

Consumption was most frequently measured with brain activity (44.68%, *n* = 84), subjective ratings (35.11%, *n* = 66), and amount consumed measures (7.98%, *n* = 15). Brain imaging studies mostly used functional magnetic resonance imaging (fMRI) (32.45%, *n* = 61) and electroencephalography (EEG) (11.70%, *n* = 22), with one study (0.53%) employing near-infrared spectroscopy (fNIRS). Behavioral studies were predominated with subjective reports (9.04%, *n* = 17) and amount consumed measures (13.33%, *n* = 8). Subjective reports were also frequent in physiological (4.26%, *n* = 8) and pharmacological studies (3.72%, *n* = 7). Less frequent measures involved electromyography (EMG) (3.72%, *n* = 7), eye tracking (2.66%, *n* = 5), and social interaction behavior (2.13%, *n* = 4).

[5] The number of studies was calculated by summing brain imaging studies that used faces (40), money (33), and feedback on performance (26) as comparison stimuli

**Figure 3**

*Representation (Content) of Social Reward Themes in Human Experimental Studies*




*Note.* Each cell represents the percentage of studies that represented a given social reward theme with a given content. For example, faces could be represented as images, movies, or in addition to text. Some studies had more than a single theme and content (for details, see Figure A2 in the Appendix). Exact study counts and percentages can be found in Table A3 in the Appendix.

Anticipation was mostly measured with task accuracy/RT (29.26%, *n* = 55) , brain activity (20.74%, *n* = 39), subjective ratings (15.96%, *n* = 30), and effort (6.38%, *n* = 12). Out of these, brain imaging studies used accuracy/RT (20.21%, *n* = 38), fMRI (15.43%, *n* = 29) and EEG (5.32%, *n* = 10). Behavioral studies used subjective reports (6.38%, *n* = 12) and effort (3.72%, *n* = 7). Similar trends appeared in physiological studies, where subjective reports (3.19%, *n* = 6) were more common than effort measures (2.66%, *n* = 5). This pattern was also seen in pharmacological studies, with subjective reports (1.60%, *n* = 3) exceeding effort (1.00%, *n* = 2). The less frequent anticipation measures included approach behavior (4.26%, *n* = 8), payment for reward (2.66%, *n* = 5), facial movement (1.60%, *n* = 3), peripheral physiological activity (1.60%, *n* = 3), and eye movement (1.06%, *n* = 2).

Lastly, learning was measured with brain activity (5.32%, *n* = 10), reinforcement (4.26%, *n* = 8), and operant/instrumental learning (2.66%, *n* = 5). Brain imaging studies used fMRI (3.72%, *n* = 7) and EEG (1.60%, *n* = 3). Behavioral studies used operant/instrumental learning (2.13%, *n* = 4). The least number of studies used discrimination (1.60%, *n* = 3), Pavlovian (1.06%, *n* = 2), and other forms of learning (0.53%, *n* = 1).

**3.7 Trends in Social Reward Contextualization**

The following sections provide a more detailed discussion of trends in how social reward was operationalized, compared, and measured across the five contextualization categories: decontextualized social rewards, feedback on performance, contextualized social rewards, feedback about the self, and status. The percentages in brackets in each section represent the proportion of studies within that specific contextualization group, not the proportion relative to the entire dataset. For instance, in the section on decontextualized social rewards, it is noted that 59.41% of studies employed smiling faces. This percentage was calculated by dividing the number of studies using smiling faces (*n* = 60) by the total number of studies on decontextualized social rewards (*n* = 101), rather than by the total number of studies in the dataset (*n* = 188). Percentages for the entire dataset have already been provided in Sections 3.4–3.6.

**3.7.1 Decontextualized Social Rewards**

Decontextualized social rewards prevailed in brain imaging (66.34%, *n* = 67), as well as behavioral (22.77%, *n* = 23), physiological (11.88%, *n* = 12), and pharmacological studies (6.93%, *n* = 7). Most studies primarily used faces (77.23%, *n* = 78), often smiling (59.41%, *n* = 60), with some also including neutral (6.93%, *n* = 7) or non-smiling, attractive female faces (4.95%, *n* = 5). The remaining studies used approval gestures (23.76%, *n* = 24), bodies (11.88%, *n* = 12), affective sounds (5.94%, *n* = 6) or biological motion (2.97%, *n* = 3).

Images were the most frequent representational content for smiling faces (83.33%, $n$ = 50)[6] and approval gestures (83.33%, $n$ = 20)[5]. Other content involved movies (34.65%, $n$ = 35), sound (18.81%, $n$ = 19), text (15.84%, $n$ = 16), as well as conspecific (3.96%, $n$ = 4), spoken words (1.98%, $n$ = 2), or conducting an action (0.99%, $n$ = 1). Some studies used multiple decontextualized social rewards, combining smiling faces with positive sounds or approving gestures (for combinations and frequency, see Figure A2 in the Appendix). Two studies (3.33%) focused on the effects of smiling faces during in-person social interactions (Fairbairn et al., 2015; Heerey et al., 2014).

#### 3.7.1.1 Social Reward Dimensions

Decontextualized social rewards had predominately visual presentations (88.12%, $n$ = 89). However, some studies had multimodal (3.96%, $n$ = 4) and auditory presentations (2.97%, $n$ = 3). Most social rewards were delivered via a screen (97.03%, $n$ = 98), with a few provided in person (5.94%, $n$ = 6). Decontextualized social rewards were mostly novel (88.12%, $n$ =89), with a few from acquaintances (12.83%, $n$ = 13) and one (0.99%) from a close person.

Most rewards lasted between 1s and 10s (78.22%, $n$ = 79). Some studies on faces, approval gestures, and bodies presented stimuli for under 1 second (8.91%, $n$ = 9), while a few face studies presented stimuli for 10 to 60 seconds (6.41%, $n$ = 5). The least number of studies presented their rewards for longer than a minute (1.98%, $n$ = 2). Duration was not stated in 11 (10.89%) studies. Decontextualized social rewards were more frequently delayed (65.35%, $n$ = 66) than presented immediately (41.58%, $n$ = 42). Studies on smiling faces (40.59%, $n$ = 41) and approval gestures (16.83%, $n$ = 17) were especially likely to delay rewards.

#### 3.7.1.2 Comparison Stimuli

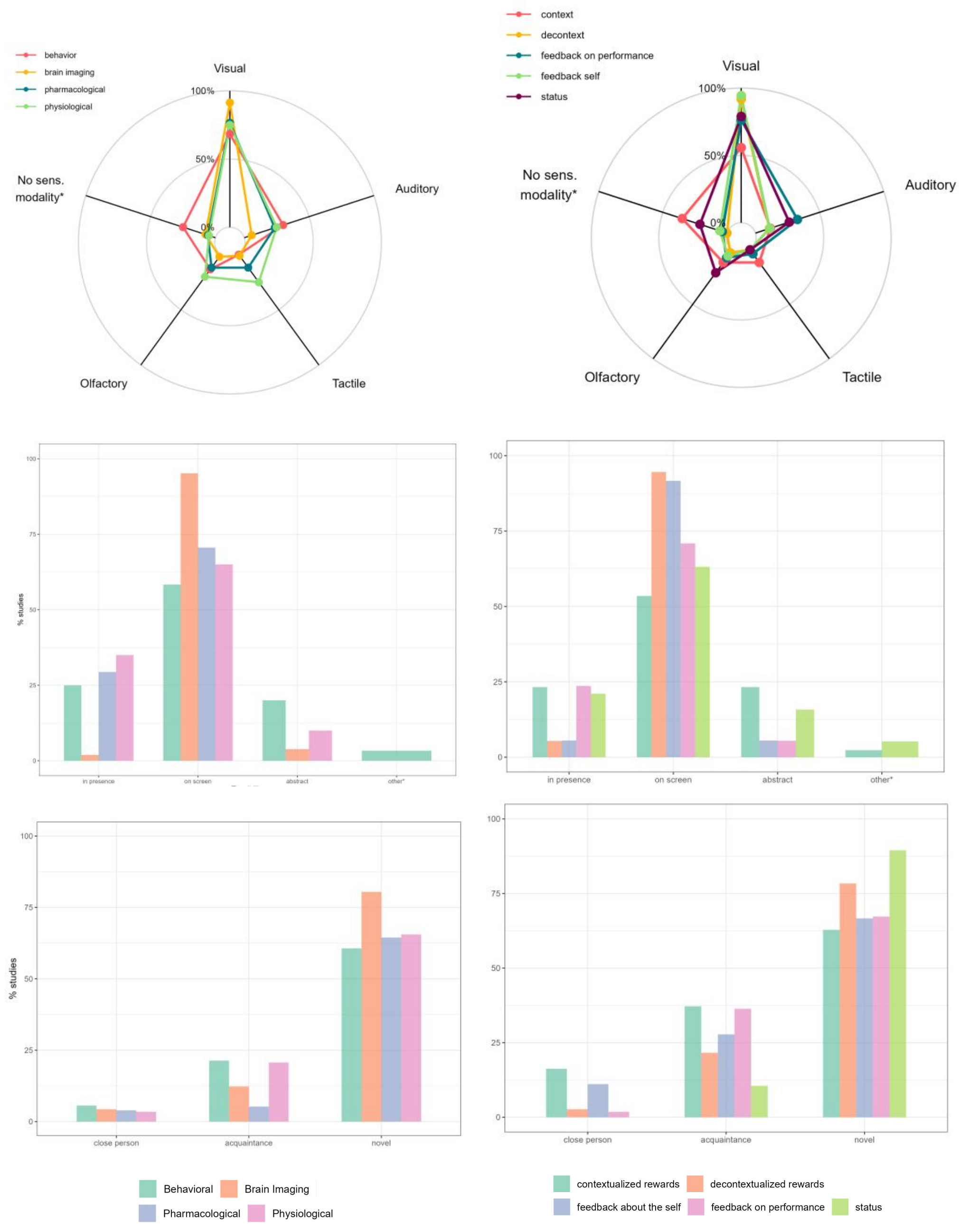
In terms of valence, decontextualized social rewards were compared to neutral (66.34%, $n$ = 67), negative (54.46%, $n$ = 55), and positive stimuli (46.53%, $n$ = 47). In most studies, social reward was compared to other faces (54.46%, $n$ = 55) with angry (19.80%, $n$ = 20), sad (10.89%, $n$ = 11), smiling (7.92%, $n$ = 8), and fearful (3.96%, $n$ = 4) facial expressions. Other comparisons involved money (31.68%, $n$ = 32), feedback on performance (29.70%, $n$ = 30), nonsocial other stimuli (20.79%, $n$ = 21), no stimulus (10.89%, $n$ = 11), feedback about the self (13.86%, $n$ = 14), socially

[6] The stated percentage represents the proportion of studies specifically on smiling faces (60) and approval gestures (24) depicted as images, not all studies concerning decontextualized social rewards (101).

blurred stimuli (10.89%, $n$ = 11), body (6.93%, $n$ = 7), affective sound (3.96%, $n$ = 4), food (2.97%, $n$ = 3),  and biological motion (1.98%, $n$ = 2).

**Figure 4**

*Dimensions of Social Reward Across Study Types and Reward Context*

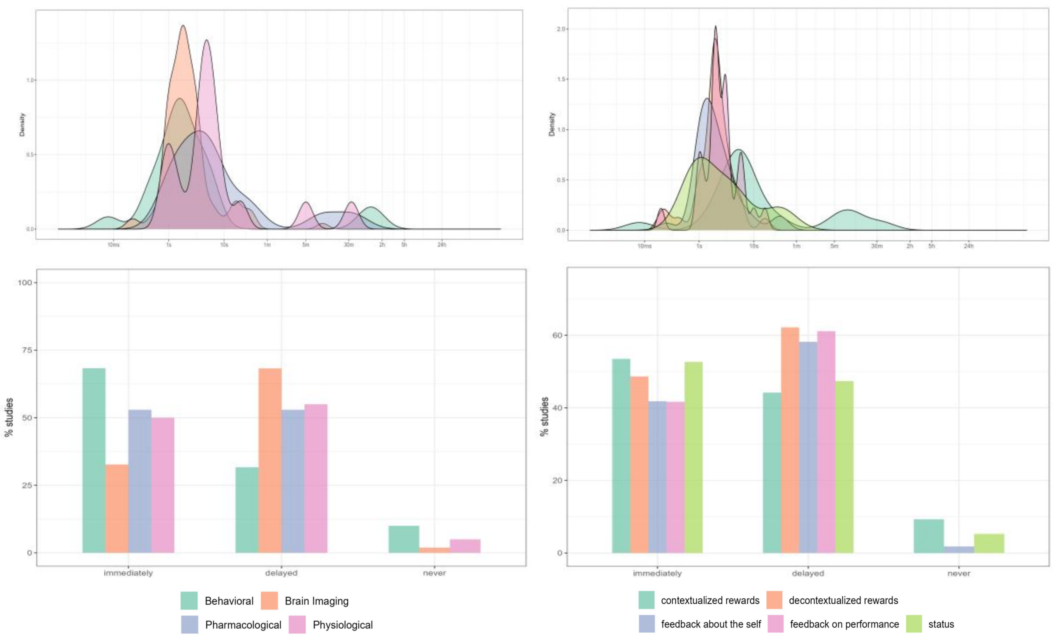



*Note.* Radar charts in the top row represent sensory modality of social reward across study types (left) and reward context (right). Bar charts in the middle row represent tangibility of social reward across study types (left) and reward context (right). Bar charts in the bottom row represent familiarity of social reward across study types (left) and reward context (right). All represented values refer to the percentage of studies that contained a specific dimension (sensory modality, tangibility, or familiarity).

Smiling faces were most often compared to monetary rewards (20.79%, *n* = 21) and positive non-social feedback on performance (14.85%, *n* = 15), while approval gestures were primarily compared to monetary rewards alone (9.90%, *n* = 10). A few studies compared decontextualized rewards with more contextualized ones, such as social interaction (1.98%, *n* = 2), joint attention (0.99%, *n* = 1), or status (0.99%, *n* = 1).

**Figure 5**

*Duration and Delay Time of Social Reward Across Study Types and Reward Context*




*Note.* Density plots at the top represent the duration of social reward across study types (left) and reward context (right). Bar plots at the bottom represent the delay times of social reward across study types (left) and reward context (right). All represented values refer to the percentage of studies employing specific duration and delay times.

### 3.7.1.3 Measures

Decontextualized social rewards were measured either directly (57.43%, *n* = 58) or both directly and indirectly (35.64%, *n* = 36), with only a few studies using indirect measures alone (6.93%, *n* = 7). Direct measures focused on consumption (69.31%, *n* = 70) and anticipation (59.41%, *n* = 60), with a lesser emphasis on learning (14.85%, *n* = 15). In that sense, consumption was measured with fMRI (32.67%, *n* = 33), subjective ratings (30.69%, *n* = 31), EEG (16.83%, *n* = 17), amount consumed (4.95%, *n* = 5), eye movements (3.96%, *n* = 4), facial movements (2.97%, *n* = 3), and social interaction behavior (0.99%, *n* = 1). Brain activity measures were mostly used for smiling faces (26.73%, *n* = 27), approval gestures (13.86%, *n* = 14), and non-smiling faces (11.88%, $n$ = 12). Subjective ratings were also used for smiling faces (13.86%, $n$ = 14), non-smiling faces (8.91%, $n$ = 9), and approval gestures (7.92%, $n$ = 8).

Anticipation was measured with accuracy/RT (44.55%, $n$ = 45), fMRI (20.79%, $n$ = 21), subjective ratings (9.90%, $n$ = 10), EEG (7.92%, $n$ = 8), approach behavior (2.97%, $n$ = 3), effort (2.97%, $n$ = 3), payment for reward (2.97%, $n$ = 3), and eye movement (1.98%, $n$ = 2). Anticipation of smiling faces was measured using accuracy/RT (31.68%, $n$ = 32), brain activity (21.78%, $n$ = 22), and subjective ratings (7.92%, $n$ = 8), while anticipation of approval gestures was mainly measured with accuracy/RT alone (10.89%, $n$ = 11). Lastly, learning was measured with reinforcement learning (4.95%, $n$ = 5), fMRI (4.95%, $n$ = 5), EEG (2.97%, $n$ = 3), Pavlovian (1.06%, $n$ = 2), discrimination (0.99%, $n$ = 1), and other forms of learning (0.99%, $n$ = 1). In particular, learning of smiling faces was measured with brain activity (6.93%, $n$ = 7), reinforcement (2.97%, $n$ = 3), and operant/instrumental learning (2.97%, $n$ = 3).

### 3.7.2 Feedback on Performance

Feedback on performance was frequently used in brain imaging (56.36%, $n$ = 31) and behavioral studies (32.73%, $n$ = 18), as well as some pharmacological (7.27%, $n$ = 4) and physiological studies (7.27%, $n$ = 4). This social reward was commonly combined with decontextualized social rewards (56.36%, $n$ = 31) such as smiling faces (38.18%, $n$ = 21), approval gestures (e.g., thumbs-up, head nodding; 12.73%, $n$ = 7), affective sounds (7.27%, $n$ = 4), or bodies (3.64%, $n$ = 2). Some studies also delivered feedback in the form of status (10.91%, $n$ = 6), affective touch (3.64%, $n$ = 2), or social interaction (1.82%, $n$ = 1).

Feedback on performance was most frequently represented as an image (45.45%, $n$ = 25), as well as text (21.82%, $n$ = 12), spoken words (20.00%, $n$ = 11), or movies (16.36%, $n$ = 9). Certain studies also delivered feedback in the form of verbal encouragement (10.91%, $n$ = 6), written encouragement (7.27%, $n$ = 5), or personal feedback about the self (7.27%, $n$ = 5).

#### 3.7.2.1 Social Reward Dimensions

Most studies had visual presentations of feedback on performance (60.00%, $n$ = 33), with some also having auditory (16.36%, $n$ = 9), multimodal (7.27%, $n$ = 4), and tactile presentations (3.64%, $n$ = 2). Most of this feedback was delivered thorough a screen (70.91%, $n$ = 39), with some also delivered in person (23.64%, $n$ = 13) or an abstract manner (5.45%, $n$ = 3). Abstract feedback presentations required participants to imagine being praised by close others (Ramirez-Marin & Shafa, 2018). Feedback on performance was mostly novel (67.27%, *n* = 37), with some also from acquaintances (36.36%, *n* = 20) or close people (1.82%, *n* = 1) .

Most studies delivered feedback between 1 and 10 seconds (60.00%, *n* = 33) or did not state duration (32.73%, *n* = 18). Some studies had duration between 10 and 60 seconds (5.45%, *n* = 3) or less than 1 second (1.82%, *n* = 1). Most studies had delayed (58.18%, *n* = 32) followed by immediate deliveries (41.82%, *n* = 23) with one study (1.82%) never delivering the promised feedback.

**3.7.2.2 Comparison Stimuli**

Regarding valence, feedback on performance was compared to neutral (60.00%, *n* = 33), positive (47.27%, *n* = 26), and negative stimuli (43.64%, *n* = 24). In particular, this social reward was mostly compared to negative (32.73%, *n* = 18) or neutral (30.91%, *n* = 17) feedback on performance. Other comparisons involved faces (32.73%, *n* = 18) with angry (9.09%, *n* = 5), sad (7.27%, *n* = 4), or smiling (7.27%, *n* = 4) expressions, as well as money (30.91%, *n* = 17), no stimulus (21.82%, *n* = 12), nonsocial other stimuli (14.54%, *n* = 8), affective sound (7.27%, *n* = 4), socially blurred stimuli (7.27%, *n* = 4), food (5.45%, *n* = 3), body (3.64%, *n* = 2), feedback about the self (3.64%, *n* = 2) and status (3.64%, *n* = 2).

**3.7.2.2 Measures**

Feedback on performance was measured with direct (58.18%, *n* = 32), both direct and indirect (30.91%, *n* = 17), or with only indirect measures (9.09%, *n* = 5). Direct measures focused on consumption (63.64%, *n* = 35), anticipation (60.00%, *n* = 33), and to a lesser extent on learning (25.45%, *n* = 14). Consumption was measured with fMRI (32.73%, *n* = 18), subjective ratings (21.82%, *n* = 12), EEG (12.73%, *n* = 7), amount consumed (7.27%, *n* = 4), EMG (1.82%, *n* = 1), social interaction behavior (1.82%, *n* = 1), and eye movement (1.82%, *n* = 1). Anticipation was measured with accuracy/RT (34.55%, *n* = 19), fMRI (18.18%, *n* = 10), EEG (10.91%, *n* = 6), effort (10.91%, *n* = 6), subjective rating (10.91%, *n* = 6), autonomic nervous system (ANS) activity (1.82%, *n* = 1), approach behavior (1.82%, *n* = 1), and payment for reward (1.82%, *n* = 1). Lastly, learning due to feedback on performance was measured with operant/instrumental (9.09%, *n* = 5), fMRI (7.27%, *n* = 4), reinforcement (5.45%, *n* = 3), discrimination learning (3.64%, *n* = 2), and EEG (1.82%, *n* = 1).

