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Development of Social Exclusion Detection: Behavioral and Physiological Correlates

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Dedicated to Dan, my rock.

ABSTRACT OF THE DISSERTATION

Development of Social Exclusion Detection:

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The present work aimed to directly test the theoretical claims about how we as human detect social exclusion using both physiological and behavioral methods across different life stages. Because feeling excluded from a group is a common human experience that starts in early childhood, this basic human need to belong or connect with others is argued to be universal and thought to have an evolutionary basis. In fact, it has been argued that the ability to detect being excluded may be present from birth and detecting exclusion occurs rapidly with little cognitive processing. Study 1 tested whether this rapid detection of exclusion is reflected in pupil dilation and how discerning this signal is of the social nature of exclusion. Study 2 tested how social exclusion detection emerges across the preschool years using both verbal and nonverbal measures.

Findings from Study 1 indicate that greater pupil dilation occurs when viewing exclusive individuals compared to inclusive individuals, regardless of whether participants were excluded by human players or non-human computerized players. Furthermore, pupil dilation occurred even when viewing third-party social exclusion, suggesting pupil dilation was sensitive to even exclusion that participants did not necessarily experience themselves. The magnitude of pupil

dilation to exclusion was not correlated to self-reported distress levels or individual differences in rejection sensitivity. The present study is the first to show that social pain response — as indexed by pupil dilation — occurs even in non-social interactions and is not limited to first-hand experiences. This result supports the hypothesized “quick” and “crude” ostracism detection system: physiological arousal to exclusion appears to be independent of the social nature of exclusion. Thus, social pain from exclusion appears to reflect the high sensitivity to detect any instances of exclusion.

Findings from Study 2 indicate that that even 3-year-old children could detect social exclusion, but their ability to detect and respond to social exclusion improves with age. Strikingly, children were able to detect social exclusion occurred regardless of whether exclusion was verbally communicated (explicit) or nonverbally communicated (implicit). Furthermore, contrary to expectations from previous research on social cognitive reasoning in infancy, young children’s nonverbal responses (i.e., preferences and sharing behavior) did not necessarily reflect detection of exclusion at an earlier age than their verbal responses. Children’s preferences closely matched their verbal distinction of exclusive and inclusive agents and both preferences and verbal reasoning appeared to mature at a similar rate across development. Such finding suggests that children show remarkably early emerging ability to notice when one is left out.

Taken together, the present body of work clarified the physiological component behind ostracism detection and the developmental trajectory of social exclusion detection in early childhood. Findings from this work have important methodological implications for the field of developmental social cognition as well as practical and clinical implications of bullying and atypical social development.

Chapter 1: Introduction

Humans have a fundamental need to form and maintain social relationships (Baumeister & Leary, 1995; Macdonald & Leary, 2005; Williams, 2007). This basic need to belong and connect with others is observed across cultures: Anthropologists have observed that every society includes groups, and the tendency to form into groups may be characteristic of all human beings (Coon, 1946; Mann, 1980). In our recent evolutionary past, species survival was heightened by security offered from being connected to caregivers and being part of a social group (Baumeister & Leary, 1995; Panksepp, 1998, 2003). As a species, humans have prolonged development and need the protection of caregivers for many years. As part of a social group, humans have a better chance of survival: Food can be distributed, mates can be easier to find, and burden of caring for offspring can be mitigated. Furthermore, hunting large animals and guarding against predators or other enemies are more effective in groups. Thus, the human propensity to connect and belong with others may have an evolutionary basis.

Due to the strong benefits of social groups, humans try to form and maintain social connections and avoid ending such connections with others. It is clear across all ages, when relationships end, most human beings respond with distress (Bridges, 1980; Hazan & Shaver, 1994). Even in situations where there is no apparent consequence of being disconnected or not being part of a group, people report distress when disconnection occurs. For example, participants report feeling distress when they get left out from a spontaneous game of catch in a waiting room (Williams, 1997). In fact, they also report distress when they are excluded in a virtual ball tossing game – a game that is not even with real people (Williams, Cheung, & Choi, 2000; Zadro, Williams, & Richardson, 2004).