### 3.7.3 Contextualized Social Rewards

Contextualized social rewards were mostly researched in behavioral studies (43.14%, *n* = 22) as well as some brain imaging (33.33%, *n* = 17), physiological (17.65%, *n* = 9) and pharmacological studies (15.69%, *n* = 8). These rewards most commonly took the form of social interaction (45.10%, *n* = 23), as well as social closeness (25.49%, *n* = 13) and prosocial actions (23.53%, *n* = 12). The less prevalent contextualized social rewards included affective touch (9.80%, *n* = 5), joint attention (5.88%, *n* = 3), observation without interaction (5.88%, *n* = 3), social support (3.92%, *n* = 2), physical closeness (1.96%, *n* = 1), and humor (1.96, *n* = 1).

In terms of content, these social rewards had varied representations across studies. The most frequent forms of content were text (39.21%, *n* = 20), conspecific (33.33%, *n* = 17) and action (27.45%, *n* = 14), as well as images (17.65%, *n* = 9), movies (11.76%, *n* = 6), and spoken words (3.92%, *n* = 2). For instance, social interaction was frequently represented as conspecific (17.65%, *n* = 9), text (13.73%, *n* = 7), images (9.80%, *n* = 5) and movies (5.88%, *n* = 3). Social closeness was mostly represented with text alone (15.69%, *n* = 8) and prosociality was investigated in the context of actions (15.69%, *n* = 8). Less frequent social rewards, such as joint attention, were also represented with images (3.92%, *n* = 2) and movies (3.92%, *n* = 2). Lastly, some studies investigated social interaction in combination with social closeness (17.39%, *n* = 4). For details on contextualized social reward and their content representations, see Tables A3-A4 in the Appendix.

#### 3.7.3.1 Social Reward Dimensions

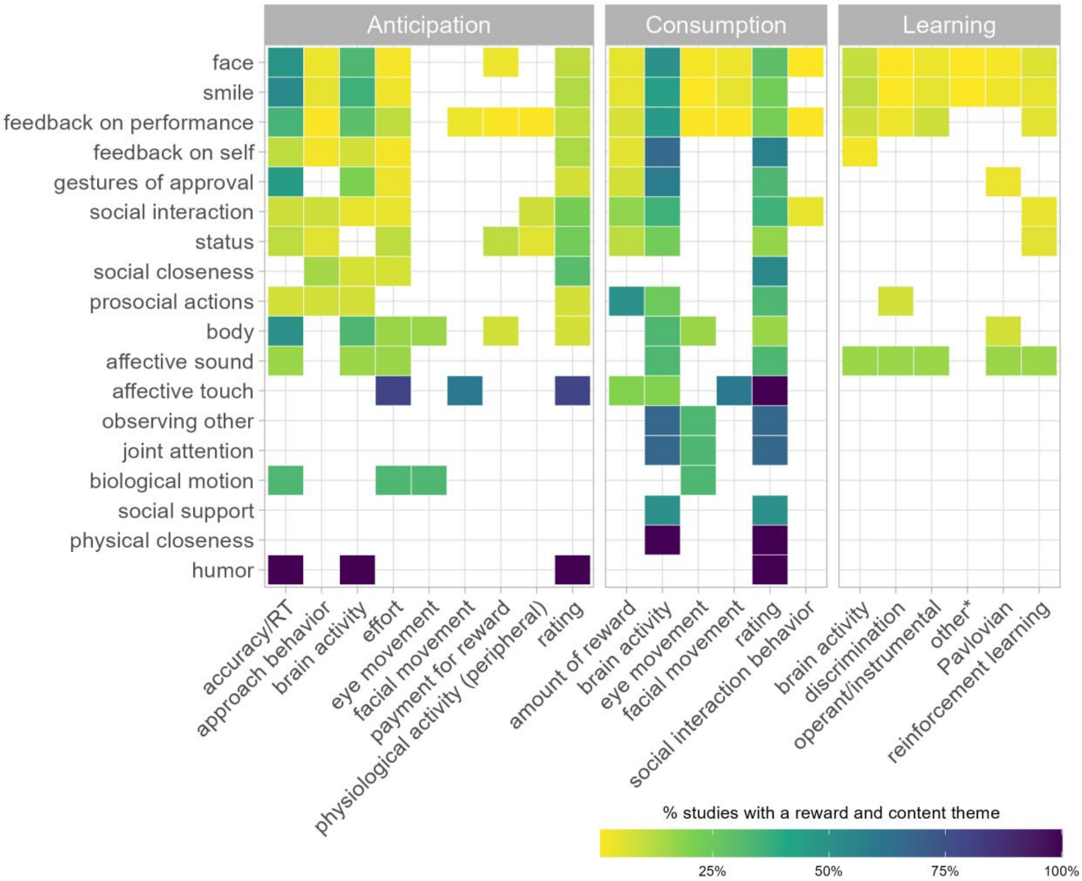
Most contextualized social rewards were also presented in a visual manner (42.00%, *n* = 21), with some studies having multimodal (15.69%, *n* = 8) or tactile presentations (9.80%, *n* = 5). Importantly, many studies lacked clarity on sensory modality (39.22%, *n* = 20). In terms of tangibility, most social rewards were presented via a screen (49.02%, *n* = 25), as well as abstractly (49.02%, *n* = 25) or in person (23.53%, *n* = 12). Most contextualized social reward were novel (58.82%, *n* = 30), and some were acquaintances (37.25%, *n* = 19) or close people (19.61%, *n* = 10).

In addition, most of these studies could not ascertain duration of social reward (58.82%, *n* = 30), especially in the case of social interaction (27.45%, *n* = 14), social closeness (17.65%, *n* = 9), and prosocial actions (15.69%, *n* = 8). When duration was stated, social reward most frequently lasted between 1 and 10 seconds (27.45%, *n* = 14) as in the case of affective touch (9.80%, *n* = 5), joint attention (5.88%, *n* = 3), observation without interaction (3.92%, $n$ = 2), physical closeness (1.96%, $n$ = 1), and humor (1.96%, $n$ = 1).

In some studies, social rewards lasted longer than 1 minute (11.76%, $n$ = 6), between 10 and 60 seconds (11.76%, $n$ = 6) or less than 1 second (1.96%, $n$ = 1). Most contextualized social rewards had immediate (49.02%, $n$ = 25) followed by delayed deliveries (41.18%, $n$ = 21). A certain number of studies never delivered their social rewards (15.69%, $n$ = 8).

**Figure 6**

*Measures of Social Reward Components*




*Note.* Every cell represents the percentage of studies with a certain social reward theme that implemented any of the listed anticipation, consumption, or learning measures. For example, the dark green cells for face indicate that most studies using this social reward theme measured consumption with brain activity and rating, and anticipation with brain activity and accuracy/response time.

### 3.7.3.2 Comparison Stimuli

The valence of the comparison stimuli was neutral (33.33%, $n$ = 17), negative (31.37%, $n$ = 16), and positive (25.49%, $n$ = 13). Contextualized social rewards were compared to social interaction (21.57%, $n$ = 11), money (15.69%, $n$ = 8), no stimulus (9.80%, $n$ = 5), nonsocial other stimuli (9.80%, $n$ = 5), and non-rewarding forms of social closeness (7.84%, $n$ = 4). Social interaction was primarily compared with other negative (17.65%, $n$ = 9) or neutral interactions (5.88%, $n$ = 3), with some studies also contrasting it with monetary rewards (3.92%, $n$ = 2). Prosocial actions were also compared to monetary rewards (9.80%, $n$ = 5) or to non-prosocial actions (5.88%, $n$ = 3).

In contrast, affective touch was mostly compared to food rewards (5.88%, $n$ = 3). Besides social interaction and prosocial actions, social closeness (3.92%, $n$ = 2) and humor (1.96%, $n$ = 1) were also compared to monetary rewards. Other comparisons included lack of joint attention (3.92%, $n$ = 2), observation without interaction (3.92%, $n$ = 2), polite smiling (3.92%, $n$ = 2), loss of status (3.92%, $n$ = 2) or unfavorable feedback about the self (3.92%, $n$ = 2). The remaining comparison stimuli, representing less than 1.96% of contextualized social reward comparisons, are listed in Table A5 in the Appendix.

**3.7.3.2 Measures**

Contextualized social rewards were measured directly (49.02%, $n$ = 25) or both directly and indirectly (43.14%, $n$ = 22). However, some studies employed strictly indirect (5.88%, $n$ = 3) or no measures at all (1.96%, $n$ = 1). Similar to other groups, direct measures focused on consumption (76.47%, $n$ = 39), anticipation (41.18%, $n$ = 21), and sometimes learning (3.92%, $n$ = 2). Consumption measures included subjective ratings (49.02%, $n$ = 25), amount consumed (21.57%, $n$ = 11), fMRI (19.61%, $n$ =10), EMG (5.88%, $n$ = 3), EEG (3.92%, $n$ = 2), social interaction behavior (1.96%, $n$ = 1), eye movement (1.96%, $n$ = 1), and fNIRS (1.96%, $n$ = 1).

In particular, social interaction was most commonly measured with subjective ratings (15.69%, $n$ = 8), brain activity (15.69%, $n$ = 8), and amount consumed (7.84%, $n$ = 4). In comparison, social closeness was measured with subjective ratings alone (13.73%, $n$ = 7). Similarly, prosocial actions were measured with amount consumed (11.76%, $n$ = 6)[7] and subjective ratings (7.84%, $n$ = 4). The less common contextualized social rewards were predominantly measured using subjective ratings (23.53%, $n$ = 12)[8] or brain activity measures (13.73%, $n$ = 7)[9].

[7]Here, amount consumed refers to the size of monetary donations made (see Burum et al., 2020 for an example).

[8] The number of studies was obtained by adding affective touch (n = 5), joint attention (n = 2), observation without interaction (n = 2), physical closeness (n = 1), social support (n = 1) and humor (n = 1).

Anticipation was also mostly measured through subjective ratings (25.49%, *n* = 13) or effort (11.76%, *n* = 6). In particular, social interaction (9.80%, *n* = 5), social closeness (7.84%, *n* = 4), affective touch (7.84%, *n* = 4), prosocial actions (1.96%, *n* = 1), and humor (1.96%, *n* = 1) were all measured with subjective ratings. Anticipation of affective touch was also measured with effort (7.84%, *n* = 4) and EMG (5.88%, *n* = 3). In contrast to other categories, less studies used accuracy/RT (7.84%, *n* = 4), approach behavior (7.84%, *n* = 4), fMRI (5.88%, *n* = 3), as well as ANS activity measures (3.92%, *n* = 2). Lastly, learning was measured through discrimination tasks for prosocial actions (1.96%, *n* = 1) or reinforcement learning for social interactions (1.96%, *n* = 1).

#### 3.7.4 Feedback About the Self

Feedback about the self was researched in brain imaging (69.44%, *n* = 25) and behavioral studies (27.78%, *n* = 25), as well as in some pharmacological (2.78%, *n* = 1) and physiological ones (2.78%, *n* = 1). In terms of content, feedback about the self was represented as images (61.11%, *n* = 22) and text (41.67%, *n* = 15), as well as movies (8.33%, *n* =3), actions (5.56%, *n* = 2), spoken words (2.78%, *n* = 1), sounds (2.78%, *n* = 1), or conspecific (2.78%, *n* = 1). This social reward was sometimes represented in combination with approval gestures (30.56%, *n* = 11), faces (11.11%, *n* = 4), social closeness (11.11%, *n* = 4) or status (11.11%, *n* = 4).

##### 3.7.4.1 Social Reward Dimensions

Feedback about the self had predominately visual presentations (86.11%, *n* = 31) with some studies also having multimodal (5.56%, *n* = 2) or auditory ones (2.78%, *n* = 1). Therefore, almost all presentations were done via a screen (91.67%, *n* = 33) with some presenting it in person (5.56%, *n* = 2) or abstractly (5.56%, *n* = 2). Most feedback about the self was novel (66.67%, *n* = 24), with some being from acquaintances (27.78%, *n* = 10) or close people (11.11%, *n* = 4).

Overall, feedback about the self lasted between 1 and 10 seconds (69.44%, *n* = 25) or duration was not stated (25.00%, *n* = 9). Other durations accounted for less than 5.56% of studies on feedback about the self and are listed in Table A4 in the Appendix. Lastly, more studies had delayed (61.11%, *n* = 22) compared to immediate deliveries of feedback (41.67%, *n* = 15).

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[9] The number of studies was obtained by adding joint attention (n = 2), observation without interaction (n = 2), physical closeness (n = 1), social support (n = 1), and affective touch (n = 1).

#### 3.7.4.2 Comparison Stimuli

Feedback about the self was compared to negative (50.00%, $n$ = 18), neutral (47.22%, $n$ = 17), and positive stimuli (47.22%, $n$ = 17). The most common comparisons involve non-rewarding feedback about the self (61.11%, $n$ = 22), money (25.00%, $n$ = 9), nonsocial other stimuli (22.22%, $n$ = 8), no stimulus (13.89%, $n$ = 5), and feedback on performance (13.89%, $n$ = 5) as well as faces (8.33%, $n$ = 3) and status (5.56%, $n$ = 2). The remaining comparisons comprised less than 5.56% of studies on feedback about the self and can be found in Table A5 in the Appendix.

#### 3.7.4.3 Measures

Most studies on feedback about the self used both direct and indirect measures (52.78%, $n$ =19) with some using direct measures alone (44.44%, $n$ =16). Direct measures predominately focused on consumption (88.89%, $n$ = 32) with some focusing on anticipation (27.78%, $n$ = 10) and learning (2.78%, $n$ = 1). Consumption was measured with subjective ratings (55.56%, $n$ = 20), fMRI (38.89%, $n$ = 14), EEG (25.00%, $n$ = 9), and amount consumed (5.56%, $n$ = 2). Anticipation was measured with subjective ratings (13.89%, $n$ = 5) or task accuracy/RT (11.11%, $n$ = 4). Other anticipation measures comprised less than 5.56% of studies and can be found in Table A6 in the Appendix. Finally, the sole study measuring learning employed fMRI (2.86%, $n$ = 1).

### 3.7.5 Ultimate Social Goals: Status

Status was mostly researched in behavioral (52.62%, $n$ = 10) and brain imaging studies (31.58%, $n$ = 6), as well as some physiological (15.79%, $n$ = 3) and one pharmacological study (5.26%, $n$ = 1). In terms of representational content, most studies used text (47.37%, $n$ = 9), images (31.58%, $n$ = 6), actions (21.05%, $n$ = 4)[10], spoken words (21.05%, $n$ = 4), or movies (15.79%, $n$ = 3).

#### 3.7.5.1 Social Reward Dimensions

Status had mostly visual (52.63%, $n$ = 10) or multimodal presentations (26.32%, $n$ = 5). For certain studies it was difficult to assign a sensory modality (21.05%, $n$ = 4). Tangible information about status was presented via a screen (63.16%, $n$ = 12) or in person (21.05%, $n$ = 4). Most status was comprised of novel stimuli (89.47%, $n$ = 17), with some studies using acquaintances (10.53%, $n$ = 2). Duration was not stated in most studies (73.66%, $n$ = 14) or was between 1 and 10 seconds (21.05%, $n$ = 4).

[10] An example of this is requiring participants to make a monetary donation for reputational gains (Burum et al., 2020)

Other durations accounted for less than 5.26% of studies on status and can be found in Table A4 in the Appendix. Otherwise, status was either delivered immediately (52.63%, *n* = 10) or delayed (47.37%, *n* = 9), with one study not delivering status altogether (5.26%, *n* = 1).

#### 3.7.5.2 Comparison Stimuli

Status was equally compared to neutral (47.37%, *n* = 9) and positive stimuli (47.37%, *n* = 9) with a lesser number of studies comparing it to negative stimuli (26.32%, *n* = 5). The comparison stimuli for status involved non-rewarding status (47.37%, *n* = 9), money (31.58%, *n* = 6), feedback on performance (21.05%, *n* = 4), no stimulus (21.05%, *n* = 4), feedback about the self (15.79%, *n* = 3), nonsocial other stimuli (10.53%, *n* = 2), and faces (5.26%, *n* = 1).

#### 3.7.5.3 Measures

Status was mostly measured with both direct and indirect (42.10%, *n* = 8) or with direct measures alone (36.84%, *n* = 7). To a lesser extent, it was also measured with indirect (10.53%, *n* = 2) or no measures (10.53%, *n* = 2). In contrast to other groups, the direct measures were comprised of anticipation (52.63%, *n* = 10), consumption (42.11%, *n* = 8), and learning (5.26%, *n* = 1).

Anticipation was mostly measured with subjective ratings (21.05%, *n* = 4), accuracy/RT (10.53%, *n* = 2), effort (10.53%, *n* = 2) or payment for reward (10.53%, *n* = 2). Consumption was primarily measured through brain activity (21.05%, *n* = 4), specifically using fMRI (15.79%, *n* = 3). It was also measured with subjective rating (15.79%, *n* = 3) or amount consumed (10.53%, *n* = 2). All other anticipation and consumption measures comprised less than 5.26% of studies on status and can be found in Table A6 in the Appendix. Finally, the only learning study researched reinforcement learning (5.26%, *n* = 1) due to status.

## 4. Discussion

This systematic review aimed to provide a comprehensive overview of the operationalization, comparison, and measurement of social reward in human experimental studies. A data-driven approach was employed, grouping the identified higher-order social reward themes into one of five contextualization categories, following the dual-model framework by Tamir and Hughes (2018). For each of these groups, comparison stimuli were extracted to assess alignment across experimental groups, and the measures were reviewed to identify potential constraints on operationalization imposed by these measures.

The following discussion further examines prevailing trends in social reward operationalization and considers how these trends may have been constrained by the methodologies available for studying the concept. Certain research gaps regarding the role of social reward in social interaction are identified and the implications for interpreting research findings are explored. Building on this information, a hierarchical operationalization framework is proposed to guide future research, aligning the types of research questions with the methodologies available to address them. Lastly, the final sections of the discussion focus on the implications for cognitive science, some limitations of the current review, and guidelines for future research.

### 4.1 Trends in Social Reward Operationalization, Comparison Stimuli, and Measurement

The primary finding of this systematic review is that more than 58% of human experimental studies operationalized social reward in the form of decontextualized social stimuli. Out of these, more than 59% were smiling faces, and more than 23% included approval gestures, while all other themes occurred in less than 12% of studies using these type of stimuli. On the other hand, more than 29% of all studies included feedback on performance, while over 19% included feedback about the self. In more than 45% of studies using either form of operationalization, the stimuli were represented as images or text.

In comparison, less than 13% of all included studies used contextualized social rewards such as social interaction or ultimate social goals like status. For detailed information on the number of studies and percentages corresponding to each social reward theme and contextualization group, refer to Figure 3 in the main text, as well as Table A2 and Figure A2 in the Appendix. The following sub-sections discuss each contextualization group in more detail, including trends in comparison and measurement, starting with the most prevalent categories and ending with the least prevalent ones.

#### 4.1.1 Decontextualized Social Rewards, Feedback on Performance and Feedback About the Self

The most commonly used forms of operationalization, including decontextualized social rewards, feedback on performance, and feedback about the self were initially grouped into three distinct contextualization categories. However, this review's findings revealed that over 60% of studies per category presented these social rewards in a similarly unimodal fashion. In particular, the studies employed novel, visual, and screen-based social reward stimuli (e.g., Izuma et al., 2008; Spreckelmeyer et al., 2009; Makowski et al., 2013; Gossen et al., 2013; Rademacher et al., 2014; Hwang et al., 2017; Wake & Izuma, 2017; Catalano et al., 2018; Frey & McCabe, 2020). Therefore, the operationalization, comparison, and measurement trends identified for these three contextualization groups are jointly addressed in the current subsection of the Discussion (for details per social reward theme, see Figures 4-5 in the main text and Table A4, Figure A1 in the Appendix).

In terms of study type, the three contextualization categories were most prevalent in brain imaging studies. The most frequent category was decontextualized social rewards, appearing in up to 52% of brain imaging studies, and the least frequent category was feedback about the self, appearing in 24%. Correspondingly, regarding the measurement of decontextualized social rewards and feedback on performance, more than 46% of studies measured brain activity upon consumption and more than 28% measured it upon anticipation of social reward (e.g., Delmonte et al., 2012; Kawamichi et al., 2016; Sharma et al., 2016; Bedi et al., 2018; Zimmermann et al., 2019; Sumiya et al., 2020). Moreover, the current systematic review found that studies using one of these two contextualization categories validated their brain activity findings with subjective ratings for consumption and task accuracy/RT measures for anticipation (more than 16% of studies for each combination). This is in alignment with social reward measures discussed by previous reviewers, such as Baez-Mendoza and Schultz (2013) or Foulkes and colleagues (2014).

In addition, less than 4% of all brain imaging studies measured brain activity during learning of smiling faces (Lin et al., 2012; Mathiak et al., 2010; Stark et al., 2019; Frey & McCabe, 2020). In comparison, less than 7% of behavioral studies measured operant/instrumental or reinforcement learning due to feedback on task performance (John & Quay, 1962; Bernard & Eisenman, 1967; Doppler et al., 2019; Chen et al., 2021). Besides learning, most behavioral studies implemented subjective ratings to measure anticipation and consumption for both contextualization categories (e.g., Lin et al., 2012; Lenaert et al., 2018; Zhu & Zhan, 2019; Evans & Britton, 2020).