Such sensitivity to even minimal signs of exclusion may be due to the fact that humans are wired to over detect exclusion – a tendency to favor false alarming for exclusion rather than entirely missing exclusion (Haselton & Buss, 2000; Schaller & Park, 2011; Spoor & Williams, 2006). Evolutionarily, groups outcast or ostracize troublesome members to increase group cohesiveness, security, and reproductive opportunities for the other members; the fate of the outcasts or ostracized members is often death (Gruter & Masters, 1986). Thus, the ability to detect instances of ostracism or social exclusion[1] is adaptive and may be present early in life (Baumeister & Leary, 1995; Spoor & Williams, 2006). Infants quickly form attachments to their caregivers and show distress when they are separated from caregivers (Ainsworth, Blehar, Waters, & Wall, 2015; Bowlby, 1969). Furthermore, if caregivers are unresponsive, infants react with alarm and distress (e.g., Tronick, Als, Adamson, Wise, & Brazelton, 1978), suggesting that the ability to detect disruptions in social connections exists early in life. However, little is known about when children start to react with distress to being disconnected from people other than caregivers. More research is needed to clarify the mechanism behind social exclusion detection and when this ability emerges in development. Before addressing the mechanism and developmental aspect of how social exclusion detection emerges, the following section reviews existing theories and models on how social exclusion detection is processed in human beings.

Temporal Need Threat Model

Kipling Williams, a leading researcher in the field of ostracism, proposed the Temporal Need Threat Model to understand how ostracism is processed (Wesselmann, Hales, Ren, &

[1] Although there have been attempts to distinguish the use of ostracism, social exclusion, and rejection as concepts (e.g., Kurzban & Leary, 2001; Macdonald & Leary, 2005), the terms are used interchangeably in the field (see Williams, 2007 for a discussion). Therefore, in this work, I use the term social exclusion interchangeably with ostracism and rejection, but attempt to honor the usage by the respective researchers when discussing their work.

Williams, 2015; Williams & Nida, 2011; Williams, 2007). He suggests that there are immediate, automatic, and reflexive responses to ostracism that are followed by more deliberative and reflective responses. According to his Temporal Need Threat model, there are three stages in how an individual respond to ostracism: 1) a reflexive stage, 2) a reflective stage, and 3) a resignation stage.

The reflexive stage is theorized to consist of immediate and automatic responses to detecting that one is ostracized. Such reflexive responses include pain and emotional reactions (e.g., increased anger and sadness). Pain is hypothesized to be an immediate response to ostracism as it is an effective way to capture attention and activate appraisal processes to remedy the situation. Immediate experiences of pain and distress when exclusion is detected appear to be not influenced by circumstantial factors. For example, people still report feeling distressed when they are excluded by computerized players (Zadro et al., 2004) and when excluded by despised outgroups, such as members of renowned hate groups (Gonsalkorale & Williams, 2007).

The reflective stage is a more deliberate process that engages appraisal and coping responses. In this stage, ostracism appears to affect cognitive processing, such that individuals who were ostracized show lower performance on challenging intellectual tasks than individuals who were not (e.g., Baumeister, Twenge, & Nuss, 2002). Also, ostracism appears to heighten attention to potential threats of ostracism as well as sources of social acceptance or affiliation (DeWall, Twenge, Gitter, & Baumeister, 2009; Williams, 2001). Many researchers also suggest that ostracism threatens fundamental needs, which are self-esteem, belonging, control, and meaningful existence; these needs are typically assessed from self-reports (Williams & Nida, 2011).

Coping responses during the reflective stage include behavioral choices of the individual, such as prosocial or antisocial behaviors towards others. Some studies suggest that ostracism causes individuals to become more antisocial: Individuals who were ostracized tend to punish others more harshly for errors than individuals who were not (e.g., Twenge, Baumeister, Tice, & Stucke, 2001). Other studies suggest that ostracized individuals may act antisocially to those who ostracized them but prosocially to new people who may be new sources of affiliation (e.g., Maner, DeWall, Baumeister, & Schaller, 2007). Dispositional characteristics may also influence this coping behavior: People high in rejection sensitivity or anxious attachment report more distress and aggression after exclusion than people low in rejection sensitivity and more secure in attachment (Ayduk, Gyurak, & Luerssen, 2008; Downey & Feldman, 1996; Pickett, Gardner, & Knowles, 2004; Romero-Canyas & Downey, 2005). Williams (2011) suggests that subsequent coping responses will be chosen depending on which fundamental needs were most threatened. For example, those who feel less control when ostracized tend to show more aggressive behaviors than those who feel more in control when ostracized (Warburton, Williams, & Cairns, 2006; Wesselmann, Butler, Williams, & Pickett, 2010).