In addition to this, more than 35% of studies on decontextualized social rewards or feedback on performance utilized accuracy/RT measures to assess the incentivizing properties of social reward (e.g., Delmonte et al., 2012; Brinkmann et al., 2014; Flores et al., 2015; Hwang et al., 2017; Kim & Anderson, 2019; Bedi et al., 2018; Zhu & Zhan, 2019). This is further evident in the manner these studies presented the rewards. Specifically, more than 60% of studies for each contextualization category delivered their social rewards over multiple trials, lasting 2 seconds each, within cognitive or learning tasks. Additionally, more than 58% of social rewards were cued and delivered after a brief delay of a few seconds. Thus, most studies using decontextualized social rewards and/or feedback on performance focused on the neural and motivational properties of these rewards.

In comparison, more than 65% of studies on feedback about the self used brain activity for consumption and more than 57% used subjective ratings for both anticipation and consumption (e.g., Via et al., 2015; Makowski et al., 2015; Pegg et al., 2019; Sumiya et al., 2020; Weinberg et al., 2021). Compared to the other two contextualization categories, these studies were more likely to incorporate familiar individuals with more than 27% using acquaintances and more than 11% using close people. However, the presentation of social rewards, in terms of duration and delay, remained consistent with the other categories (for details, see Table A4 in the Appendix).

In terms of comparison stimuli, more than 30% of studies utilizing decontextualized social rewards or feedback on performance compared them to non-rewarding facial expressions, non-rewarding or non-social feedback on performance, or to monetary rewards (for details, see Table A5 in the Appendix). On the other hand, more than 61% of studies on feedback about the self compared it to its non-rewarding counterparts, 25% compared it to monetary rewards, and 22% compared it to non-social other stimuli. These findings further align with previous reviewers asserting that social rewards were most frequently compared to non-social monetary rewards or other experimentally matched, non-rewarding counterparts of social reward (Lockwood et al., 2020; Matyjek et al., 2020b).

Therefore, the findings of the current systematic review reveal that most social reward studies used decontextualized social rewards, feedback on task performance, or feedback about the self to investigate how they compare to their non-rewarding counterparts or non-social monetary rewards in terms of brain activity or behavioral performance in cognitive or learning tasks. As such, the prevalence of the three contextualization categories discussed in the current sub-section can be attributed to several methodological factors. The primary reason consists of the ease of measurement and quantification associated with these forms of operationalization

(Hamilton & Holler, 2023). For example, compared to dynamic social interactions, smiling faces are better suited for single-brain neuroimaging research designs. In particular, these social reward stimuli can be presented in numerous short-duration trials, allowing researchers to effectively capture the corresponding fMRI or EEG signals (van Atteveldt et al., 2018).

Secondly, the predominantly static nature of these social rewards makes them suitable for comparisons with non-social monetary rewards which have been better researched in the literature (Lutz & Widmer, 2014; Balodis & Potenza, 2015; Jauhar et al., 2021; Gill et al., 2021). Thus, in alignment with assertions made by previous reviewers, this systematic review also postulates that most social reward research aimed to determine the specificity of social reward processing by comparing it to the better researched effects of non-social rewards (Lockwood et al., 2020). As a result, research paradigms such as the monetary incentive delay (MID) paradigm were adapted to explore social rewards (Knutson, 2000; Martins et al., 2021). This adaptation necessitated the use of simple and predictable social stimuli rather than complex and uncertain social interactions.

With these factors taken into account, the use of decontextualized social rewards, feedback on task performance, or feedback about the self offers clear guidelines for maintaining experimental control and repeatability. Therefore, consistently implementing the same social stimulus across participants lowers variability and increases the likelihood of isolating neural and behavioral effects that are specific to social reward. In comparison, research on contextualized social rewards faces larger methodological challenges in capturing their dynamic and uncertain nature. These challenges and the varied manners in which contextualized social rewards were operationalized is discussed in more detail in the subsection below.

#### 4.1.2 Social Interaction, Social Closeness, and Other Contextualized Social Rewards

As a composite of several social reward themes, contextualized social rewards were represented in a larger number of studies than was feedback about the self (i.e., 27.13% for contextualized social rewards compared to 19.15% for feedback about the self). However, the most frequently occurring contextualized social reward, social interaction, was present in 12.23% of all included studies. As such, individual themes in the contextualized social reward category were less occurring in the dataset than was feedback about the self. Therefore, the previous sub-section discussed feedback about the self as the third most frequently occurring social reward, alongside decontextualized social rewards and feedback on performance.

Otherwise, contextualized social rewards had varied representations across studies. For instance, more than 39% of studies on social interaction implied the presence of another conspecific (Heerey & Crossley, 2013; Fairnairn et al., 2014; 2015; Hayward et al., 2018). However, more than 21% also used written statements or images to convey this social reward (e.g., Morelli et al., 2014; Niedeggen et al., 2014; Guo et al., 2020; Camerini et al., 2022). Similarly, more than 61% of studies on social closeness relied on textual prompts (Inagaki et al., 2016; Fussner et al., 2017; 2018; Ramirez-Marin & Shafa, 2018). Besides the inherently relational nature of these social rewards, more than 97% of studies utilizing them adapted the rewards for screen-based presentations. Moreover, 42% of those adaptations were visual in nature, while 39% had an undefined modality.

In terms of measurement, over 76% of studies on contextualized social rewards were interested in how they were processed upon consumption. Therefore, over 49% used subjective ratings and over 25% used single-brain imaging to gauge their effects. In comparison, it was more difficult to capture anticipation for these social rewards. In over 25% of studies on contextualized social rewards, the most common measure for anticipation were subjective ratings with less than 12% also using effort. However, these single-brain focused and static methodologies impose challenges for capturing the dynamic and uncertain nature of social interactions (Hadley et al., 2022). This is further evidenced by the fact that more than 58% of studies on contextualized social rewards could not ascertain clear duration, which was one of the prerequisites for the lack of variability in studies on decontextualized social rewards or both forms of feedback.

Therefore, researchers used one of two approaches to address methodological challenges pertaining to experimental control and quantification of social interaction. The first approach was more represented and mirrors the most common practice employed for decontextualized social rewards, feedback on task performance and feedback about the self. In the nine studies that used this approach, researchers had trial-based, screen-presentations to display the positive outcomes of social interactions (Weschke & Niedeggen, 2013; Gromann et al., 2013; 2014; Morelli et al., 2014; Niedeggen et al., 2014; Smith et al., 2014; Kawamichi et al., 2016; Beltzer et al., 2019;

Zhang et al., 2020). On the other hand, in the six studies adopting the second approach, participants were prompted to imagine interactions with either unfamiliar social partners or close others (Phillip-Müller & MacDonald, 2017; Crawford et al., 2020; Guo et al., 2020; Seaman et al., 2020; 2021; Teichman, 2021).

The remaining studies on social interaction employed diverse approaches to its representation, without any discernible trends emerging. These pertained to anticipated interaction for good performance or connection (Brinkmann & Franzen, 2017; Hudd & Moscovitch, 2020), obtained interaction as a reward for good performance in non-social tasks (Gächter & Fehr, 1999), digital interactions (Camerini et al., 2020) and other forms (Hayward et al., 2018). Lastly, three studies dealt with full scale, in-person social interactions and these are discussed later in the text (Heerey & Corssley, 2013; Fairbairn et al., 2014; 2015).

The primary aim of the first of the two dominant approaches to representing social interaction was to measure brain activity during the consumption of positive interaction outcomes. For that purpose, almost half of the studies adopting this approach used the Cyberball paradigm (Weschke & Niedeggen, 2013; Niedeggen et al., 2014; Kawamichi et al., 2016; Beltzer et al., 2019). In this paradigm, social inclusion is measured by the number of digital ball throws participants receive from other players, with varying levels of participation reflecting different degrees of inclusion or exclusion.

The remaining studies investigated the social reward effects of reciprocated trust utilizing neuro-economic games such as the trust game (Gromann et al., 2013; 2014; Hanssen et al., 2021). In these games, trust is reciprocated when Player B returns a portion of the initial investment to Player A. When little or no investment is returned, the outcome is considered to indicate unreciprocated trust. Therefore, the Cyberball paradigm and trust game both place emphasis on screen-based presentations of social reward. However, some researchers enhanced validity of the interaction by having participants meet face-to-face either before or after completing the interaction paradigm (Gächter & Fehr, 1999; Smith et al., 2014; Weschke & Niedeggen, 2013).

The second predominant approach to representing social interaction was used in several ways. Two studies implemented this approach to prompt participants to make a decision in a two-choice task (Seaman et al., 2020; 2021), comparing the effects of social interaction with close others to those of health benefits and monetary rewards. The remaining studies used it to account for familiarity by asking participants to imagine being praised by close others, connecting with them, or helping them in a hypothetical scenario (Ramirez-Marin & Shafa, 2018; Crawford et al., 2020; Guo et al., 2020). Unlike the studies using Cyberball or the trust paradigm, these studies used subjective ratings to measure the reported effects of pleasant social interactions.

In addition, the studies on imagined social interaction illustrate the research challenges faced in the quantification and measurement of familiar social rewards (i.e., interactions with close others). This notion is further supported by the fact that more than 65% of studies on social interaction involved unfamiliar social partners, while only 13% focused on interactions with close individuals. When close individuals were involved, researchers might have been inclined to use the second approach to representing social interaction to maintain control and reduce variability among participants (Machia et al., 2020). The research gaps related to familiarity and the proposed solutions to this issue are discussed in more detail in sub-section 4.2.1.

On the other hand, studies investigating social closeness represented their social rewards by combining the two approaches to representing social interaction described above. In most of these studies participants viewed screen presentations of images or statements intended to evoke a sense of social closeness (Gere et al., 2013; Stinson et al., 2014; Fussner et al., 2017; 2018; Crawford et al., 2020). Similar to the first approach used in social interaction studies, these social closeness outcomes were presented in a trial-based format. In the social interaction studies, participants received concrete outcomes, such as social inclusion in Cyberball or reciprocated trust in the trust game.

However, the studies on social closeness involved more abstract outcomes, focusing on participants' perceptions of compatibility or potential for friendship. Consequently, the simulated nature of the outcomes aligns them more closely with the second approach in social interaction studies, where participants were asked to imagine the interaction scenarios. In terms of measurement, over 53% of the studies on social closeness used subjective ratings rather than brain activity to assess the consumption of social reward.

Overall, the two approaches to representation of social interaction and social closeness were used to enhance experimental control and minimize interaction outcome uncertainty (Machia et al., 2020). For this purpose, the interaction outcomes were intentionally pre-programmed in studies using the first approach. For example, researchers would pre-program the exact number of received ball throws in Cyberball to simulate social inclusion or exclusion (Niedeggen et al., 2014; Kawamichi et al., 2016; Beltzer et al., 2019). On the other hand, the second approach assured control and interaction outcome certainty through the explicit instructions provided in the prompt. For instance, participants were directly instructed to imagine a positive or a negative outcome of the interaction (Ramirez-Marin & Shafa, 2018; Ferguson et al., 2020; Guo et al., 2020). In this approach, all participants received the same prompt, but imagined different interactions with different people. Thus, as previously discussed, researchers minimized stimulus presentation variability while accounting for familiarity at the same time.

Despite their strengths, both approaches primarily focus on how individual participants process various interaction outcomes or imagined scenarios. In contrast, only five of the studies on social interaction and social closeness focused on full scale, in-person social interactions (Heerey & Crossley, 2013; Fairbairn et al., 2014; 2015; Philipp-Müller & MacDonald, 2017; Tchalova & MacDonald, 2020). The methodological challenges of multi-person neuroimaging are evident in the fact that all of these studies were behavioral and relied on subjective ratings for outcome measures. Three of the studies also measured overt social interaction behaviors, such as the amount spent interacting or the number of reciprocated smiles (Heerey & Crossley, 2013; Fairbairn et al., 2014; 2015). Since the nature of in-person interactions makes it challenging to clearly distinguish discrete reward components such as consumption and anticipation, these studies focused on social reward delivery (van Atteveldet et al., 2018).

Similarly, less than 10% of the studies investigating contextualized social rewards focused on narrower concepts that could still only be defined within the scope of an in-person interaction (Hobson, 2008). These included affective touch, joint attention, observation without interaction, and physical closeness (Stroebe & Diehl, 1981; Preller et al., 2014; Ma et al., 2018; Soussignan et al., 2019; Zimmermann et al., 2019; Korb et al., 2020a; 2020b; Massaccesi et al., 2021; 2022). Compared to the screen-based and imagined scenario approaches, these in-person social rewards warrant more dynamic interaction outcome measurements. Such outcomes involve the synchronization and attunement that is established between two interacting individuals (Hadley et al., 2022; Hamilton & Holler, 2023). In contrast to individual brain activity or subjective ratings, these interaction outcomes represent multi-person processes that require multi-person measurements (Hobson, 2008).

Compared to full-scale social interactions, these more narrowly defined aspects are easier to investigate within controlled research environments (Caruana et al., 2017b). Therefore, despite the involvement of multiple individuals in the representation of these social rewards, the studies investigating them continued to rely on conventional individual measures, such as subjective ratings (Preller et al., 2014; Ma et al., 2018; Zimmermann et al., 2019; Korb et al., 2020a; 2020b; Massaccesi et al., 2021; 2022), brain activity (Preller et al., 2014; Ma et al., 2018; Zimmermann et al., 2019) or effort (Korb et al., 2020a; 2020b; Massaccesi et al., 2021; 2022). However, some studies also strove to capture more dynamic and embodied aspects of the individual processing of social reward such as facial (Korb et al., 2020a; 2020b; Massaccesi et al., 2021; 2022) and eye movement (Preller et al., 2014).

Nonetheless, these individual measures fall short of capturing the multi-person outcomes of social rewards, indicating potential research gaps in the field. The corresponding measures that can be used to address these gaps are further discussed in sub-section 4.2.3. In contrast, the following two sub-sections discuss social reward within the context of prosocial actions and status, which are complex social constructs in themselves.

### 4.1.3 Social Rewards in the Context of Prosocial Actions

Some of the less frequent trends, present in less than 10% of all included studies, involved operationalizing social reward within the context of more complex behaviors, such as prosocial actions or broader social goals like achieving status. While driven by social reward processes, both prosociality and status are intricate constructs in themselves and the current discussion will focus on those features that are relevant for the operationalization of social reward (for detailed discussions on the constructs, see Pfattheicher et al., 2022, and Xu et al., 2022). The current sub-section discusses prosocial actions, and the subsequent sub-section, 4.1.4, discusses status.

Prosocial actions were initially categorized as a form of contextualized social reward, as they reflect how participants relate to others through acts of giving intended to benefit those individuals (Pfattheicher et al., 2022). However, prior research has also shown that prosocial actions are particularly sensitive to audience effects, as both prosocial behaviors and neural activity in brain reward areas increase when participants are observed (Izuma et al., 2010a). Thus, this intricate and direct link between prosocial actions and reputational management distinguishes them from other contextualized social rewards, such as social interaction or social closeness. Governed by established norms and societal expectations more than other social rewards, prosocial actions reflect an individual's connection to society as a whole (Wu & Hong, 2023). Therefore, prosocial actions are differentiated from other contextualized social rewards and treated as a distinct theme in this discussion.

Researchers took a straightforward approach to quantifying prosocial actions. Specifically, this theme often manifested in the form of monetary donations, with the amount donated serving as a measure of increased social reward (e.g., Soutschek et al., 2017; Sparrow et al., 2021; Andreoni & Serra-Garcia, 2021). These studies were more likely to account for familiarity, comparing the prosocial behaviors towards strangers to those towards close others or familiar charities (Soutschek et al., 2016; 2017; Sparrow et al., 2021). Measures were highly variable across studies, but similar to other themes, brain activity and subjective ratings emerged as slightly more prevalent (for details, see Tables A4 and A6 in the Appendix).

In terms of comparison stimuli, over 33% of the studies on prosocial actions compared their reward effects to those of keeping the money for oneself (i.e., monetary reward). This suggests that researchers have an underlying assumption that prosocial rewards are influenced by weighting the costs and benefits of helping others versus benefiting oneself (Batson & Powell, 2003). In turn, these assumptions may have limited the operationalization of prosociality to monetary donation made at a personal cost, overlooking the broader role of the social environment in shaping its value (Labroo et al., 2023).

When operationalized beyond the act of monetary donations, prosocial actions took the form of modifying task performance to help others or investigating negative actions, such as punishing norm violations in the ultimatum game (Hayward et al., 2018; Gabay et al., 2018). Nonetheless, studies on non-monetary forms of prosocial reward are fewer in number in the included dataset, indicating a potential research gap. Thus, future research could focus on exploring the relationship between social context and prosocial behaviors in reward valuation, as well as the role of social rewards across multiple forms of prosociality (for details, see sub-section 4.2.4).

#### 4.1.4 Social Reward and the Pursuit of Status

To gain a better overview of the various manners in which status was operationalized, the Discussion will utilize concepts from Xu et al.'s (2022) review on defining status.

In particular, these concepts pertain to reputational and relational forms of status. Reputational status reflects an individual's social standing within a group compared to other people. In contrast, relational status represents the degree of respect and admiration one individual has towards another.

Based on these distinctions, social reward was more frequently operationalized as reputational rather than relational status. Reputational status was most commonly defined as recognition for successful task performance compared to others (Sugawara et al., 2012; Pascual-Ezama et al., 2013; Brinkmann et al., 2014; Bradley et al., 2019; Fandakova et al., 2021). Some studies examined broader forms of social acknowledgment, such as public recognition for prosocial behaviors or displays of norm adherence driven by audience effects (Hysom, 2009; Izuma et al., 2010b; Burum et al., 2020). Lastly, one study defined reputational status as receiving more social media likes than others (Rosenthal-von der Pütten et al., 2019), and another as receiving more digital ball throws in Cyberball (Kawamichi et al., 2016).

Therefore, the presentation of reputational status varied across studies. For instance, studies on superior task performance delivered their social reward in a single instance at the end of experiment (Sugawara et al., 2012; Pascual-Ezama et al., 2013; Brinkmann et al., 2014; Bradley et al., 2019; Fandakova et al., 2021). In some studies, recognition took the form of a tangible social reward, like an event invitation or an honor certificate (Wang et al., 2017; 2020). This approach parallels the acquisition of real monetary rewards at the end of experiments, enabling social and non-social rewards to be experimentally matched in tangibility and duration (Matyjek et al., 2020b). Further details on this topic are elaborated in section 4.2.2, which discusses research gaps.

In contrast, studies focusing on societal recognition, such as social media likes or inclusion in Cyberball, employed a more trial-based approach to presenting status outcomes (Kawamichi et al., 2016; Rosenthal-von der Putten et al., 2019). Nonetheless, more than 52% of the studies on status had visual, screen-based presentations comprised of decontextualized stimuli like images or text. In terms of comparison stimuli, over 47% of the studies on status compared it to non-rewarding forms of itself. However, over 31%, all focusing on reputational status, also compared it to monetary rewards. Moreover, most studies on reputational status used a wide range of measures, showing no discernible trends (for details on measures of status overall, see Figure A6 in the Appendix).

In comparison, relational status was less commonly represented in the social reward literature. Most studies operationalized this form of status as recognition from another individual (Kumakawa, 2013; Bos et al., 2021; Mercadante & Tracy, 2022), the provision of valuable advice (Hertz et al., 2020; Li et al., 2020), or agreeing with knowledgeable others (Tobler et al., 2016). In all studies on relational recognition, the feedback was provided by individuals who were unfamiliar to the participant.

Compared to reputational status, relational status was most frequently compared to its non-rewarding counterparts (e.g., providing good advice was compared to providing bad advice), rather than to non-social, monetary rewards. The range of measurements for reputational status was also diverse with brain activity being the only measure occurring in two different studies (Tobler et al., 2016; Li et al., 2020). Other forms of measurement occurred in a single study each. Nonetheless, similarly to reputational status, relational status was conveyed through images and text and delivered in screen and trial-based formats.

Therefore, the social reward literature predominately operationalized status in its reputational form, while relational status was less represented. Regardless of the exact definition used, both forms of status were likely to be presented in visual, screen, and trial-based formats. Reputational status was more likely to be compared to non-social monetary rewards, while it can difficult to discern clear measurement trends for either form of status. This suggests a lack of consensus on the operationalization and measurement of status in the social reward literature, emphasizing the need for a more cohesive framework to unify its diverse forms and representations.

**4.2 Social Reward Operationalization, Research Gaps, and Future Directions**

The previous section highlighted decontextualized social rewards, feedback on performance and feedback about the self as the most frequently occurring forms of social reward operationalization. To preserve experimental control and methodological pragmatism, all of these social reward themes were presented in a similarly unimodal fashion (i.e., visual, screen-based, and novel). Correspondingly, social specificity was determined by comparing their neural and behavioral effects to those of their non-rewarding or non-social counterparts (e.g., comparing smiling faces to scrambled images) or to non-social, monetary rewards.