The resignation stage is only reached after extended periods of ostracism – being ignored for months and years – and people in this stage feel helpless, alienated, depressed, and unworthy. People who are excluded extensively may respond to such exclusion with drastic and violent choices to regain their feelings of worth and control – such as mass shootings (Leary, Kowalski, Smith, & Phillips, 2003; Twenge, 2000). However, investigating prolonged periods of ostracism is difficult to do ethically in experimental settings.

Immediate Response to Ostracism: Social Pain

Immediate pain responses in the reflexive stage to ostracism have been hypothesized to occur rapidly without much cognitive processing (Williams, 2009). However, the relationship between detection of ostracism and pain is still unclear. Pain stemming from the perception of being excluded is often called *social pain* (Eisenberger & Lieberman, 2004; Lieberman & Eisenberger, 2015; MacDonald & Leary, 2005).

Robust research suggests there is considerable overlap in the nervous system pathways and neutral circuitry that process social pain with those that process physical pain (see Eisenberger & Lieberman, 2004; Eisenberger, 2012, for a review). Thus, various studies have looked at how immediate physiological arousals may index the reflexive social pain felt from ostracism. Neuroimaging studies have found that self-reported distress after being excluded positively correlated with activations of the dorsal anterior cingulate cortex (e.g., Eisenberger, Lieberman, & Williams, 2003) or the ventral anterior cingulate cortex (e.g., Somerville, Heatherton, & Kelley, 2006). Building on such work, studies report that when experiencing exclusion, heart rate slows (Gunther Moor, Crone, & van der Molen, 2010), skin conductance levels (i.e., a slow tonic modulation of sympathetic arousal that is an index of slow adjustments in physiological arousal over time) increase (Kelly, McDonald, & Rushby, 2012), and pupil dilation increases (Silk et al., 2012; Vanderhasselt, Remue, Ng, Mueller, & De Raedt, 2015). However there are some mixed results on physiological arousal to exclusion (e.g., Iffland, Sansen, Catani, & Neuner, 2014) and little is known about how physiological arousal relates to behavior and individual differences when responding to exclusion. Although Williams (2009) initially hypothesized that the immediate pain response to exclusion is independent and not moderated by individual differences, some studies report physiological response are modulated by individual differences. For example, how sensitive individuals are to rejection affects their neural activity and attentional control in response to experiencing exclusion (Downey, Mougios, Ayduk, London, & Shoda, 2004; Kross, Egner, Ochsner, Hirsch, & Downey, 2007).

Measuring Social Exclusion through Pupillometry

A relatively underexplored physiological measure for assessing exclusion detection is pupillometry. Pupillometry is a useful measure of investigating reactions to social exclusion as it indicates both emotional arousal (Bradley, Miccoli, Escrig, & Lang, 2008; Partala & Surakka, 2003) and cognitive load (Beatty, 1982; Beatty & Lucero-Wagoner, 2000; Siegle, Steinhauer, Carter, Ramel, & Thase, 2003). It is well established that changes in pupil size occur from baseline when emotionally arousing stimuli are present, for both positive and negative valence (Bayer, Sommer, & Schacht, 2011; Bradley et al., 2008; Granholm & Steinhauer, 2004; Partala, Jokiniemi, & Surakka, 2000; Partala & Surakka, 2003). Furthermore, autonomic dilatory pupil responses have been associated with the anterior cingulate cortex (Critchley, Tang, Glaser, Butterworth, & Dolan, 2005), which is consistently activated in neuroimaging studies using social exclusion tasks (Lieberman & Eisenberger, 2015). In further support of the utility of using pupillometry to investigate social exclusion, pupillometry is a noninvasive and relatively cost-effective methodology that can be easily applied to study the cognitions of children and infants because it is more comfortable for participants (i.e., requires less restrictive measures) than other physiological measures, such as heart rate, skin conductance, or neuroimaging (Geangu, Hauf, Bhardwaj, & Bentz, 2011; Hepach, Vaish, & Tomasello, 2012). Thus, clarifying how pupil dilation indexes arousal in response to social exclusion in adults will be the first step to eventually applying this method to study social exclusion detection in young children.

Therefore, the aim of Study 1 is to determine if pupillometry could be a reliable index of arousal in response to social exclusion. Study 1 proposes to use *cyberball*, a virtual ball-tossing game that is one of the most widely used experimental paradigms to elicit social exclusion (Hartgerink, van Beest, Wicherts, & Williams, 2015) to determine if pupil dilation increases when experiencing exclusion compared to inclusion. Study 1 will also investigate if pupil dilation to social exclusion is related to individual differences in sensitivity to rejection and behavior.