In comparison, contextualized social rewards and status were less prevalent in the literature and presented more heterogeneously across studies. Thus, the preferential implementation of certain operationalization forms and research practices over others has yielded several research gaps in the current social reward literature. In turn, this might have compromised our understanding of the concept and limited the interpretation of findings.

The most prominent research gaps across all social reward themes and contextualization groups pertain to familiarity and interaction. In the case of decontextualized social rewards, feedback on performance, and feedback about the self, they also pertain to the uniform choice of certain comparison stimuli over others. In addition, this review has revealed that the literature lacks understanding of the social reward effects of non-monetary forms of prosocial behavior. Lastly, there appears to be a lack of uniformity in the operationalization of status. When investigated, status was more likely to be operationalized in its reputational over its relational form. All of these research gaps, their implications, and suggestions for future research are discussed in more detail in the sub-sections below.

#### 4.2.1 Familiarity

More than 58% of studies within each contextualization group used novel social rewards. Therefore, familiarity represents one of the most prominent research gaps in the literature across all social reward themes and contextualization groups (for more details per category, see Table A4 in the Appendix). Even studies investigating social closeness used imagined scenarios in over 46% of cases (Gere et al., 2013; Ramirez-Marin & Shafa, 2018; Ferguson et al., 2020; Crafword et al., 2020; Seaman et al., 2020; 2021) and emphasized perceived compatibility or potential for closeness with previously unfamiliar individuals in more than 38% of studies (McAllister, 1980; Phillip-Müller & MacDonald, 2017; Fussner et al., 2017; 2018; Tchalova & MacDonald, 2020).

Compared to acquaintances and close people, novel social rewards in the form of unfamiliar stimuli or social partners are easier to administer. Additionally, novel social rewards promote research control by reducing between-subject variability since each participant is exposed to the same stimulus or interacts with the same social partner (Smith, 2014). On the other hand, researching familiarity may present methodological challenges, as it requires the provision of a unique, personalized stimulus or social partner for each participant.

However, neglecting the role of social reward familiarity within controlled research designs may underestimate its role in reward value derivation in real-world contexts. For example, the Introduction argued how people prefer interacting with familiar over unfamiliar individuals and can better use ToM to predict the outcomes of these interactions (Fareri et al., 2015; Hughes & Zaki, 2015; Hackel et al., 2017). Moreover, there might be qualitative and neural differences in how faces of strangers are processed compared to those of close people or celebrities (Liccione et al., 2014; Ramon & Gobbini, 2018). Finally, there may be systematic differences in how familiarity is processed for social and non-social stimuli (Baez-Mendoza & Hoffman, 2009) or across different populations (Pankert et al., 2014).

Given these considerations, several of the included studies adopted various approaches to studying familiar social rewards in order to maintain experimental control and reduce between-subjects variability. In the most straightforward approach, researchers presented written statements from close others (Morelli et al., 2014; Inagaki et al., 2016b) or photographs of loved ones (Inagaki et al., 2016a) to preserve presentation uniformity for all participants. When photographs of loved ones were used, the stimuli followed preset standardization guidelines and were submitted by each participant before the experiment. Other research groups maintained stimuli standardization and reduced variability by using smiling photographs (Matyjek et al., 2020a; 2021) or statements of praise by the experimenters conducting the research (Lenaert et al., 2018; Fulford et al., 2018).

In the case of screen-based social interactions, some researchers enhanced the validity of their research design by having participants meet with each other in person either before or after completing the task (Gächter & Fehr, 1999; Weschke & Niedeggen, 2013). Other researchers reduced stimulus variability by investigating instant messaging interactions between close social partners (Camerini et al., 2022). This enabled the researchers to preserve ecological validity while still controlling the content and timing of the text messages appearing on screen.

Another creative approach was adopted by Massaccesi and colleagues (2021b) in their study on affective touch. These researchers led participants to believe that the caresses were delivered by a close friend who came with them to the experimental session. In reality, the caresses were delivered by an experimenter from behind a screen. Thus, stimulus standardization was maintained while familiarity was also accounted for in the research design.

Other relevant aspects regarding familiarity include social relevance of the stimuli or partners used (Ramon & Gobbini, 2018). This can be accounted for by comparing different levels of varying familiarity, from friends to romantic partners to colleagues. Moreover, future research could investigate familiarity in the context of face-to-face social interactions, an area that remains unexplored thus far. As such, future research can implement any of the research approaches outlined above to incorporate familiarity into their research designs and improve our understanding on how this social reward dimension contributes to reward valuation and drives decision-making.

#### 4.2.2 Comparison Stimuli

Consistent with previous reviewers (Lockwood et al., 2020; Matyjek et al., 2020b), this review confirmed that monetary rewards were the most commonly used non-social comparison stimulus. In particular, monetary rewards were used in more than 30% of studies that utilized decontextualized social rewards and in over 30% of studies that used feedback on task performance (for more details on the remaining comparison combinations, refer to Table A5 in the Appendix). However, as discussed before, determining social specificity by comparing decontextualized social stimuli to monetary rewards might be overlooking other differences between the two experimental conditions.

In particular, the Discussion already argued that these differences refer to several additional reward dimensions such as primacy, tangibility, and duration (Matyjek et al., 2020b). While primacy may be more challenging to match in the case of monetary rewards, future research could operationalize the concept in a more tangible and lasting form to avoid conflating sociality with other dimensions of social reward as much as possible. For example, Pascual-Ezama and colleagues (2013) declared the top-performing participants in a word search puzzle as winners at the end of experiment. Therefore, compared to more transient stimuli like images of smiling faces, these authors offered a more lasting form of reputational recognition.

Similarly, Wang and colleagues (2017; 2020) delivered honor certificates indicating the rank and points earned in a target detection task at the end of experiment. Thus, they provided a more lasting form of reputational recognition that was also tangible. Correspondingly, the authors of these studies granted social rewards in a manner similar to the acquisition of real monetary rewards at the end of the experiments, aligning the two experimental conditions across as many parameters as possible.

On the other hand, considering that food and drugs were used as comparison stimuli in less than 4% of all included studies, research has a limited understanding of how social rewards compare to non-social rewards other than monetary ones. In that sense, drugs might have been avoided due to the ethical concerns they raise in human research (Fry et al., 2006). However, when the two experimental conditions are properly matched on as many dimensions as possible, using food as a primary reward comparison can provide a more nuanced understanding of social reward processing (Rogers & Hardman, 2015). Therefore, incorporating food as a comparison broadens the possibilities for social reward operationalization, allowing for the inclusion of more dynamic and interactive stimuli.

For instance, two research groups successfully matched their experimental conditions on primacy, tangibility and duration by comparing food to affective touch (Korb et al., 2020a; 2020b). The interactive and dynamic nature of affective touch also allowed these researchers to use embodied measures such as electromyography (EMG) during the phases of reward anticipation and consumption. Thus, the researchers obtained a more nuanced understanding of social reward processing which extended beyond its neural activity and behavioral outcomes.

Lastly, this review revealed that the current social reward research lacks data on how different dimensions of the same social reward compare within the same task. For example, these may include the social reward effects of praise delivered as static images compared to those of in-person feedback. Therefore, future social reward research may also benefit from investigating the perceptual and valuation differences between different types of reward representations for the same overarching concept (Prunty et al., 2021; Greene et al., 2022). Thus, researching the various comparison approaches outlined above promises to deepen our understanding of social reward processing and improve experimental validity overall.

#### 4.2.3 Interaction and Contextualized Social Rewards

In our everyday lives, social rewards are predominantly experienced within the context of dynamic and reciprocal social interactions (Hamilton & Holler, 2023). However, as discussed in sub-section 4.1.1., the various methodological challenges pertaining to quantification and research control made it challenging to investigate in-person social interactions (van Atteveldet et al., 2018). Therefore, only six of all included studies operationalized social reward as an in-person interaction (Gächter & Fehr, 1999; Heerey & Crossley, 2013; Fairbairn et al., 2014; 2015; Phillip-Müller & MacDonald, 2017; Tchalova & MacDonald, 2020).

This is further evidenced by the fact that up to 58% of all included studies investigated the reception of decontextualized social rewards, feedback on performance, or feedback about the self (for details per social reward theme, see Table A2 in the Appendix). In comparison, less than 29% investigated contextualized social rewards and out of these, less than 13% of all included studies were specifically focused on social interaction.

Secondly, even in studies centered on social interactions, the emphasis was primarily on the reception of positive outcomes from these interactions, such as social inclusion (e.g., Weschke & Niedeggen, 2013; Niedeggen et al., 2014; Ethridge et al., 2017; Ethridge & Weinberg, 2018; Pegg et al., 2019; 2021; Weinberg et al., 2021; Freeman et al., 2022). When participants imagined the outcomes (Ramirez-Marin & Shafa, 2018; Ferguson et al., 2020; Guo et al., 2020; Seaman et al., 2020; 2021), it is likely that the researchers primarily captured processes related to memory and future-oriented thinking rather than the immediate processes of social reward (Zheng et al., 2014). In comparison, interaction reciprocity was somewhat addressed in studies examining reciprocated trust within the context of the trust game (e.g., Gromann et al., 2013; 2014; Hanssen et al., 2021). However, the screen-based nature of the trust game limited the experience of reciprocated trust to a received, trial-based outcome. As such, interaction dynamics and reciprocity were not adequately captured, even in studies focusing on social interaction.

Finally, more than 43% of studies on social interaction had visual, screen-based presentations of social reward to adhere to the demands of controlled research environments (van Atteveldet et al., 2018). Thus, multi-modal social rewards were present in less than eight studies per contextualization category in the literature as a whole (for details, see Table A4 in the Appendix). This trend might also explain the detected under-utilization of embodied measures like eye and facial movement, as well as peripheral physiological responses, with each measure type present in less than four studies per reward component for all contextualization categories (for details, see Table A6 in the Appendix). Therefore, overlooking the role of social reward in interaction reciprocity might have compromised our research understanding of social reward processing as a whole, as well as some individual differences that have been detected in this regard (Di Paolo & De Jaegher, 2012; Clements et al., 2018).

For instance, previous research has shown that individuals with ASD direct their attention less to social stimuli involving interpersonal interactions and show reduced autonomic neural specificity for biological motion (Hedger et al., 2020; Knight et al., 2022). This indicates that clinical populations exhibit greater difficulties with the processing of dynamic social stimuli (Prunty et al., 2021; Greene et al., 2022). Incorporating more dynamic and interactive stimuli in social reward research could improve our understanding of perceptual differences between static and dynamic social stimuli (Risko et al., 2012; Richos et al., 2018). This approach may also reveal how these perceptual differences affect social reward processing in individuals with ASD and other clinical populations.

Secondly, research in second-person neuroscience has shown that the “mentalizing” network is more engaged during active interaction than during passive observation of social stimuli. In particular, this network is comprised of the medial prefrontal cortex (mPFC), temporoparietal junction (TPJ), and posterior superior temporal sulcus (pSTS) (Redcay & Schilback, 2020). Therefore, understanding the role of social reward in the valuation of reciprocal interaction may further clarify how higher-order cognitive functions, such as theory of mind, drive potential individual differences in motivation for social interaction and social bond formation (Krach et al., 2010).

Lastly, understanding in-person social interaction warrants a greater involvement of embodied measurements. This approach promises to broaden our research understanding of social reward by providing data on its dynamic interactive properties which give rise to synchrony and attunement (Di Paolo & De Jaegher, 2012). Both of these dynamic outcomes exceed the sum of the individual behaviors of the two interacting partners, offering the possibility for unique insights into social reward processing and valuation (Hobson, 2008). Some researchers have also asserted that the utilization of embodied measurements in order to understand the relationship between synchrony, attunement, and social reward emergence may pave the way for innovative, body-centric therapeutic practices (Mende & Schmidt, 2021).

Given these considerations, several research approaches can be employed to address the methodological challenges of studying social reward during reciprocal, in-person social interactions. These include: 1) decomposing complex interactions into smaller, foundational "building blocks" (Hamilton & Holler, 2023); 2) utilizing multi-person brain imaging and behavioral methodologies (Kelsen et al., 2022; Hadley et al., 2022); and 3) examining digital and virtual interactions (Meshi et al., 2015; Caruana et al., 2017b).

It was already discussed that full-scale social interactions are difficult to quantify and measure. However, social interactions have many smaller building components such as mimicry, joint attention, and turn-taking during conversation, all of which contribute to their successive outcomes and rewarding value (Hamilton & Holler, 2023). Similar to full-scale interactions, these smaller building blocks can also provide insight into dynamic reward properties such as synchrony and attunement while their narrow scope makes them easier to define and measure within controlled research designs.

For example, one of the included studies interpreted dynamic facial mimicry as an indication of stronger social affiliation (Meier et al., 2016). The researchers maintained research control by presenting the participants with video clips of the same dynamic facial expressions which transitioned from neutral to smiling. Simultaneously, the dynamic properties of mimicry were captured through the application of embodied, EMG measurements. In a similar fashion, some of the remaining studies utilized embodied eye movement measures to capture inter-personal synchrony during joint attention as an indication of mental alignment, a pre-requisite for the development of theory of mind (Preller et al., 2014; Soussignan et al., 2019). Therefore, the types of social reward operationalization used by these research groups enabled them to isolate specific social interaction behaviors. In turn, this elucidated the synchronous embodied responding during mimicry or joint attention as one of the driving mechanisms of social reward during in-person interactions.

Besides the chosen forms of operationalization, the exploration of reciprocal synchrony and attunement during in-person interactions can be further aided by the application of multi-person brain imaging and behavior measurements. For example, hyperscanning was used by previous researchers to document inter-brain synchrony during turn-taking in conversations (Kawasaki et al., 2013; Nozawa et al., 2016; Ahn et al., 2018; Hirsch et al., 2018; Kelsen et al., 2022), and was also associated with prosociality (Hu et al., 2017), cooperation (Czeszumski et al., 2022), social adjustment (Vicente et al., 2023), as well as with online gaming (Wikström et al., 2022). Given these research links, inter-brain synchrony during in-person interactions may also be associated with the experience of social reward. However, this connection is yet to be explicitly addressed in the corresponding literature.

In addition to inter-brain synchrony, researchers can also quantify overt behavioral synchrony during in-person interactions through the application of advanced motion capture technology (Hadley et al., 2022). In that sense, some of the included studies already used more manual behavior coding approaches to capture the reciprocation of smiles during in-person interactions (Heerey & Crossley, 2013; Fairbairn et al., 2014; 2015). However, the application of advanced motion capture software may broaden the range of social interaction behaviors indicative of social reward to also include the coordination of posture, gestures, and overall alignment, as well as non-verbal recoveries during communication breakdowns (Di Paolo & De Jaegher, 2012; Hamilton & Holler, 2023).

In addition to in-person interactions, inter-personal synchrony and attunement may also indicate social reward during digital exchanges, such as instant messaging (Camerini et al., 2022). Digital interactions are becoming increasingly common in daily life, with people predominately using social media and other similar platforms for one-on-one exchanges with close relational partners (Hill, 2016; Alalwan et al., 2017). However, the current systematic review revealed that our understanding of digital social reward processing and behavior is mostly limited to the passive reception of social media "likes" (Foulkes et al., 2014; Ait Oumeziane, 2017; 2019; Rosenthal-von der Pütten et al., 2019; Hudd & Moscovitch, 2021).

In comparison, the one study investigating instant messaging found that the lack of synchrony in delayed responses may contribute to heightened electrodermal physiological activity when participants observed that their interaction partner finally started typing to respond to their message (Camerini et al., 2022). However, the relationship between digital interaction synchrony, physiological responses, and social reward is yet to be further investigated by future studies.

Therefore, investigating the role of social reward during digital interactions promises to elucidate the driving mechanisms of online social behavior and to emphasize its differences and similarities with offline social behavior. In that sense, the minimalist nature of digital social stimuli provides a unique opportunity for maintaining experimental control and ecological validity in social reward research (Meshi et al., 2015).

Lastly, an unexplored avenue in social reward research concerns virtual reality (VR) environments which enable the investigation of real-time social interactions in naturalistic and immersive settings while maintaining experimental control (Caruana et al., 2017a). However, to date, this approach has been represented in a limited number of studies on joint attention, none of which explicitly reference social reward (Caruana et al., 2017a; 2017b). In one of these studies, a VR paradigm was used to study participants' responses to intentional and communicative cues including eye gaze and hand gestures in collaborative tasks that required joint attention (Caruana et al., 2017b). The participants interacted with a pre-programmed computer avatar while believing that they are interacting with a real person. Thus, these researchers preserved ecological validity in an experimentally controlled setting during a social interaction.

However, the possibilities of VR paradigms remain unexplored in the social reward literature, making them a fertile ground for future social interaction research. In addition to the remaining approaches outlined in this section, the implementation of VR paradigms promises to broaden our understanding of the connection between social reward and in-person social interactions in the real world.

#### 4.2.4 Prosocial Reward Beyond Monetary Donations

In total, 75% of studies investigating prosocial behavior operationalized this concept in the form of monetary donations (for more details, see sub-section 4.1.3). Therefore, non-monetary forms of benefiting another such as volunteering remain overlooked in the current social reward literature with only three of all included studies focusing on these types of prosociality (Hayward et al., 2018; Guo et al., 2020; Tham et al., 2022). Conflating prosocial reward with monetary donations in this manner may skew the interpretation of the corresponding findings in several ways.

First, depending on the costliness of the donated resources to a given individual, different populations may pursue social reward through different forms of prosocial behavior. For example, one study found that middle-aged adults derived social reward from monetary donations. In comparison, younger adults were more likely to benefit other people through volunteering and other forms of investing their time (Best & Freund, 2021). This is in accordance with the fact that time is a limited resource for middle-aged adults, while the same holds true for monetary resources for younger adults. Therefore, in order to understand how social reward drives prosocial behaviors across different populations, future research should consider forms beyond monetarily benefiting another individual.

Second, this Discussion already argued that prosocial rewards are subject to audience effects and societal norms and expectations (Izuma et al., 2010a; 2010b).

Therefore, previous reviewers have asserted that one's prosocial choices and experience of social reward are significantly influenced by the immediate social context and the choices of other individuals in their environment (Labroo et al., 2023). This argument indicates that the decision about which cause to support is driven by trade-offs between competing social causes, rather than by a trade-off between self-interest and charitable donation. As such, the field of social reward needs further research to better understand how the wider social context influences the choice and manifestation of prosocial actions.

Lastly, the wider social context holds particular relevance for influencing prosocial behavior in digital environment settings. Specifically, the hyper-connected spaces provided by social media and other digital environments enable individuals to observe the prosociality of others, base their own actions on these observations, and publicly broadcast them in a similar manner (Labroo et al., 2023). Therefore, future research could further investigate this link between prosocial reward and audience effects in hyper-connected digital spaces.

### 4.2.5 Social Reward as Relational and Reputational Status

There is high diversity in the operationalization of status across the social reward literature. This is accordance with previous reviewers who have highlighted the complexity of status as a concept in itself (Xu et al., 2022). However, in the context of social reward, further research is needed to better understand how social reward drives the pursuit of different forms of status across different types of context.

In addition, this systematic review established that a higher number of studies investigated reputational compared to relational status. Therefore, the current social reward literature may lack insight into how relational status shapes the valuation of social rewards, particularly how individuals use the advice of others to develop trust models of third parties (Delgado et al., 2006). For example, prior research has found that expert advice modulated activity in the ventral striatum and influenced whether individuals provided positive or negative evaluations of third party individuals (Bhanji & Delgado, 2014).

In addition to affecting the reputation of others, the provision of high-quality advice also affected how the advisor's own reputation was perceived (Fouragnan et al., 2013).Therefore, social reward research could benefit from further investigations into the driving mechanisms behind the acquisition of relational status and how this in turn leads to individuals influencing one another based on their acquired ranks.

### 4.3 Integrating Key Insights: A Framework for Operationalizing Social Reward

The aim of this systematic review is to offer a comprehensive overview of the operationalizations, comparisons, and measurement approaches employed in the study of social reward, with the goal of informing and guiding future research in the field. To this end, the current section introduces a hierarchical three-level framework designed to guide the operationalization of social reward, aligning with the specific research questions being addressed and the available measures to investigate them. For a visual representation of this framework and the arguments presented below, please refer to Figure 7.

This systematic review builds on previous social reward reviews by proposing that, in addition to being a multifaceted construct, social reward can also be understood as a hierarchical construct. The first level of the framework focuses on operationalizations that investigate how social reward *stimuli* are processed at the neural level and their influence on various behaviors. This operationalization level includes decontextualized social rewards, feedback on task performance, and feedback about the self. The second level explores how we *interact* with and relate to others, encompassing contextualized social rewards. It is further divided into i) received, screen-based forms of interaction, ii) more narrowly defined rewards tied to interactions, such as joint attention or physical closeness, and iii) more complex, fully developed social interactions. Finally, the third level examines how individuals relate to *groups* and *society*, with operationalizations categorized into prosocial resource provision and the receipt of societal recognition in the form of reputational or relational status.