Is Ostracism Detection Present Early in Life?

In addition to clarifying the immediate response mechanism behind exclusion detection in adulthood, this work also aims to test the hypothesis that social exclusion detection is present early in life. As reviewed above, children form attachments with caregivers and show distress when such attachments are disrupted (Ainsworth et al., 2015; Bowlby, 1969; Tronick et al., 1978). However, besides caregiving relationships, little is known about when children become aware of group dynamics specific to social exclusion. Classic studies on children's play suggest during the preschool years children transition from predominately playing alone (i.e., solitary play) to playing with others (i.e., group play) (Parten, 1932; Smith, 1978). Such transitions are suggestive of children developing in their cognitive abilities and becoming social members of society. Around 3 and 4 years of age, children start to exhibit socially exclusive behaviors, such as intentionally leaving out another from joining a play activity (Crick, Casas, & Mosher, 1997). During this age, children also start to identify bullies and victims of bullying in their classrooms (Monks & Smith, 2006) and robustly judge exclusion based on race or gender as wrong when interviewed by adults (Killen, 2007; see Killen & Rutland, 2011 for a review). However, it is unclear to what extent preschool age children can independently detect social exclusion and understand social exclusion without the aids of adults.

Although there has been a surge of interest in using cyberball (a virtual ball-tossing game that simulate social exclusion) with children, these studies have been limited to school age children (Hawes et al., 2012; Scheithauer, Alsaker, Wölfer, & Ruggieri, 2013; Zadro et al., 2013). Only a few recent studies have conducted cyberball with children around age 4 and 5, but none with children younger than age 3 (Over & Carpenter, 2009; Song, Over, & Carpenter, 2015; Watson-Jones, Whitehouse, & Legare, 2015). Little is known whether even young 3-year-old children can detect exclusion occurred in an on-going social dynamic.

Therefore, the aim of Study 2 is to determine if young children aged 3 to 6 react in a similar manner to adults when they are excluded. Study 2 proposes to use age-appropriate paradigms to elicit social exclusion in children and to test if children prefer or share more with people who include them over people who exclude them. Study 2 will investigate if there are developmental differences when experiencing explicit, verbal exclusion (Experiment 1) compared to implicit, nonverbal exclusion (Experiment 2) and whether children's detection differ across verbal and nonverbal modalities. These experiments will be the first steps to clarifying how detection of social exclusion emerges in development.

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Chapter 2: Social Exclusion Detection in Adults

When people are excluded by others, most report feeling hurt – the sense of experiencing pain. Such pain, often called social pain, is defined as an emotional reaction to the perception of being excluded or ostracized from relationship partners or groups (Macdonald & Leary, 2005). Social pain appears to activate neural circuitry and physiological pathways that are also activated when one experiences physical pain, suggesting the process of detecting social exclusion has a physiological component (see social-physical pain overlap theory; Eisenberger, 2012; Panksepp, 2003). Neuroimaging research reveals that the anterior cingulate cortex (ACC) and anterior insula are more active during experiences of exclusion than inclusion (see Cacioppo et al., 2013; Eisenberger, 2012; Rotge et al., 2015, for review). Physiological studies also show that when experiencing social rejection, heart rate slows (Gunther Moor, Crone, & van der Molen, 2010), skin conductance levels increase (Kelly, McDonald, & Rushby, 2012; Iffland, Sansen, Catani, & Neuner, 2014), and pupil size increases (Silk et al., 2012; Vanderhasselt, Remue, Ng, Mueller, & De Raedt, 2015).

It appears immediate physiological arousal occurs in response to social exclusion. This immediate response to exclusion is argued to be a result of a "quick and crude" ostractism detection system (Haselton & Buss, 2000; Kerr & Levine, 2008; Spoor & Williams, 2007; Williams & Nida, 2011): "quick" because individuals feel immediate distress to even minimal cues of exclusion and "crude" because the system over-detects instances of exclusion. However, whether physiological arousal to social exclusion is not only "quick" but also "crude" has not been extensively tested. In particular, it is unclear whether physiological arousal to exclusion is discerning between social versus non-social exclusion or between experiencing exclusion first-hand versus witnessing exclusion. Clarifying the sensitivity of physiological arousal to exclusion will not only aid in furthering our theoretical understanding of social exclusion but also in creating more useful tools to investigate outstanding psychological research questions.