The organization of this framework is labeled as hierarchical for two reasons. Firstly, concepts from the lower levels can give rise to concepts from the higher levels. For instance, seeing a digital ball passed around between level one cartoon images of smiling faces can give rise to a level two screen-mediated social interaction (Eisenberger et al., 2003). Similarly, receiving a higher number of ball throws compared to other individuals during this level two interaction can give rise to level three reputational status (Kawamichi et al., 2016).

However, each lower level in this framework is more limited in the types of research questions it can address compared to the higher levels. For instance, level one social rewards provide insights into how individuals process the reception of various social stimuli, including smiling faces, approval gestures, or affective sounds, at the neural and behavioral level and how these may motivate performance in certain cognitive or learning tasks (e.g., Brinkmann et al., 2014; Flores et al., 2015; Hwang et al., 2017; Kim & Anderson, 2019). However, these forms of operationalization are limited in elucidating the social reward effects during interaction reciprocity and the role of mentalization in reward value derivation (Di Paolo & Di Jaegher, 2012).

In comparison, level two social rewards can provide insight into how social reward drives interaction reciprocity or how mentalization is used to determine social reward value (e.g., Gromann et al., 2013; 2014; Fairbarin et al., 2014; 2015). However, insights obtained from dyadic interactions are limited in explaining the effects of societal norms (e.g., fairness) in prosocial behaviors or the interaction group dynamics of individuals of higher and lower status ranks (Moore et al., 2012). Each level of the hierarchical framework, as well as the strengths and limitations of each form of operationalization are discussed in more detail in the sub-sections below.

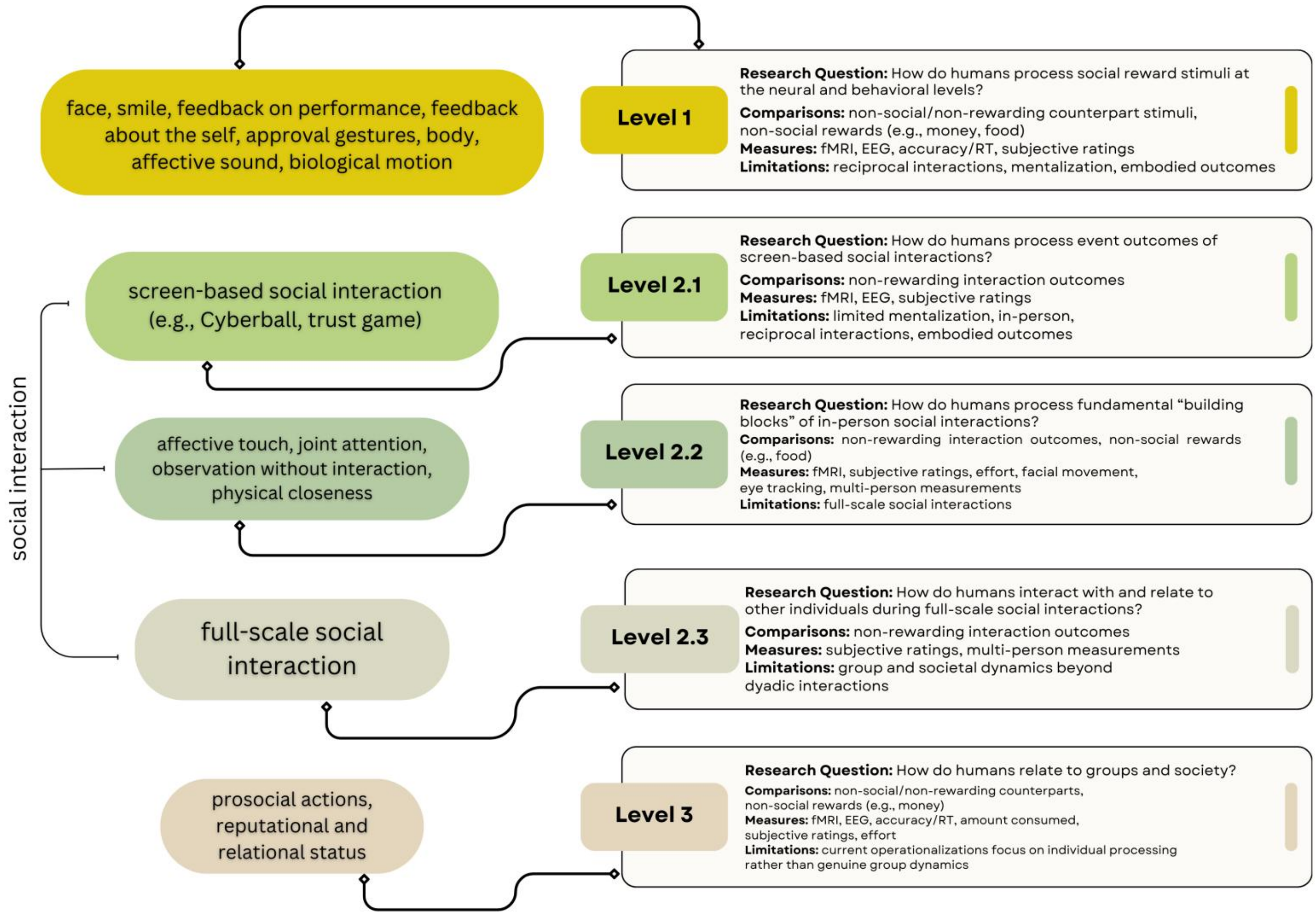
### 4.3.1 Level One: Social Reward Stimuli

To reiterate, level-one social rewards are comprised of social stimuli, including smiling faces, approval gestures, affective sounds, bodies, and biological motion as well as feedback on performance and feedback about the self. These forms of operationalization can answer research questions pertaining to how social stimuli are processed in the brain and how they motivate and influence behavioral performance across various cognitive or learning tasks (e.g., Rademacher et al., 2014; Radke et al., 2016; Chen et al., 2021). In some of the included studies, the neural effects of smiling faces and other stimuli were examined during passive observation tasks (e.g., Bedi et al., 2009; Smith et al., 2014; Ogoshi et al., 2016; Matyjek et al., 2021).

In terms of measurement, the neural processing of social stimuli was captured with individual brain activity measures (e.g., fMRI, EEG) and behaviorally validated through subjective ratings (for more details, see sub-section 4.1.1). In addition, some included studies measured task performance motivation induced by social reward stimuli through the application of accuracy and response time measures. In that sense, social specificity in terms of neural effects and behavioral task performance was determined by comparing the social reward effects of social stimuli to those of their non-social counterparts (e.g., smiling faces to scrambled images or to monetary rewards) or non-rewarding counterparts (e.g., smiling faces to angry faces) (e.g., Spreckelmeyer et al., 2013; Barman et al., 2015; Catalano et al., 2018; Crawford et al., 2020; Matyjek et al., 2021).

**Figure 7**

*Hierarchical Framework for Social Reward Operationalization and Measurement*




*Note.* This figure illustrates the hierarchical framework for social reward operationalization and measurement based on the social reward, comparison, and measurement themes extracted in this systematic review. Each level specifies the relevant operationalizations, comparisons, and measures that can be used to answer research questions in one of three domains: i) individual neural and behavioral processing of social stimuli (Level 1); ii) individual or multi-person neural and behavioral processing of social interaction (screen-based, fundamental "building blocks" or full-scale) (Levels 2.1-2.3); iii) individual neural and behavioral processing of prosocial actions and status (i.e., how humans relate to groups and society) (Level 3). Lastly, the figure states the research limitation at each of the three levels.

In terms of valuation, level-one social stimuli are expected to depend on associations between their external attributes and positive past outcomes (Beer, 2000). For example, smiling faces are valued based on the positive valence and genuineness of the emotional expression, as well as the attractiveness of the face (Adolphs, 2009;

Heerey, 2014). The positive valence of these attributes causes individuals to associate them with positive past experiences (Daniel & Pollman, 2014). For example, genuine smiles become associated with pleasant social interactions based on past experiences with genuinely smiling individuals. Similarly, the tone of voice shapes how different forms of affective sound are valued across different individuals (Gale et al., 2022). In comparison, biological motion is valued based on the movement patterns it produces as these indicate the agent's identity and potential actions and intentions (Keri & Benedek, 2009; Troje, 2013).

When presented as feedback on task performance, level-one social stimuli are additionally valued for the positive information they convey about the participant's performance (Rodriguez et al., 2006; Tricomi & Fiez, 2012). In a similar manner, feedback about the self acquires its value through the positive evaluation it conveys about the participant as well as the implied social connection with the person offering the feedback (Brudner et al., 2023). This simultaneous emphasis on the positive content of the feedback as well as the implied social connection incorporates valuation elements from both level-one and level-two operationalizations.

However, studies on feedback about the self are generally focused on how this social reward is individually processed as a rewarding social stimulus rather than on the implied interaction between the participant and the person providing the feedback (e.g., Sharma et al., 2016; Bedi et al., 2018; Zimmermann et al., 2019; Sumiya et al., 2020). In addition, in over 41% of studies investigating it, feedback about the self took the form of images of thumbs-up icons or written statements (Foulkes et al., 2014; Chevallier et al., 2016) reinforcing its conceptualization as a stimulus rather than as an interaction. Given these considerations, feedback about the self remains categorized at the first level of the framework.

Since the social specificity of level-one stimuli is frequently determined by comparing their effects to their non-rewarding or non-social counterparts, it is important to experimentally match all comparison conditions as closely as possible to each other (Lockwood et al., 2020; Matyjek et al., 2020b). In comparison, this practice is less relevant for level-two social interactions. Unlike social stimuli, the social specificity of interaction effects is implicitly implied in the research designs investigating them. Therefore, rewarding forms of social interaction are compared to its neural or negative counterparts (e.g., social inclusion to social exclusion or reciprocated to unreciprocated trust) rather than to non-social stimuli or events (e.g., Weschke & Niedeggen, 2013; Gromann et al., 2013; 2014 Niedeggen et al., 2014; Ethridge et al., 2017; Ethridge & Weinberg, 2018; Hanssen et al., 2021).

However, experimentally matching all comparison conditions as closely as possible to each other becomes relevant again at level-three of the framework. At this level, prosocial actions and status emerge as higher-order concepts derived from simpler level-one stimuli representations. For example, certain cognitive tasks use smiling faces as social reward for good task performance in a given trial of the task. As such, participants can attain a form of reputational status when provided with an additional recognition (e.g., honor certificate) for outperforming others (Wang et al., 2017; 2020). In turn, performance in the social conditions of this task is compared to those of non-social, monetary conditions.

Similarly, prosocial actions can be represented as monetary donations in a level-one two-choice task. In turn, charitable giving can also be compared to monetary self-benefit (Soutschek et al., 2017; Sparrow et al., 2021). Therefore, reducing these level three concepts to more fundamental level one stimuli makes it possible to experimentally match and compare them to non-social monetary rewards.

Overall, level-one social stimuli provide can answer research questions pertaining to the individual processing of social reward at the neural and behavioral levels. These forms of operationalization are valued based on their positive external attributes and/or content as well as associations with positive past events (Beer, 2000; Daniel & Pollman, 2014). Their social specificity is determined by comparing them to experimentally matched non-rewarding or non-social counterparts (Lockwood et al., 2020; Matyjek et al., 2020b). However, level-one social stimuli are limited in answering research questions regarding the role of social reward in interactions (Di Paolo & Di Jaegher, 2012), mentalization (Krach et al., 2010), and embodiment (Hamilton & Holler, 2023). In turn, these research questions can be better answered by utilizing level-two operationalizations instead and are further elaborated on in the subsequent section.

### 4.3.2 Level Two: Social Reward Interaction

Social reward operationalizations positioned at the second level of the hierarchical framework focus on how humans interact with and relate to other individuals. This level includes contextualized social rewards such as social interaction, social closeness, affective touch, joint attention, observation without interaction, physical closeness, and social support. These forms of operationalization require the actual or implied presence of another individual (Honson, 2008; Caruana et al., 2017b), even in cases when the outcome measurements capture individual processing.

Therefore, compared to level-one social stimuli, level-two social rewards represent social behaviors or processes even though their representation may vary in dynamicity across studies. In addition, the valuation of level-two social rewards depends on the level of interaction represented in a given operationalization. As such, the second level of this hierarchical framework is further divided into three sub-levels, based on how interaction was represented in the definition: i) screen-based social interactions and their positive outcomes; ii) fundamental "building blocks" of in-person social interactions, such as affective touch, joint attention, or physical closeness; iii) full-scale social interactions.

Level-two social rewards were most commonly represented as screen-based social interactions or hypothetical scenarios in the case of social closeness (e.g., Weschke & Niedeggen, 2013; Niedeggen et al., 2014; Fussner et al., 2017; 2018). As such, theses representations were comprised of trial-based positive outcomes within screen-mediated tasks. Most of the studies that utilized this form of representation were brain imaging ones and were interested in brain activity (e.g., fMRI, EEG) upon delivery of the positive interaction outcome (for more details, see sub-section 4.1.2). In turn, in the case of social interaction, these positive outcomes included social inclusion in Cyberball (Weschke & Niedeggen, 2013; Niedeggen et al., 2014; Kawamichi et al., 2016; Beltzer et al., 2019) or reciprocated trust in the trust game (Gromann et al., 2013; 2014; Hanssen et al., 2021). On the other hand, in the case of social closeness the positive outcomes were comprised of perceived compatibility or potential for friendship with a social partner (Fussner et al., 2017; 2018).

In comparison, behavioral studies were more likely to represent the positive interaction outcomes by presenting participants with hypothetical scenarios or asking them to imagine the interactions (Gere et al., 2013; Ramirez-Marin & Shafa, 2018; Ferguson et al., 2020; Seaman et al., 2020; 2021). Therefore, behavioral studies measured the outcomes of social reward delivery through subjective ratings. Regardless of the different approaches taken, both brain imaging and behavioral studies place emphasis on individual neural and self-reported processing of positive interaction outcomes rather than on their impact on cognitive or learning task performance.

Therefore, the value of screen-based social interactions is comprised of the positive valence of their outcomes (e.g., inclusion is preferred to exclusion; Weschke & Niedeggen, 2013; Kawamichi et al., 2016). However, similar to feedback about the self, the valuation of outcomes also depends on the immediate relationship between interaction partners, rather than on associations formed outside the task[11] (e.g., Niedeggen et al., 2014; Fussner et al., 2017; Hanssen et al., 2021). As such, some forms of these outcomes, such as reciprocated trust in the trust game, are processed through theory of mind. In particular, participants use this form of higher-order cognition to interpret the beliefs and intentions of their co-players based on their display of reciprocation behavior or the lack thereof (Fehr & Camerer, 2007). Thus, unlike level-one social stimuli, level-two social rewards can provide insight into the role of mentalization processes in deriving the reward value of social interactions (Krach et al., 2010).

Overall, the screen-based nature of the reward operationalizations at this sub-level allows researchers to answer how individuals process the positive outcomes of various interaction scenarios and how they base subsequent-decision making on these positive outcomes (e.g., trust game) (Gromann et al., 2013; 2014; Hanssen et al., 2021). However, since researchers are focused on the reception of the positive interaction outcomes, rather than on the process of engaging in interaction, these operationalization cannot elucidate the role of social reward during reciprocal, in-person exchanges.

In comparison, the process of engaging in an interaction is better addressed by social reward operationalizations at the second and third sub-levels of the framework. The definitions represented at these sub-levels predominantly deal with multi-modal, in-person exchanges. As previously discussed, definitions at the second sub-level refer to smaller, foundational "building blocks" of social interaction, like affective touch, joint attention, observation without interaction, and physical closeness. On the other hand, definitions at the third sub-level deal with full-scale, in-person social interactions.

The narrow scope of social reward concepts at the second sub-level of the framework allowed researchers to present them in brief, trial-based durations, similar to how level-one social stimuli were studied (Preller et al., 2014; Ma et al., 2018;

[11] The only exception might be when participants imagine the interaction, as they must then draw on prior memories and associations to construct the imagined scenario.

Zimmermann et al., 2019; Soussignan et al., 2019; Korb et al., 2020a; 2020b; Massaccesi et al., 2021; 2022). Thus, in terms of measurement, the effects of these social rewards were predominately captured with subjective ratings and fMRI brain activity. However, the dynamic nature of affective touch and joint attention prompted some researchers to use embodied facial and eye movement measurements, respectively (Preller et al., 2014; Korb et al., 2020a; 2020b, Massaccessi et al., 2021).

In the studies on affective touch, facial movements in the form of EMG activity were implemented to align human hedonic "liking" measures with the orofacial expressions used in animal research (Korb et al., 2020a; 2020b). Simultaneously, these measures extended beyond what could be captured with brain activity and subjective rating measures to indicate certain embodied markers of social reward manifestation, such as the main smiling facial muscles (i.e., zygomaticus major) (Korb et al., 2020b).

On the other hand, Preller and colleagues (2014) used eye movements to capture congruence and reciprocity during joint attention between the human participants and anthropomorphic computer avatars used for research control. Thus, the measure in question captured an outcome (i.e., congruence) that was a property of the interaction process itself, and could not have been exhibited individually by the participants (Moore et al., 2013). In turn, this congruence during joint attention was taken as an indicator of mental alignment between the participants and computer avatars, and as a pre-requisite for the motivation to engage in social interaction (Shepherd, 2010).

Therefore, these social interaction "building blocks" and provide revealing insights into the foundations of humans sociality and drive for interaction (Stephenson et al., 2021). While their narrow scope allows these social rewards to be investigated in a similarly controlled manner like level-one stimuli, it simultaneously limits the implications of the corresponding findings. Firstly, full-scale social interactions consist of several of these "building blocks" (e.g., mimicry, joint attention, non-verbal expressions, hand and facial gesticulations, etc.), interacting with each other to give rise to the experience of social reward (Hamilton & Holler, 2023). Thus, the properties of their interaction cannot be captured by studying any of the "building blocks" in isolation from the rest.

Secondly, as previously discussed, the narrow scope of affective touch, joint attention, and physical closeness as concepts allows them to be investigated in research designs that are similar in structure to those used for level-one social stimuli. Therefore, with the exception of joint attention, the research focus for the remaining concepts at this sub-level was on how their reception was individually processed as multi-modal, social reward stimuli (Zimmermann et al., 2019; Korb et al., 2020a; 2020b; Massaccesi et al., 2021; 2022). This was in spite of the fact that both affective touch and physical closeness cannot be delivered without the overt presence of another individual, hinting at their inherently interactive nature.

As such, the narrow scope of operationalizations at the second sub-level of the framework can provide fundamental insights into the “building blocks” of more complex social interactions (Hamilton & Holler, 2023). These operationalizations also allow researchers to investigate the properties of social reward during in-person interactions while maintaining research control in a manner similar to the one employed for level-one social rewards (Caruana et al., 2017b). However, because of this, some researchers treated affective touch and physical closeness similar to level-one social stimuli, and not as interactive processes (Zimmermann et al., 2019; Korb et al., 2020a; 2020b; Massaccesi et al., 2021; 2022). Therefore, future research could benefit from investigating these social rewards within active social interaction engagement, akin to the studies on joint attention.

Nonetheless, the full-scale complexity of social reward during in-person social interactions can only be captured by concepts at the third sub-level of the framework. All of the studies utilizing some form of these operationalizations focused on behaviors displayed during in-person social interactions, with smile reciprocation (Heerey & Crossley, 2013; Fairbairn et al., 2014; 2015) and the experience of interpersonal warmth (Phillip-Müller & MacDonald, 2017; Tchalova & MacDonald, 2020) being among the most remarkable ones.

Since the properties of full-scale social interactions are challenging to discern and quantify, all of these researchers adopted behavioral research designs. Correspondingly, the most frequently adopted measures included subjective ratings (Fairbairn et al., 2014; Phillip-Müller & MacDonald, 2017; Tchalova & MacDonald, 2020), with some studies also using the amount spent interacting (Heerey & Crossley, 2013; Fairbairn et al., 2014) and overt social interaction behaviors (i.e., the number of reciprocated smiles) (Fairbairn et al., 2015).

Several previous researchers have indicated that the positive and rewarding outcome of social interactions may depend on the overall synchrony and attunement displayed during the interaction (Di Paolo & Di Jaegher, 2012; Hamilton & Holler, 2023). However, research is yet to determine the valuation components of real-time social interactions as well as their potential dependence on various verbal and non-verbal cues (e.g., mutual gaze, mimicry, and posture coordination) (Hamilton & Holler, 2023). In that sense, sub-section 4.2.3 suggested measuring coordination transitions (e.g., recoveries after communication breakdown) as a potential measure of the real-time manifestation of social reward, with smoother recoveries indicating greater reward experience (Di Paolo & Di Jaegher, 2012).

In a similar fashion, the current research lacks neuroimaging data on social reward during in-person interactions which could be addressed by future hyperscanning studies elucidating the role of inter-brain synchrony in the process (Kelsen et al., 2022). Moreover, advances in sophisticated motion capture software promise to more precisely capture various social interaction behaviors (Hadley et al., 2022). For instance, the software might be able to capture and quantify the overall coordination in smile reciprocation between two individuals (Cornejo et al., 2017), compared to merely counting the number of reciprocated smiles as an indicator of social reward.