Pupillometry is an especially useful measure for investigating physiological arousal to exclusion as it is associated with both autonomic arousal and activity in the ACC (Beatty & Lucero-Wagoner, 2000; Critchley, Tang, Glaser, Butterworth, & Dolan, 2005). Pupils increase in response to both positive and negative valence emotional stimuli (Bayer, Sommer, & Schacht, 2011; Bradley, Miccoli, Escrig, & Lang, 2008). Further, pupillometry is a noninvasive and relatively cost-effective methodology especially promising for studying preverbal and nonverbal populations (e.g., infants, neurological patients) (Laeng, Sirois, & Gredebäck, 2012). Recent studies using a social feedback paradigm found that participants show greater pupil dilation when viewing photos of individuals who rejected them compared to those who accepted them, suggesting an alert or threat response captured by pupil dilation (Price et al., 2013; Silk et al., 2012; Vanderhasselt et al., 2015).

In these social feedback paradigms, participants are explicitly and verbally rejected. In contrast, real life social exclusion tends to be more subtle and implicit – as in the Cyberball paradigm (Williams, Cheung, & Choi, 2000). Cyberball is a virtual ball-tossing paradigm in which participants are either included (receive the same number of tosses as the other players) or excluded (receive fewer tosses than the other players) that is commonly used in neuroimaging research (Cacioppo et al., 2013).

To date, only one study (Sleegers, Proulx, & van Beest, 2017) has investigated pupil reactivity in Cyberball. Sleegers et al. found that pupil sizes diminished during the course of an exclusive compared to inclusive game – contrary to the findings from the social feedback studies in which pupil size increases when viewing individuals who rejected the participant compared to those who accepted them (Silk et al., 2012; Vanderhasselt et al., 2015). Sleegers et al. suggests the decrease in pupil size they observed reflects a numbing response to social pain. Sleegers et al. measured pupil size during the game itself across multiple ball tosses, which may be capturing participants' own efforts to self-regulate their emotional response to exclusion rather than the immediate detection of exclusion. Measuring pupil size during the game itself makes it difficult to identify the exact time point at which the participants detected exclusion. In contrast, in the social feedback paradigm, pupil size was measured when participants were immediately responding to individuals who rejected them versus those who included them. Thus, differences in the internal processes of the participants as well as the time scale of responding to exclusion may have caused the difference in participants who exhibit a numbing response (decrease in pupil size) versus an arousal response (increase in pupil size) when encountering social exclusion.

In the current study, we combined the advantages of the Cyberball and the social feedback paradigms and minimized their limitations: we measured participants' pupil reactivity to viewing exclusive versus inclusive players immediately after interacting with these players in Cyberball. This approach allowed us to measure immediate physiological response to detecting exclusive individuals and test whether the time scale of responding to exclusion elicits differential psychological response patterns. To further clarify what underlying socio-cognitive processes pupil dilation indexes when individuals encounter social exclusion, this study also addressed two unanswered questions about pupil reactivity to exclusion.

First, it is unclear whether pupil reactivity differs for social versus non-social exclusion. A seminal study suggests exclusion by computers elicited comparable levels of distress as exclusion by humans, suggesting social pain responses may not discriminate between social and non-social exclusion (Zadro, Williams, & Richardson, 2004). In contrast, others have found that exclusion by humans caused more distress and less engagement than exclusion by non-human entities (Driscoll, Barclay, & Fenske, 2017). This sensitivity to human versus non-social players may be due to the non-human entities in Driscoll et al. being pipes instead of human-like avatars as in Zadro et al. If non-social exclusion elicits less distress than social exclusion, physiological responses should also reflect this lower distress levels. In support of this possibility, heart rate and attention show less discrimination of rejection versus acceptance in non-social conditions compared to social conditions (Dewall, Maner, & Rouby, 2009; Gunther Moor et al., 2010; Somerville et al., 2006).

Second, it is unclear whether pupils react when people witness exclusion. Witnessing another person being excluded in Cyberball causes people to report distress and exhibit neural activities similar to first-hand experiences of exclusion (see Wesselmann, Williams, & Hales, 2013, for a review). To date, no study has examined pupillary reactivity to witnessing exclusion. However, pupil size does increase in response to seeing emotionally-arousing or empathy-inducing event (Bradley et al., 2008; Hepach, Vaish, & Tomasello, 2012), suggesting physiological arousal to exclusion may occur not only when experiencing exclusion but also when witnessing exclusion.