Therefore, despite the methodological challenges of studying in-person social interactions, multi-person methodologies show promise in elucidating the role of social rewards and their real-time development during dynamic, reciprocal interactions. However, due to their focus on interaction, level-two social rewards may still fall short in explaining how pre-established group and societal expectations may influence social behavior towards those groups or societies (e.g., prosocial actions) (Izuma et al., 2010a). Alternatively, operationalizations at this level may also be unable to explain how individuals process the acquisition of status and how this in turn may influence the corresponding group dynamics (Aureli & Schino, 2019). In order to address how social reward interacts with and drives other complex social behaviors, such as prosocial actions and status acquisition, researchers can utilize operationalizations from the third and highest level of the framework.

### 4.3.3 Level Three: Prosocial Reward and Reputation

While both prosocial actions and status are driven by social reward, they are multifaceted societal constructs that extend beyond social reward processing. For instance, prosocial actions describe how individuals relate to groups and society through the provision of resources (Batson & Powell, 2003). However, similar to social reward, previous reviewers have asserted a lack of consensus on the definition of prosociality in the corresponding literature. In particular, these reviewers argue that scientific definitions of prosociality differ in their emphasis on intentions and actions, as well as costs and benefits, and the societal context (Pfattheicher et al., 2022).

On the other hand, status has been characterized as an individual's rank and position relative to other members of a given group or society (Magee & Galinsky, 2008; Anderson & Kilduff, 2009). Compared to social reward and prosocial actions, previous reviewers have argued for a similar lack of consensus in the definition of status (Xu et al., 2022). In particular, Xu and colleagues (2022) describe status as fundamental to the human self-concept and as temporally dynamic, emphasizing that individuals constantly update both their own social standing and that of others.

Given that both of these concepts are related to social reward, but simultaneously represent broader societal phenomena that have inspired review articles of their own (Pfattheicher et al., 2022; Xu et al., 2022), prosocial actions and status were positioned at the third and highest level of the hierarchical framework. Thus, this positioning reflects their conceptual complexity and potential for research insight, rather than the complexity of their representations in the studies reviewed.

Sub-sections 4.1.3-4.1.4 already discussed the susceptibility of prosocial behaviors to audience effects and their dependence on societal norms and expectations (Izuma et al., 2010a; 2010b). However, audience effects are also present in the cases of some level-two social rewards, such as physical closeness or observation without interaction (Zimmermann et al., 2019). The main difference between the two is that, in the latter case, the audience effects are triggered by the immediate presence of others. On the other hand, in the case of prosocial actions, audience effects and societal norms influence social reward processing and drive behavior even when others are not immediately present in the same room (Zhang et al., 2023).

In a similar fashion, status is received by larger groups or entire societies (Anderson & Kilduff, 2009). It was previously discussed that social reward reviewers characterize status as an ultimate social goal (Tamir & Hughes, 2018). Therefore, status is a temporally enduring form of recognition that also persists in the physical absence of the group that granted said status. Similarly to prosocial actions, status is tied to societal and cultural norms, as well as the collective memories of others and can drive group decision-making and behaviors (Ridgeway & Markus, 2022). Thus, it can be concluded that both prosocial actions and status have the potential to provide social reward research insights that are qualitatively distinct from those attained at the earlier levels of the framework.

Regarding social reward valuation, social stimuli at the first level of the framework depended on their external attributes and the positive content of the information they conveyed (Rodriguez et al., 2006; Adolphs, 2009; Tricomi & Fiez, 2012; Heerey, 2014). On the other hand, social interactions at the second level depended on inter-personal alignment and reciprocity (Di Paolo & Di Jaegher, 2012; Hamilton & Holler, 2023). In comparison, prosocial actions are valued based on the provision of resources to other individuals or groups to build social bonds with them and to manage one's reputation (Izuma et al., 2010b; Tamir & Hughes, 2018; Pfattheicher et al., 2022).

Additionally, compared to other social rewards, the valuation of prosocial actions is more dependent on environmental factors, such as the immediate social context and behaviors of others (Labroo et al., 2022). Thus, the public broadcasting of one's prosocial behaviors can enhance the social reward experience as well as one's own reputation (Meshi et al., 2015; Berman et al., 2015). Therefore, future research should strive to better understand how social reward drives prosocial behaviors in a manner that is aligned with a given set of societal values.

In comparison, status is valued based on the reception of positive recognition in relation to a given individual or group (Xu et al., 2022). In that sense, the dependence on positive recognition makes the valuation of status similar to how level-one social stimuli are valued. However, as previously discussed, status holds a more enduring, but also temporally evolving quality compared to level-one social stimuli and its effects extend beyond the immediate trial in the task at hand (Prato et al., 2024).

In addition, being characterized as an ultimate social goal, status can arise from social reward operationalizations at either of the first two levels of the framework. For example, reputational status is acquired when outperforming others in cognitive tasks in which each trial is reinforced with a level-one social stimulus (e.g., a smiling face) (Wang et al., 2017; 2020) or from level-two interaction dynamics such as receiving preferential treatment (i.e., a proportionally larger number of digital ball throws compared to other players) in Cyberball (Kawamichi et al., 2016).

The situation is a bit more nuanced for relational status. In terms of concept, the studies investigating this form of status focused on gaining insight into hierarchical interaction dynamics, such as gaining influence through the provision of good advice or expressing agreement with experts (Tobler et al., 2016; Hertz et al., 2020; Li et al., 2020). However, in terms of representation, these interaction concepts were represented in a screen and trial-based format, in the form of images and text, aligning them more closely with level-one social stimuli. Thus, since status can be earned both through simpler, level-one social stimuli and more complex, level-two interactions, it was classified as a level-three social reward.

Otherwise, both prosocial actions and status were represented in a manner that was more aligned with level-one social stimuli, rather than with level-two social interactions. In particular, more than 63% of studies that investigated either social reward relied on visual, screen-based presentation formats. Therefore, the most frequent measures overlapped with those for level-one social stimuli. Specifically, more than 23% of studies for each social reward measured brain activity upon delivery (Izuma et al., 2010a; Gromann et al., 2014; Tobler et al., 2016; Kawamichi et al., 2016; Soutschek, et al., 2017; Li et al., 2020; Hanssen et al., 2021).

Correspondingly, more than 17% of studies per social reward implemented subjective ratings for both anticipation and consumption (Sugawara et al., 2012; Brinkmann et al., 2014; Kawamichi et al., 2016; Rosenthal-von der Pütten et al., 2019; Li et al., 2020; Guo et al., 2020; Burum et al., 2020; Hanssen et al., 2021; Tham et al., 2021). Given the representation format and choice of measurement for both prosocial actions and status, it can be inferred that researchers were interested in how these social rewards were neurally and experientially processed at the individual level rather than on their impact on interaction or group dynamics.

Besides brain activity, 50% of studies on prosocial actions measured reward consumption through donation size (Soutschek et al., 2016; 2017; Gabay et al., 2018; Burum et al., 2020; Andreoni & Serra-Garcia, 2021; Sparrow et al., 2021). On the other hand, over 21% of the studies on status measured anticipation in the form of participants' willingness to forgo a certain monetary amount to earn the reputational recognition (Pascual-Ezama et al., 2013; Bradley et al., 2019; Hertz et al., 2020; Bos et al., 2021). Overall, the types of measures used for both prosocial actions and status were highly diverse and it was challenging to identify consistent trends.

Therefore, the lack of consensus in social reward operationalization with regard to prosocial actions and status is unsurprising considering the indicated multi-facedness of each concept by previous reviewers (Pfattheicher et al., 2022; Xu et al., 2022). This lack in concept and measurement consistency indicates that the investigation of the role of social reward in prosocial actions and status is still evolving. Both forms of operationalization have the research potential to provide conceptual insight into the role of social reward across various group and societal dynamics.

However, the operationalizations employed in the included studies are limited regarding the type of insights they can offer. In particular, the representation and measurement of both social rewards was mostly aligned with those for level-one social stimuli. Thus, it can be concluded that researchers to date were more interested in the individual processing of level-three social rewards rather than in their impact on genuine group dynamics.

### 4.4 Importance for Cognitive Science

With respect to cognitive science, this systematic review identified social reward as a hierarchical concept in order to improve communication across the disciplines within the field that focus on social cognition (for details, see Figure 7). Each level of the hierarchical framework is shaped by the types of research questions posed and the measures available to study social reward. As such, this framework is also useful in illuminating the cognitive science frameworks that have been most influential in defining the concept of social reward.

In that sense, each cognitive science discipline can provide research input at different levels of the hierarchy. For example, as discussed above, psychology and neuroscience can answer research questions at the first two levels of the framework, but might be limited in their methodology with regard to answering research questions pertaining to genuine group dynamics at the third level. However, these might be better addressed by anthropological ethnographic methods which rely on observation and interviews to understand group dynamics across various communities (Gatt & Ingold, 2013). In particular, anthropology is frequently concerned with social rewards such as status, reciprocity, and cooperation as well as social and cultural norms (Gächter & Herrmann, 2008).

In comparison, the existing social knowledge from psychology and neuroscience can be embedded into computational models of interaction and cognition to expand the range of explanations from controlled to real-world environments (FeldmanHall & Nassar, 2021). Building on this knowledge, multi-agent environments can be simulated to understand how social rewards drive cooperation, competition, and seeking approval in real time, answering research questions at the second level of the framework (Gonzalez, 2023). Therefore, each cognitive science discipline offers distinct methodologies that determine the level at which research questions can be addressed. By integrating these cross-level, interdisciplinary insights, the disciplines can meaningfully build on one another.

On the other hand, the current systematic review established that most of the included studies used decontextualized social rewards, feedback on task performance, or feedback about the self to investigate how these level-one social stimuli were neurally processed upon delivery and how they motivated performance in target detection and other cognitive tasks (e.g., Delmonte et al., 2012; Gossen et al., 2013; Bhandari et al., 2014; Rademacher et al., 2014; Flores et al., 2015; Radke et al., 2016; Richey et al., 2017; Hwang et al., 2017; Catalano et al., 2018; Doppler et al., 2019; Zhu & Zhan, 2019; Frey & McCabe, 2020; Chen et al., 2021). Given the focus on neural processing and motivational properties of social reward in these studies, it can be concluded that most researchers operationalized the concept in accordance with the reinforcement learning and predictive coding approaches to cognition (Schultz, 1998; Clark, 2013).

In these studies, social reward was presented as an externally observed stimulus aiming to reinforce accuracy and response times in a given task. In alignment with the reinforcement learning and predictive coding frameworks, participants were expected to internally process this stimulus and evaluate it based on prior positive associations (Schultz, 1998; Clark, 2013; Eck & Turner, 2016). Participants who were successfully motivated by the positive social stimuli at the end of each trial were expected to accurately and quickly repeat the behavior (e.g., button press) that led to the acquisition of social reward in the previous trial (Schultz, 1998; Berridge & Robinson, 1998). Simultaneously, the neural activity observed in the relevant midbrain dopaminergic reward regions was interpreted as an indication of the brain processing the reward stimulus during consumption (Baez-Mendoza & Schultz, 2013; Fareri & Delgado, 2014).

In addition, even some studies on contextualized social rewards like social interaction, presented the positive outcome of said interaction in a brief, trial-based format lasting for a predetermined number of seconds (e.g., social inclusion, reciprocated trust) (Weschke & Niedeggen, 2013; Gromann et al., 2013; 2014; Ethridge & Weinberg, 2018; Hanssen et al., 2021). In a similar manner, the research focus was on how these interaction outcomes were neurally processed upon delivery and how they impacted the behavior and subjective reward experience of participants.

Given these considerations, it can be concluded that the current human experimental literature on social reward generally understands this concept as a positive social stimulus (e.g., approval gesture, smiling face, positive social feedback about the self, praise on performance, etc). Similar to non-social rewards, the reception of these positive social stimuli is expected to reinforce the behaviors that led to their acquisition and to facilitate the construction of positive prediction models (e.g., a friend's smile matches the expectation of a positive interaction and decreases the prediction error) (Berridge & Robinson, 1998). Therefore, the conceptualization of social reward resembles that of non-social reward, as both are expected to activate dopamine-mediated neural pathways and engage similar cognitive algorithms (Schultz, 1998; Fareri & Delgado, 2014).

However, over-relying on reinforcement learning and predictive coding approaches to cognition in the operationalization of social reward can lead to two main issues. The first issue pertains to the fact that this practice can cause an overestimation of the similarities between social and non-social rewards (Matyjek et al., 2020b). The Introduction already discussed several important differences between social and non-social rewards regarding the cognitive and neural mechanisms they engage. For instance, besides reinforcement learning and predictive coding, humans use theory of mind to infer the intentions and beliefs of others and to derive the reward value of social interactions (Krach et al., 2010).

In turn, theory of mind has been implicated to activate higher cortical brain regions such as the medial prefrontal cortex (mPFC), superior temporal sulcus (STS), temporoparietal junction (TPJ), as well as the amygdala in the limbic system (Adolphs, 2003). Moreover, in addition to dopamine, the neurotransmitter oxytocin is increasingly implicated in the formation and maintenance of social bonds (Han & Ma, 2024). In order to explain these socially specialized cognitive and neural mechanisms, future social reward research may need to rely on alternative approaches to cognition when operationalizing the concept.

On the other hand, the second issue pertains to the potential challenges of generalizing controlled laboratory findings to real-world human behavior (Di Paolo & De Jaegher, 2012). As previously discussed, in the real-world, social reward is mostly encountered within the context of dynamic, temporally evolving, and reciprocal social interactions. Within the scope of these interactions, social reward is grounded in various verbal and non-verbal signals (Hamilton & Holler, 2023). Moreover, instead of being an external social stimulus, social reward becomes manifested in the synchrony and coordination dynamics between the interacting partners, which is larger than the parts of their individual behaviors (Hobson, 2008).

Therefore, future social reward research could benefit from integrating embodied and enacted approaches to cognition into the conceptualization of social reward. Both of these frameworks have been scarcely implemented in the current literature, as evidenced by the limited number of studies investigating properties of in-person social interactions and the complete absence of studies implementing multi-person methodologies. The larger incorporation of embodied approaches will broaden our understanding of how social reward physically manifests in the body (e.g., eye movements, facial movement, physiology) and is communicated through non-verbal cues (e.g., smiles, mimicry, posture, gestures) (Goldman & Vignemont, 2009)

On the other hand, the incorporation of enacted approaches can help us understand the relational and dynamic properties of social reward within the scope of the social interaction process itself. In terms of measurements, this would place emphasis on outcomes such as inter-brain and inter-behavioral synchrony as well as coordination transitions during communication (Goldman & Vignemont, 2009; Di Paolo & De Jaegher, 2012). Thus, social reward can be re-conceptualized to include both verbal and non-verbal behaviors, each contributing to social competence and manifesting in the interdependent, cooperative interactions individuals have with each other and their social environment (De Jaegher et al., 2010).

### 4.5 Limitations and Future Directions

The main aim of this systematic review was to provide a comprehensive overview of the ways social reward was operationalized, compared, and measured in human experimental studies. However, these findings should be considered in light of several limitations imposed by the methodology that was adopted in the review. Firstly, the search strategy was comprised of a single keyword, “social reward”. This approach was chosen by Stijovic and colleagues (2024) to minimize the influence of preconcieved notions about social reward on the review’s findings.

Thus, the influence of biased interpretation of social reward on the review’s findings was effectively avoided by exclusively focusing on those studies that explicitly referenced “social reward” in their title, abstract, or main text. However, the rigorousness of the approach might have excluded papers that investigated similar concepts, such as beautiful faces or romantic love, but did not explicitly refer to them as social rewards (e.g., Aharon et al., 2001; Bartels & Zeki, 2004; Moll et al., 2006; Schilbach et al., 2010; Tamir & Mitchell, 2012; Will et al., 2017; Hammerschmidt et al., 2018).

In a similar fashion, it is possible that the search strategy also excluded papers that used “social incentive” or “social reinforcer” to refer to terms that might be otherwise related to social reward. The exact definitions and measures employed in these papers may have systematically differed from those extracted in the included studies. In addition, both “social incentive” and “social reinforcer” originate as terms from the behavioral psychology and reinforcement learning literature (Jones et al., 2011; Brauer & Tittle, 2012). Therefore, if “social incentive” and “social reinforcer” were used as terms over “social reward” in studies investigating learning, there is a possibility that this caused the small inclusion of studies that investigated social reward learning.

However, considering the heterogeneity of operationalizations employed in the field, choosing “social reward” as the sole term in the search strategy facilitated the minimization of bias during data collection and analysis. Therefore, despite the potential limitations in scope of the chosen search term, this systematic review still provides a comprehensive and targeted overview of the operationalization, comparison, and measurement trends in the experimental human literature on social reward. This overview can be expanded by future reviewers who can incorporate terms such as “social incentive” or “social reinforcer” in their search strategies to identify potential overlaps and differences with “social reward”.

Second, the inclusion criteria of this systematic review excluded studies with non-experimental research designs (e.g., reviews, surveys, interventions, interviews) or with exclusively clinical and/or children or adolescent samples. Therefore, it is possible that the operationalization, comparisons, and measures chosen for these research designs systematically differed from those chosen for experimental studies and healthy adult populations. As such, future reviewers could include non-experimental research designs and studies with exclusively clinical and/or children/adolescent populations in their sample to identify potential differences in findings.

Third, the sample of the current systematic review primarily consisted of studies conducted in the United States, Germany, the United Kingdom, and other Western countries (for details, see section 3.2 in the main text or Table A1 in the Appendix). Therefore, the review does not account for any potential differences in social reward operationalization between Western societies and other regions of the world. For example, compared to individualist Western countries, collectivist societies such as Japan and China may be more likely to conceptualize social reward in the form of status and honor (Markus & Kitayama, 2003). This notion is further supported by the fact that 36.84% of the includes studies on status were conduced in one of these two countries. Therefore, future reviewers could also broaden our understanding of social reward by addressing the differences in operationalization, comparisons, and measures between different parts of the world.

Lastly, the influence of particular papers and research groups in the field may have contributed to the prevalence of certain social reward operationalizations over others. For example, some research groups may have garnered larger influence in the field by producing a larger research output or receiving more citations than others. This in turn, may have led less influential researchers to adopt similar research designs and operationalizations in their own studies. However, the current systematic review did not account for the quality of research designs and the impact of findings of the included studies. Therefore, future reviewers could address the reasons behind the prevalence of certain operationalizations over others by accounting for the role of quality of research designs and impact of findings in their methodology.

**4.6 Conclusion**

In general terms, social rewards represent the positive experiences derived from interacting with others. These positive experiences facilitate adaptive social behaviors such as cooperation and bond formation to promote the survival and reproduction of the species (Adolps, 2003). Therefore, social rewards are the cornerstone of broader social competence, including the acquisition of important developmental milestones (Hughes & Leekam, 2003). On the other hand, impaired social reward processing can lead to social anhedonia and cause the development of various psychopathological disorders (Barkus, 2021).

Nonetheless, there is a lack of consensus on the operationalization of social reward in the human experimental literature, compromising the interpretation and implication of findings. Thus, the current systematic review addressed this gap by employing a data-driven approach to provide a comprehensive overview of the operationalization, comparison, and measurement trends in the social reward literature. Expanding on the dual-model contextualization framework proposed by Tamir and Hughes (2018), this systematic review found that most of the included studies used decontextualized social rewards (i.e., smiling faces, approval gestures), feedback on performance, or feedback about the self in their social reward operationalizations.

These social rewards were compared to their non-rewarding counterparts (e.g., smiling faces compared to non-smiling faces), non-social monetary rewards or non-social and/or non-rewarding feedback on task performance (e.g., “correct!” as textual feedback for good task performance). In terms of measurement, most studies used brain activity (i.e., fMRI, EEG) and subjective ratings for consumption, and task accuracy and response times for anticipation. In comparison, the literature overall paid less attention to learning. Therefore, most social rewards were visually presented through a screen and oftentimes involved novel social stimuli or unfamiliar social interaction partners. In addition, most studies represented social reward in brief, trial-based formats, lasting around 2 seconds per trial.

In terms of research gaps, the current systematic review revealed that there is limited information on the social reward processing of contextualized social rewards, such as social interaction, social closeness, prosocial actions, affective touch, joint attention, observation without interaction, and physical closeness as well as on the ultimate social goal of status. Consequently, the current social reward literature is focused on how various social reward stimuli are being processed in the brain and how they influence accuracy and response times in target detection and other cognitive tasks. As such, there is limited information on the role of social reward during multi-modal, in-person and reciprocal social interactions. In terms of measurements, the literature has limited information on the embodied manifestations of social reward in the form of eye movement, facial movements, or physiological outcomes. On the other hand, it does not have any information on multi-person outcomes such as inter-brain and inter-behavioral synchrony.

Other notable research gaps included the limited use of familiar social rewards such as acquaintances or close people, as well as non-social reward comparison stimuli other than monetary ones. Considering the aforementioned trends and research gaps in the literature, this systematic review proposed a three-level hierarchical framework for social reward operationalization. The operationalizations at each level are defined by the type of research questions they can answer and the measures available to address them (for details, see Figure 7).

The research questions at each level were outlined as follows: i) how various social *stimuli* are processed; ii) how humans *interact* with and *relate* to one another; iii) how social reward drives complex social behaviors (i.e., prosocial action and status), enabling individuals to relate to their *groups* and *societies* at large. Therefore, social reward concepts at lower levels can give rise to those at higher levels (e.g., stimulus > interaction > group). However, lower levels are limited in the types of research questions they can address, particularly regarding scale. Nonetheless, while the higher levels are conceptually more complex than the lower levels of the framework, current studies are limited by research designs closely aligned with those used at the first level of the framework.

Lastly, current social reward research relies on concepts from reinforcement learning and predictive coding approaches to cognition, giving precedence to internal evaluations of externally observed social stimuli. Therefore, the literature has limited insight into reciprocal interactivity, and the embeddedness of social reward in real world contexts. To address these gaps, future social reward research may benefit from concepts present in the embodied and enactive approaches to cognition. In that sense, understanding social reward as a hierarchical concept promises to facilitate the integration of cross-level, interdisciplinary insights, enabling cognitive science disciplines to build more effectively on each other's findings.

# Appendix

## A1. Search Strategy: Search Strings and Number of Records per Database

The search strategy outlined below is reproduced from the Supplementary Materials in the paper by Stijovic et al. (2024), conducted by the paper's first author.

### A1.1 First Literature Search (database inception until 8th October, 2020)

PubMed (via https://pubmed.ncbi.nlm.nih.gov/)

| Search string | Results |
|---|---|
| "social reward*"[Text Word] OR "socially rewarding" [Text Word] OR "prosocial reward*"[Text Word] | 549 |

Web of Science - all collections (via https://www.webofscience.com/wos/woscc/basic-search)

| Search string | Results |
|---|---|
| TS = ("*social* reward*")<br>Databases = WOS, BCI, BIOSIS, CSCD, CCC, DRCI, DIIDW, INSPEC, KJD, MEDLINE, RSCI, SCIELO, ZOOREC Timespan=All years<br>Search language=Auto | 1,136 |
| TS = ("*social* reward*")<br>Indexes = SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, BKCI-SSH, CCR-EXPANDED, IC Timespan=All years | 860 |

Scopus (via https://www.scopus.com/)

| Search string | Results |
|---|---|
| TITLE-ABS-KEY ("*social* reward*") | 923 |

BioRxiv (via https://www.biorxiv.org/)

| | |
|---|---|
| Title or Abstract - phrase - "social reward" | 20 |
| Title or Abstract - phrase - "social rewards" | 2 |
| Title or Abstract - phrase - "prosocial reward" | 0 |
| Title or Abstract - phrase - "prosocial rewards" | 0 |
| Title or Abstract - phrase - "socially rewarding" | 0 |

PsyArxiv (via https://psyarxiv.com/)

| | |
|---|---|
| "social reward" OR "social rewards" OR "prosocial reward" OR "prosocial rewards" OR "socially rewarding" | 20 |

Total number of imported references: 3468 + 42

Order of import (Endnote):

1. PubMed
2. Web of Science Core collection

3. Scopus

4. Web of Science other databases

5. BioRXiv

6. PsyarXiv

Final number of references after de-duplication: 1253

| Database | Remaining number |
|---|---|
| PubMed | 548 |
| WoS - Core Collection | 357 |
| Scopus | 157 |
| WoS - all databases | 169 |
| BioRxiv | 12 |
| PsyarXiv | 10 |

**A1.2 Second Literature Search (9th October, 2020 until 18th May, 2022)**

*Limiting searches to a specific day was not possible in Scopus and PsyArXiv. Therefore, articles published before 9th October 2020 were manually excluded by two of the authors of Stijovic et al. (2024) during the abstract screening stage.

PubMed

| Search string | Results |
|---|---|
| social* reward* [tw] OR "socially rewarding" [tw] OR "prosocial* reward*" [tw] AND ("2020/10/08"[Date - Create] : "3000"[Date - Create] | 125 |

Web of Science

| Search string | Results |
|---|---|
| TS = ("*social* reward*")<br>All Databases<br>Timespan: 2020-10-09 to 2022-05-18 (Publication Date) | 220 |

Scopus

| Search string | Results |
|---|---|
| TITLE-ABS-KEY (("*social* reward*")) AND PUBYEAR > 2019 | 258 |

BioRxiv

| | |
|---|---|
| abstract or title ""social reward "" (match phrase words) and posted between "09 Oct, 2020 and 18 May, 2022" | 9 |
| abstract or title ""social rewards "" (match phrase words) and posted between "09 Oct, 2020 and 18 May, 2022" | 1 |
| abstract or title ""prosocial reward "" (match phrase words) and posted between "09 Oct, 2020 and 18 May, 2022" | 0 |
| abstract or title ""prosocial rewards "" (match phrase words) and posted between "09 Oct, 2020 and 18 May, 2022" | 0 |
| abstract or title ""socially rewarding "" (match phrase words) and posted | 1 |

| |
|---|
| between “09 Oct, 2020 and 18 May, 2022” |

| PsyArxiv | |
|---|---|
| “social reward” OR “social rewards” OR “prosocial reward” OR “prosocial rewards” OR “socially rewarding” | 29 |

Total number of imported references: 603 + 40

Order of import (Endnote):

1. PubMed
2. Web of Science Core collection
3. Scopus
4. Web of Science other databases
5. BioRXiv
6. PsyarXiv

Final number of references after de-duplication: 351

| Database | Remaining number |
|---|---|
| PubMed | 125 |
| WoS - all databases | 103 |
| Scopus | 99 |
| BioRxiv | 7 |
| PsyarXiv | 17 |

## A2. Data Items: Coding Sheet Example

This is an example of a "merged" coding sheet containing the agreed upon data items between I.B. and A.K., both authors of Stijovic et al. (2024). I.B. is also the author of this systematic review. The coding sheet was compiled by A.S., the first author of Stijovic et al. (2024). For a detailed description of the data collection procedure and the data items, refer to sub-sections 2.5 and 2.6 under Methods, respectively.

| | |
|---|---|
| Title | Individual attachment style modulates human amygdala and striatum activation during social appraisal |
| Authors | Vrticka, P. and Andersson, F. and Grandjean, D. and Sander, D. and Vuilleumier, P. |
| Year | 2008 |
| doi | 10.1371/journal.pone.0002868 |
| Journal | PLoS One |
| Country where the study is performed | Switzerland |
| Type of study | Brain imaging, behavioral |
| Clinical study | No |
| Children study | No |
| **Sample** | |
| Species | Human |
| Ethnicity (humans) (+ proportions) | n.s. |
| Age (average, SD) | 23.6 (3.6) |
| Gender (+ proportions of females) | 50% |
| Sample size | 16 |
| **Task(s) that involve social reward** | |
| 1 | • Name: Visual dot-counting<br>• Short description: Participants were presented with a visual display divided in two parts with dots on each side. indicated which side of the screen contained more dots. They got feedback consisting of a face (supposedly given by a different group member) paired with a verbal indication of actual performance. |
| Coder or author | Author |
| 1: **Social reward stimuli** | |
| Social reward | Smiling Face on WON trial |
| Coder or author | Author |
| Content | Image and word |
| Familiar/novel | Novel |
| Sensory modality | Visual |
| Given/received | Received |
| Duration | 1500 ms per trial (128 trials in total) |
| Delivery time | Immediately |
| Announced | No |
| 1: **Control stimuli for social reward** | |
| Comparison stimulus | Smiling Face on LOST trial |
| Coder or author | Author |
| Content | Image and word |
| 2: **Control stimuli for social reward** | |
| Comparison stimulus | Angry Face on WON trial |
| Coder or author | Author |
| Content | Image and word |

| | |
|---|---|
| 3: **Control stimuli for social reward** | |
| Comparison stimulus | Angry Face LOST trial |
| Coder or author | Author |
| Content | Image and word |
| 1: **Measures of social reward** | |
| What was measured? | (1) Reward system activation<br>(2) visual inspection<br>(3) Degree of satisfaction/frustration<br>(4) Subjective experience of faces<br>(5) Subjective irritation by in-congruence<br>(6) Task performance |
| Coder or author | 1) coder<br>(2-5) Author<br>(6)coder |
| Direct/indirect | (1) direct<br>(2) ns<br>(3) direct<br>(4) direct<br>(5) direct<br>(6) indirect |
| Content of the measure | (1) BOLD signal<br>(2) the number and duration of fixations (eye tracker)<br>(3) 5-point Lickert scale<br>(4) 5-point Likert scale<br>(5) 5-point Likert scale<br>(6) Accuracy, reaction times |
| Contrast reward | (1 )Yes<br>(2) yes<br>(3) no<br>(4) no<br>(5) no<br>(6) no |
| Contrast social | (1) No |
| Comment | |
| Coder´s name | Merged (I.B. and A.K.) |
| Date | 17.04.2021 |

### A3. Procedure for Social Reward Theme Extraction

The theme extraction procedure is reproduced from Stijovic et al. (2024) and took place in several steps. First, an inductive approach was used on all raw textual entries for the fields "social reward concept", "social reward content", "comparison stimulus concept" and "comparison stimulus content". The free-entry fields for "measure concept" and "measure content" were merged before the theme extraction was performed. Three pairs of raters, including three authors from Stijovic et al. (2024), one of whom is also the author of this systematic review, extracted keywords for each of the six specified data items using a sample of 50 randomly selected coded studies. The raters aimed to extract the minimal number of keywords necessary to adequately describe all free-entry textual data items in the dataset.

For example, if the social reward concept was "face with a smile", the keywords would be "face" and "smile" (Flores et al., 2015). On the other hand, if the social reward concept was "social approval for good performance", the keywords were "approval for performance" (Brinkmann et al., 2014). To extract these keywords, the raters relied solely on terms already present within the raw entries for each data item. Once the keywords from all the raters were merged, five keywords lists were formed. The lists corresponded to the five items mentioned above: "social reward content", "social reward concept", "comparison stimulus content", "comparison stimulus concept" and "measures".

Following this, the keyword frequencies were displayed with bar charts and word clouds during pilot meetings between the raters. During these meetings, keywords with similar meanings were grouped into single themes, and theme names were determined by consensus. After the theme lists were formed, all studies were split between the three raters to assign one or more themes for each data item belonging to one of the five theme lists. For example, if the social reward concept was feedback in the form of a smiling face showing thumbs-up, that entry was coded to belong to four different social reward themes, including "face", "smile", "approval gestures", and "feedback on performance".

Additionally, a miscellaneous "other" category was created during categorization to capture any raw entries that did not clearly fit into the extracted themes for each data item. As a result, additional themes were formed for some of the data items that were missed during the first synthesis. The themes for all five data items were formed following data collection from the first literature search (October, 2020). The studies from the second literature search (May, 2022) were coded for occurrence within the already existing themes by one of the authors of Stijovic et al. (2024).

**A4. General Study Characteristics: Countries of Publication**

**Table A1**

*Countries of Publication for Experimental Social Reward Studies in Humans*

| Country | Number of studies (%) |
|---|---|
| United States (US) | 51 (27.13) |
| Germany | 21 (11.17) |
| United Kingdom (UK) | 19 (10.11) |
| China | 13 (6.91) |
| Canada | 12 (6.38) |
| Japan | 11 (5.85) |
| Netherlands | 7 (3.72) |
| Switzerland | 7 (3.72) |
| Austria | 5 (2.66) |
| France | 2 (1.06) |
| South Africa | 2 (1.06) |
| Spain | 2 (1.06) |
| Ireland | 1 (0.53) |
| Norway | 1 (0.53) |
| Singapore | 1 (0.53) |
| Taiwan | 1 (0.53) |
| Turkey | 1 (0.53) |
| US and France | 1 (0.53) |
| US and Germany | 1 (0.53) |

| | |
|---|---|
| UK, Netherlands, Germany, and Italy | 1 (0.53) |
| Not stated | 28 (14.89) |

## A5. Tables of Social Reward Operationalizations and Dimensions

**Table A2**

*Study Counts and percentages of Social Reward Themes Across Study Types*

| Social Reward Context Type | Social Reward Theme | Total number of studies (%) | Behavioral, 60 (%) | Brain imaging, 104 (%) | Pharmacological, 17 (%) | Physiological, 20 (%) |
|---|---|---|---|---|---|---|
| Decontextualized Social Rewards | Face | 78 (41.49) | 16 (26.67) | 54 (51.92) | 7 (41.18) | 9 (45.00) |
| | Smile | 60 (31.91) | 12 (20.00) | 40 (38.46) | 7 (41.18) | 8 (40.00) |
| | Approval gestures | 24 (12.76) | 7 (11.67) | 16 (15.38) | - | 1 (5.00) |
| | Body | 12 (6.38) | 4 (6.67) | 5 (4.81) | - | 2 (10.00) |
| | Affective Sound | 6 (3.19) | 3 (5.00) | 2 (1.92) | 1 (5.88) | 1 (5.00) |
| | Biological Motion | 3 (1.60) | 1 (1.67) | - | - | 2 (10.00) |
| Feedback | Performance | 55 (29.26) | 18 (30.00) | 31 (29.81) | 4 (23.53) | 4 (20.00) |
| Contextualized Social Rewards | Social Interaction | 23 (12.23) | 10 (16.67) | 9 (8.65) | 1 (5.88) | 3 (15.00) |
| | Social Closeness | 13 (6.91) | 10 (16.67) | 1 (0.96) | 2 (11.76) | - |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Prosocial Actions | 12 (6.38) | 6 (10.00) | 5 (4.81) | 3 (17.65) | - |
| | Affective Touch | 5 (2.66) | - | 1 (0.96) | 2 (11.76) | 5 (25.00) |
| | Joint Attention | 3 (1.60) | - | 2 (1.92) | 1 (5.88) | 1 (5.00) |
| | Obs. No Interaction** | 3 (1.60) | 1 (1.67) | 2 (1.92) | - | 1 (5.00) |
| | Social Support | 2 (1.06) | 1 (1.67) | 1 (0.96) | - | - |
| | Physical Closeness | 1 (0.53) | - | 1 (0.96) | - | 1 (5.00) |
| | Humor | 1 (0.53) | - | 1 (0.96) | - | - |
| Feedback | About Self | 36 (19.15) | 10 (16.67) | 25 (24.04) | 1 (5.88) | 1 (5.00) |
| Ultimate Social Goal | Status | 19 (10.11) | 10 (16.67) | 5 (4.81) | 1 (5.88) | 3 (15.00) |
| Other | Other Stimuli | 6 (3.19) | 5 (8.33) | 1 (0.96) | - | - |

*Note:* *The total number of studies included per study type is as follows: 60 behavioral, 104 brain imaging, 17 pharmacological, and 20 physiological; **Obs. No Int. = Observation without Interaction

**Table A3**

*Study Counts and percentages of Social Reward Themes and Contents*

| Social Reward Context Category | Social Reward Theme and Content, N (%) | Image, 105 (55.85) | Text, 45 (23.94) | Movie, 23 (12.23) | Action, 17 (9.04) | Spoken Word, 14 (7.45) | Conspecific, 13 (6.91) | Sound, 7 (3.72) | Touch, 5 (2.66) |
|---|---|---|---|---|---|---|---|---|---|
| Decontextualized Social Rewards | Face, 78 (41.49) | 67 (85.90) | 5 (6.41) | 13 (16.67) | 1 (1.28) | - | 2 (2.56) | 6 (7.69) | - |
| | Smile, 60 (31.91) | 50 (83.33) | 5 (8.33) | 10 (16.67) | - | - | 2 (3.33) | 5 (8.33) | - |
| | Approval Gestures, 24 (12.77) | 17 (70.83) | 4 (16.67) | 5 (20.83) | - | 1 (4.17) | - | 1 (4.17) | - |
| | Body, 12 (6.38) | 7 (58.33) | 1 (8.33) | 5 (41.67) | - | - | - | 2 (16.67) | - |
| | Affective Sound, 6 (3.19) | 4 (66.67) | 1 (16.67) | - | - | 1 (16.67) | - | 5 (83.33) | - |
| | Biological Motion, 3 (1.60) | 1 (33.33) | - | 2 (66.67) | - | - | - | - | - |
| Feedback | Performance, 55 (29.26) | 25 (45.45) | 12 (21.82) | 9 (16.36) | - | 11 (20.00) | 1 (1.82) | 4 (7.27) | 2 (3.64) |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Contextualized Social Rewards | Social interaction, 23 (12.23) | 5 (21.74) | 7 (30.43) | 3 (13.04) | 4 (17.39) | - | 9 (39.13) | - | - |
| | Social closeness, 13 (6.91) | 1 (7.69) | 8 (61.53) | - | - | 1 (7.69) | 3 (23.08) | - | - |
| | Prosocial actions, 12 (6.38) | - | 4 (33.33) | - | 8 (66.67) | 1 (8.33) | - | - | - |
| | Affective touch, 5 (2.66) | - | - | - | - | - | 1 (20.00) | - | 5 (100.00) |
| | Joint attention, 3 (1.60) | 2 (66.67) | - | 2 (66.67) | 2 (66.67) | - | - | - | - |
| | Observation without interaction, 3 (1.60) | - | - | 1 (33.33) | - | - | 2 (66.67) | - | - |
| | Social support, 2 (1.06) | - | 1 (50.00) | - | - | - | 1 (50.00) | - | - |
| | Physical closeness, 1 (0.53) | - | - | - | - | - | 1 (100.00) | - | - |
| | Humor, 1 (0.53) | 1 (100.00) | - | - | - | - | - | - | - |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Feedback | About the Self, 36 (19.15) | 22 (61.11) | 15 (41.67) | 3 (8.33) | 2 (5.56) | 1 (2.78) | 1 (2.78) | 1 (2.78) | - |
| Ultimate Social Goal | Status, 19 (10.11) | 6 (31.58) | 9 (47.37) | 3 (15.79) | 4 (21.05) | 4 (21.05) | - | - | - |

**Table A4**

*Social Reward Dimensions Across Study Types and Reward Context*

| Social Reward Dimensions | Study Types (%) | | | | Context Category (%) | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Behavioral | Brain imaging | Pharmacological | Physiological | Decontextualized | Feedback Performance | Contextualized | Feedback Self | Status |
| <u>Sensory Modality</u> | | | | | | | | | |
| Visual | 30 (50.00) | 90 (86.54) | 10 (58.82) | 10 (50.00) | 89 (88.12) | 33 (60.00) | 21 (42.00) | 31 (86.11) | 10 (52.63) |
| Auditory | 7 (11.67) | 1 (0.96) | 1 (5.88) | - | 3 (2.97) | 9 (16.36) | - | 1 (2.78) | - |
| Multimodal | 11 (18.33) | 5 (4.81) | 3 (17.65) | 5 (25.00) | 4 (3.96) | 4 (7.27) | 8 (15.69) | 2 (5.56) | 5 (26.32) |
| Tactile | - | 1 (0.96) | 2 (11.76) | 5 (25.00) | - | 2 (3.64) | 5 (9.80) | - | - |
| Undefined | 15 (25.00) | 8 (7.69) | 1 (5.88) | 1 (5.00) | - | 2 (3.64) | 20 (39.22) | 2 (5.56) | 4 (21.05) |
| <u>Tangibility</u> | | | | | | | | | |
| On screen | 35 (58.33) | 99 (95.19) | 12 (70.59) | 13 (65.00) | 98 (97.03) | 39 (70.91) | 98 (97.03) | 33 (91.67) | 12 (63.16) |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| In presence | 15 (25.00) | 2 (1.92) | 5 (29.41) | 7 (35.00) | 6 (5.94) | 13 (23.64) | 6 (5.94) | 2 (5.56) | 4 (21.05) |
| Abstract | 12 (20.00) | 4 (3.85) | - | 2 (10.00) | - | 3 (5.45) | - | 2 (5.56) | - |
| Other | 2 (3.33) | - | - | - | - | - | - | - | 1 (5.26) |
| Familiarity | | | | | | | | | |
| Novel | 40 (66.67) | 88 (84.61) | 12 (70.59) | 14 (70.00) | 89 (88.12) | 37 (67.27) | 30 (58.82) | 24 (66.67) | 17 (89.47) |
| Acquaintance | 19 (31.67) | 17 (16.35) | 4 (23.53) | 6 (30.00) | 13 (12.83) | 20 (36.36) | 19 (37.25) | 10 (27.78) | 2 (10.53) |
| Close person | 5 (8.33) | 6 (5.77) | 3 (17.65) | 1 (5.00) | 1 (0.99) | 1 (1.82) | 10 (19.61) | 4 (11.11) | - |
| Not stated | - | 1 (0.96) | 1 (5.88) | - | - | - | - | - | - |
| Duration | | | | | | | | | |
| Less than 1s | 5 (8.33) | 6 (5.77) | - | 1 (5.00) | 9 (8.91) | 1 (1.82) | 1 (1.96) | 1 (2.78) | 1 (5.26) |
| 1s to 10s | 15 (25.00) | 80 (76.92) | 11 (64.71) | 13 (65.00) | 79 (78.22) | 33 (60.00) | 14 (27.45) | 25 (69.44) | 4 (21.05) |
| 10s to 60s | - | 9 (8.65) | 2 (11.76) | 1 (5.00) | 5 (6.41) | 3 (5.45) | 3 (5.88) | 2 (5.56) | 1 (5.26) |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| More than 1 min | 2 (3.33) | 1 (0.96) | 2 (11.76) | 2 (10.00) | 2 (1.98) | - | 6 (11.76) | - | - |
| Not stated | 45 (75.00) | 11 (10.58) | 3 (17.65) | 6 (30.00) | 11 (10.89) | 16 (32.73) | 30 (58.82) | 9 (25.00) | 14 (73.68) |
| <u>Delay Time</u> | | | | | | | | | |
| Immediate | 41 (68.33) | 34 (32.69) | 9 (52.94) | 10 (50.00) | 42 (41.58) | 23 (41.82) | 25 (49.02) | 15 (41.67) | 10 (52.63) |
| Delayed | 19 (31.67) | 71 (68.27) | 9 (52.94) | 11 (55.00) | 66 (65.35) | 32 (58.18) | 21 (41.18) | 22 (61.11) | 9 (47.37) |
| Never | 6 (10.00) | 2 (1.92) | - | 1 (5.00) | - | 1 (1.82) | 8 (15.69) | - | 1 (5.26) |
| Not stated | 1 (1.67) | 1 (0.96) | 1 (5.88) | 1 (5.00) | - | - | - | 1 (2.78) | - |

**Table A5**

*Study Counts and Percentages of Comparison Stimuli Across Social Reward Context*

| Comparison Stimuli Themes | Total number of studies (%) | Social Reward Context Categories (%) | | | | |
|---|---|---|---|---|---|---|
| | | Decontextualized Social Rewards | Feedback on Performance | Contextualized Social Rewards | Feedback about the Self | Status |
| Face | 56 (29.80) | 55 (54.46) | 18 (32.73) | - | 3 (8.33) | 1 (5.26) |
| Money | 48 (25.50) | 32 (31.68) | 17 (30.91) | 8 (15.69) | 9 (25.00) | 6 (31.58) |
| Feedback on Performance | 43 (22.90) | 30 (29.70) | 32 (58.18) | - | 5 (13.89) | 4 (21.05) |
| Nonsocial other | 33 (17.60) | 21 (20.79) | 8 (14.55) | 5 (9.80) | 8 (22.22) | 2 (10.53) |
| No stimulus | 25 (13.30) | 11 (10.89) | 12 (21.82) | 5 (9.80) | 5 (13.89) | 4 (21.05) |
| Feedback About the Self | 24 (12.80) | 14 (13.86) | 2 (3.64) | 2 (3.92) | 22 (61.11) | 3 (15.79) |
| Angry | 20 (10.60) | 20 (19.80) | 5 (9.09) | - | 1 (2.78) | - |
| Socially blurred stimuli | 12 (6.38) | 11 (10.89) | 4 (7.27) | - | - | - |
| Sad | 11 (5.85) | 11 (10.89) | 4 (7.27) | - | - | - |
| Social interaction | 11 (5.85) | 2 (1.98) | - | 11 (21.57) | - | - |
| Status | 10 (5.32) | 1 (0.99) | 2 (3.64) | 2 (3.92) | 2 (5.56) | 9 (47.37) |
| Smile | 8 (4.26) | 8 (7.92) | 4 (7.27) | 2 (3.92) | - | - |
| Body | 7 (3.72) | 7 (6.93) | 2 (3.64) | - | - | - |

| | | | | | | |
|---|---|---|---|---|---|---|
| Food | 7 (3.72) | 3 (2.97) | 3 (5.45) | 3 (5.88) | 3 (5.45) | - |
| Affective sound | 5 (2.66) | 4 (3.96) | 4 (7.27) | - | 1 (2.78) | - |
| Prosocial actions | 5 (2.66) | - | - | 3 (5.88) | - | - |
| Observation without Interaction | 5 (2.66) | - | 1 (1.82) | 2 (3.92) | 1 (2.78) | - |
| Afraid | 4 (2.13) | 4 (3.96) | - | - | - | - |
| Social closeness | 4 (2.13) | - | - | 4 (7.84) | - | - |
| Biological motion | 2 (1.06) | 2 (1.98) | - | - | - | - |
| Joint attention | 2 (1.06) | 1 (0.99) | - | 2 (3.92) | - | - |
| Social support | 2 (1.06) | - | - | 1 (1.96) | 1 (2.78) | - |
| Drug | 1 (0.53) | - | - | 1 (1.96) | - | - |

**Table A6**

*Study Counts and Percentages of Social Reward Component Measures Across Context Categories*

| Reward Components | Measure Themes | Social Reward Context Categories (%) | | | | |
|---|---|---|---|---|---|---|
| | | Decontextualized Social Rewards | Feedback on Performance | Contextualized Social Rewards | Feedback About the Self | Status |
| Consumption | all themes | 70 (69.31) | 35 (63.64) | 39 (76.47) | 32 (88.89) | 8 (42.11) |
| | brain activity | 50 (49.50) | 25 (46.30) | 13 (25.49) | 23 (65.71) | 4 (23.53) |
| | ratings | 31 (30.69) | 12 (22.22) | 25 (49.02) | 20 (57.14) | 3 (17.65) |
| | amount of reward | 5 (4.95) | 4 (7.41) | 11 (21.57) | 2 (5.71) | 2 (11.76) |
| | facial movements | 3 (2.97) | 1 (1.85) | 3 (5.88) | - | - |
| | eye movements | 4 (3.96) | 1 (1.85) | 1 (1.96) | - | - |
| | social interaction behaviors | 1 (0.99) | 1 (1.85) | 1 (1.96) | - | - |
| | peripheral physiological activity | - | - | - | - | - |

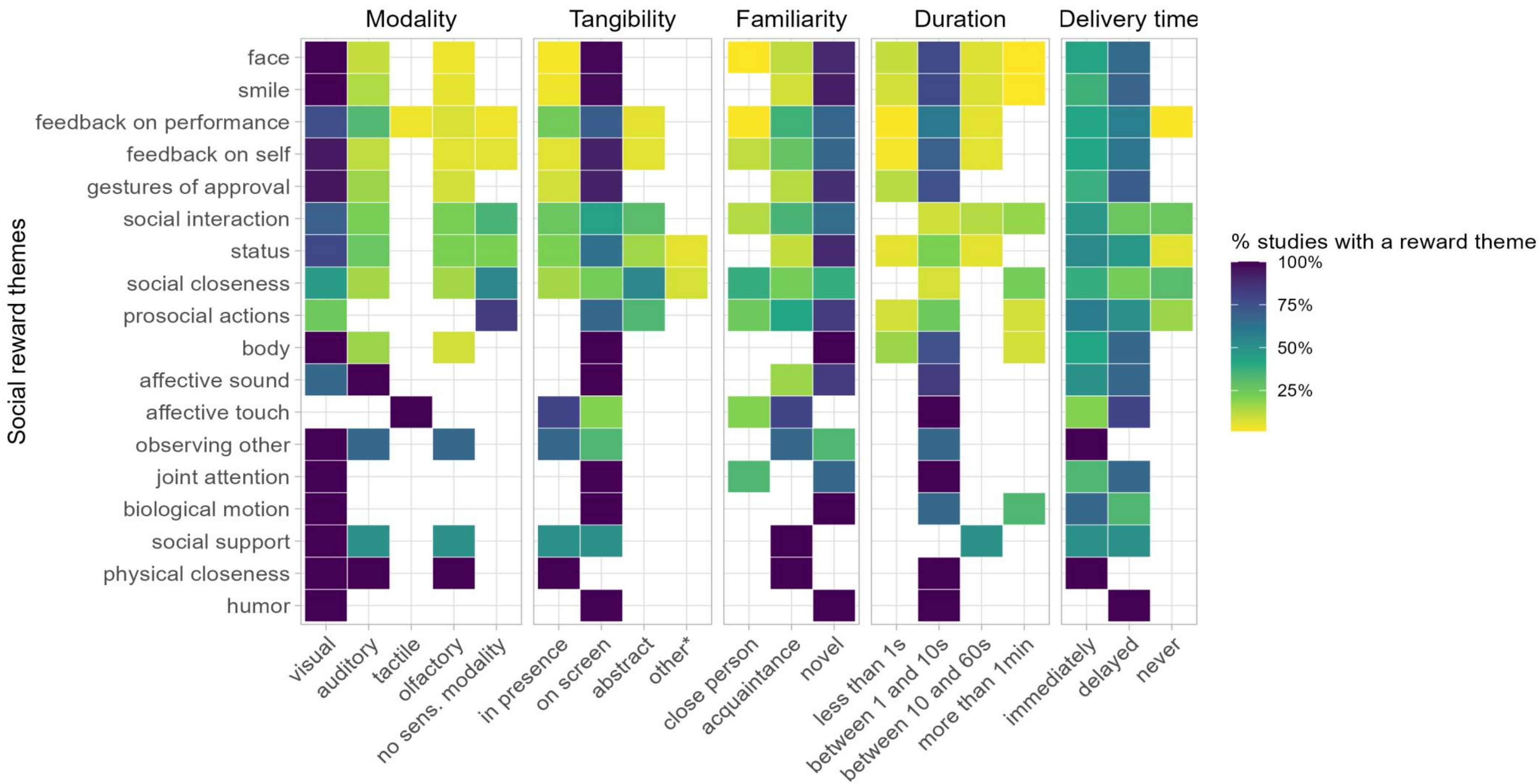
| | | | | | | |
|---|---|---|---|---|---|---|
| Anticipation | all themes | 60 (59.41) | 33 (60.00) | 21 (41.18) | 10 (27.78) | 10 (52.63) |
| | approach behavior | 3 (2.97) | 1 (1.85) | 4 (7.84) | 1 (2.86) | 1 (5.88) |
| | effort | 3 (2.97) | 6 (11.11) | 6 (11.76) | 1 (2.86) | 2 (11.76) |
| | accuracy/response time | 45 (44.55) | 19 (35.19) | 4 (7.84) | 4 (11.43) | 2 (11.76) |
| | brain activity | 29 (28.71) | 16 (29.63) | 3 (5.88) | 3 (8.57) | - |
| | rating | 10 (9.90) | 6 (11.11) | 13 (25.49) | 5 (14.29) | 4 (23.53) |
| | payment for reward | 3 (2.97) | 1 (1.85) | - | - | 2 (11.76) |
| | facial movement | - | 2 (3.70) | 3 (5.88) | - | - |
| | peripheral physiological activity | - | 1 (1.85) | 2 (3.92) | - | 1 (5.88) |
| | eye movement | 2 (1.98) | - | - | - | - |
| Learning | all themes | 15 (14.85) | 14 (25.45) | 2 (3.92) | 1 (2.78%) | 1 (5.26) |

| | | | | | | |
|---|---|---|---|---|---|---|
| | brain activity | 8 (7.92) | 5 (9.26) | - | 1 (2.86) | - |
| | reinforcement learning | 5 (4.95) | 3 (5.56) | 1 (1.96) | - | 1 (5.88) |
| | operant/ instrumental learning | 3 (2.97) | 5 (9.26) | - | - | - |
| | discrimination learning | 1 (0.99) | 2 (3.70) | 1 (1.96) | - | - |
| | Pavlovian learning | 2 (1.06) | - | - | - | - |
| | conditioned preference | - | - | - | - | - |
| | other | 1 (0.99) | - | - | - | - |
| Indirect/uncategorized | | 43 (42.57) | 22 (40.00) | 25 (49.02) | 19 (52.78) | 10 (52.63) |
| No measure recorded | | - | 1 (1.82) | 1 (1.96) | 1 (2.78%) | 2 (10.53) |

## A6. Heatmaps of Social Reward Operationalizations and Dimensions

**Figure A1**

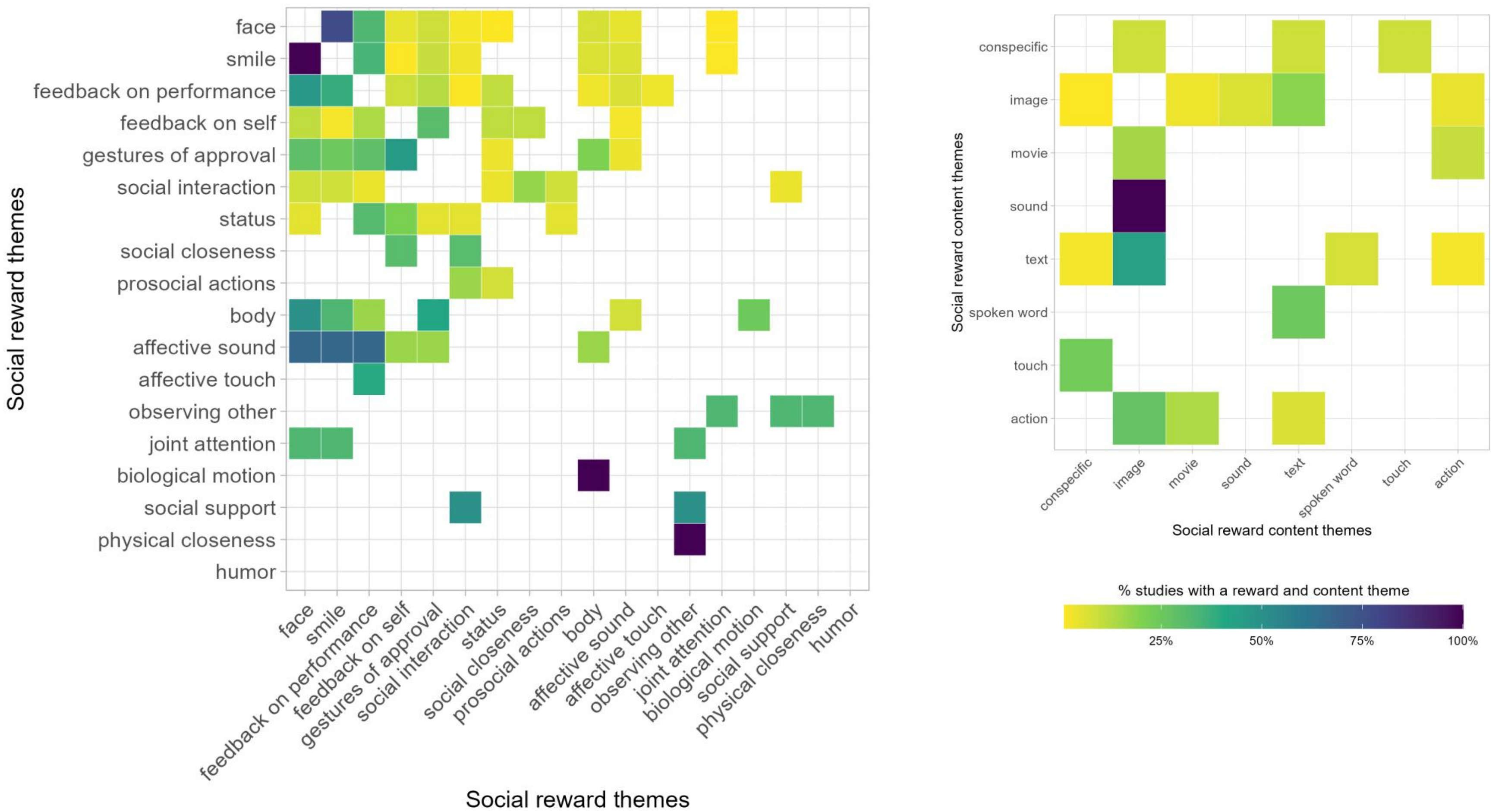
*Social Reward Themes, Dimensions, Duration, and Delay Time Across Studies*



*Note.* Each cell in the heatmap represents the percentage of studies that contained a certain reward theme with regard to its sensory modality, tangibility, familiarity, duration, and delay time. For example, 60% of studies on feedback of performance engaged the visual sensory modality, 70.91% of studies represented feedback on a screen, and 67.27% of studies on feedback included novel social rewards. In a similar fashion, in 27.45% of studies feedback lasted between 1s and 10s and in 49.02% of studies it was immediately delivered. For a full overview on social reward dimensions, duration, and delay time in terms of study counts and percentages, see Table A4 in the Appendix.

**Figure A2**

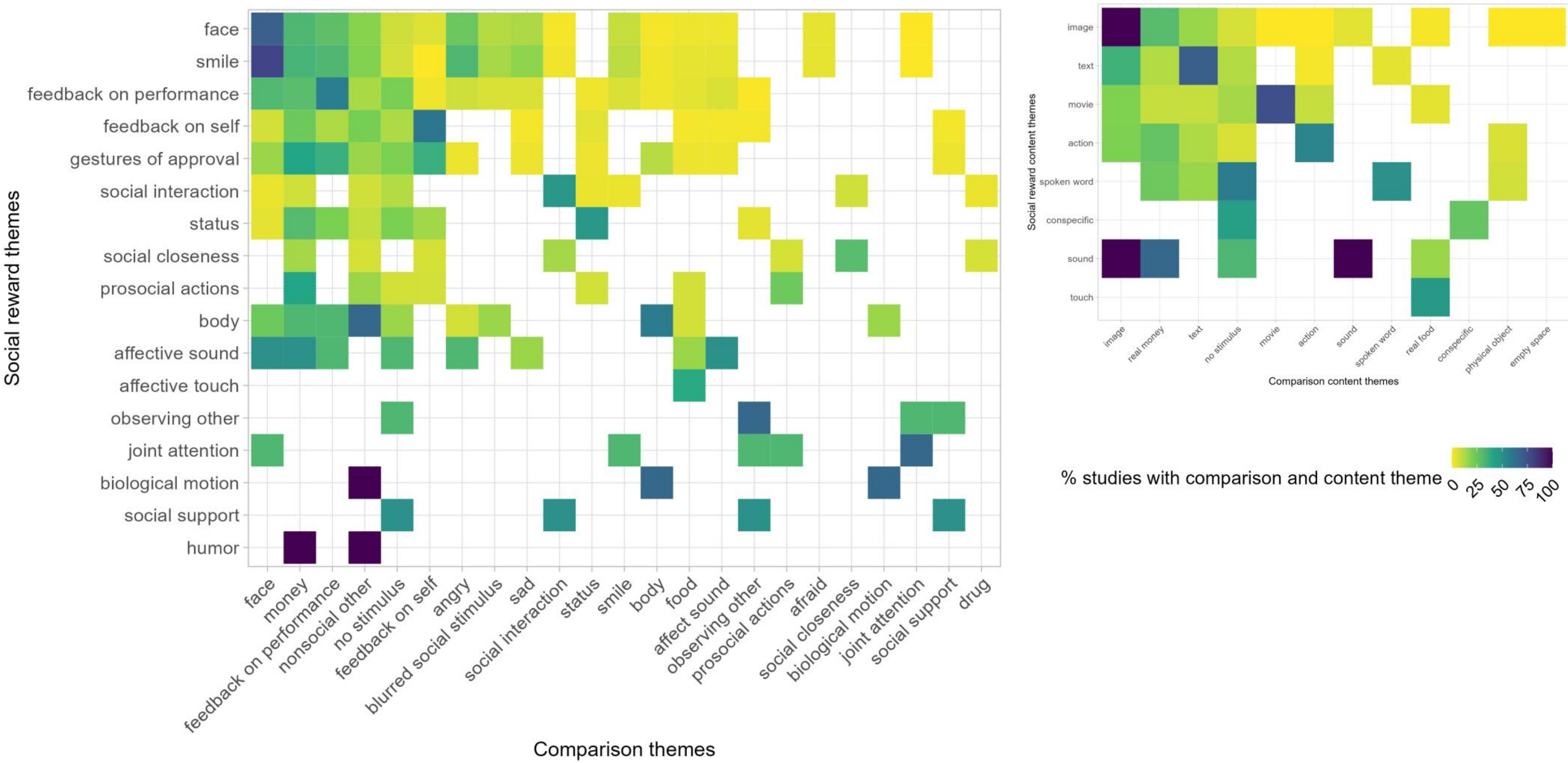
*Social Reward Themes as They Co-occurred Across Studies and Their Representational Content*



*Note.* On the left, each cell represents the percentage of studies that included more than a single social reward theme and that represented them together (e.g., all studies that included smiles also included faces or feedback on performance was frequently represented as faces, smiles, approval gestures, and affective touch). On the right, each cell represents the percentage of studies that used more than one representational content when administering social reward (e.g., sounds were frequently represented with images).

**Figure A3**

*Comparison Stimuli of Social Reward (Themes and Contents)*



*Note.* On the left, each cell represents the percentage of studies that compared a certain social reward theme to a certain comparison stimulus. For example, faces were frequently compared to other faces, money, and feedback on performance. On the right, each cell represents the percentage of studies that compared a given social reward content (e.g., image) to a given comparison content (e.g., images with images or images with text).

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