The present study tested three hypotheses to elucidate the underlying socio-cognitive processes indexed by pupil dilation. First, if immediately viewing socially exclusive players elicits an arousal response rather than a numbing response, we hypothesized pupil size should increase rather than decrease when viewing socially exclusive individuals compared to inclusive individuals. Second, we hypothesized that participants should show a decrease in pupil size when viewing non-social players compared to social players and potentially even not differentiate between exclusive and inclusive non-social players because physiological arousal tends to decrease in response to non-social stimuli. However, if pupil reactivity reflects the "crude" ostracism detection system that over-detects instances of exclusion, pupil size may increase even when encountering exclusion by non-social entities. Third, if pupil reactivity indeed indexes the distress felt when observing social exclusion, we hypothesized pupil size should increase when witnessing exclusion, not only when experiencing exclusion.

Experiment 1

Experiment 1 investigated if pupil size is greater when viewing exclusive compared to inclusive players, and when viewing social (human) compared to non-social (computer) players.

Participants

Forty-eight undergraduate students (26 female; M_{age} = 19.39 years, SD = 1.38) participated for course credit. Participants consisted of the following racial categories: 47.91% White, 22.91% Asian, 14.58% Black, 8.33% Latinx, 4.16% bi- or multi-racial, 2.08% chose not to answer. Fifteen additional participants were excluded from the final sample due to equipment failure (3), difficulty with calibration (2), experimenter error (4), disruption due to participants' phones ringing (3), participants failing to follow instructions (2), and not completing the study (1).

We anticipated a medium effect size (d = .50) difference in exclusion versus inclusion and player type based on previous research (e.g., Silk et al., 2012) and a pilot study. Power analysis using G*Power (Faul, Erdfelder, Lang, & Buchner, 2007) indicated that at an alpha of .05, a sample size of 48 should provide 97.68% power to detect our hypothesized effects in an ANOVA analysis.

Design

All participants experienced both type of games (inclusion and exclusion) and players (human and computer). Player type was blocked such that half of the participants played with human players first for four games whereas the other half played with computer players first. Within each block, participants played two inclusion games and two exclusion games in a randomized order.

Apparatus & Materials

An EyeLink 1000 (SR Research, Mississauga, ON, Canada), a video-based eye tracker sampling at 1000 Hz, recorded pupil size of the left eye every 1 millisecond in pixel units. Stimuli were presented on a 1920 x 1080 display using a 53 cm x 30 cm LCD monitor with a 100 Hz refresh rate. A chin and headrest were provided to minimize movement artifacts and to maintain a distance of 94 cm between the participant's eye and the screen. Participants sat in front of a computer monitor with their head stabilized on a chin and headrest. Participants' pupils were calibrated to a threshold between 75 and 110 and corneal reflection to a threshold below 230. To calibrate the eye tracker, participants fixated sequentially on nine different points across the monitor. The threshold for calibration error was an average error of .5 degrees or less, with the maximum allowed error being 1 degree. If error was greater, calibration was repeated until the error was below 1 degree before proceeding to the experiment.

Cyberball (Williams & Jarvis, 2006) was administered using PsychoPy (Peirce, 2007). For human players, participants saw photographs of college-age individuals pilot tested to ensure they matched in attractiveness, friendliness, and facial expressiveness. For computer players, participants saw abstract images pilot tested to ensure images matched in complexity. Which human or computer pair images were exclusive or inclusive were counter-balanced across participants. Luminance of all the photographs and images were equated.

Procedure

Participants were told they would play one session with undergraduate students from partnering universities and one session with computerized players. In reality, all players were computerized. Before the first trial, participants underwent a warm-up session to familiarize themselves with the Cyberball game and the experiment flow. At the start of the test games, participants saw a connecting screen that indicated they had either been connected to other players or that they would instead play with computerized players. After the connecting screen, a fixation cross appeared for 6 seconds and then participants saw the photographs or images of two players they were going to play with for 3 seconds, during which *pre-game* pupil size was measured. The photographs and images were followed by a second fixation cross for 6 seconds and then the game started.

In the game, three baseball mitts were arranged in a triangle: the upper two mitts were accompanied by photographs and initials of the other players, whereas the participant's mitt was accompanied only by their initials. Participants were asked to email a photograph of themselves prior to the study and were told that although their photograph was not visible to them, the other players were viewing it. Ball tosses were randomized, but programmed to ensure participants received 4 of 12 tosses in the inclusion games and 2 of 12 tosses in the exclusion game. Each game lasted approximately one minute. Participants then viewed a fixation cross for 6 seconds followed by photographs and images of the two players they just played with for 3 seconds, during which *post-game* pupil size was measured. See Figure 1 for a diagram of the experimental flow.

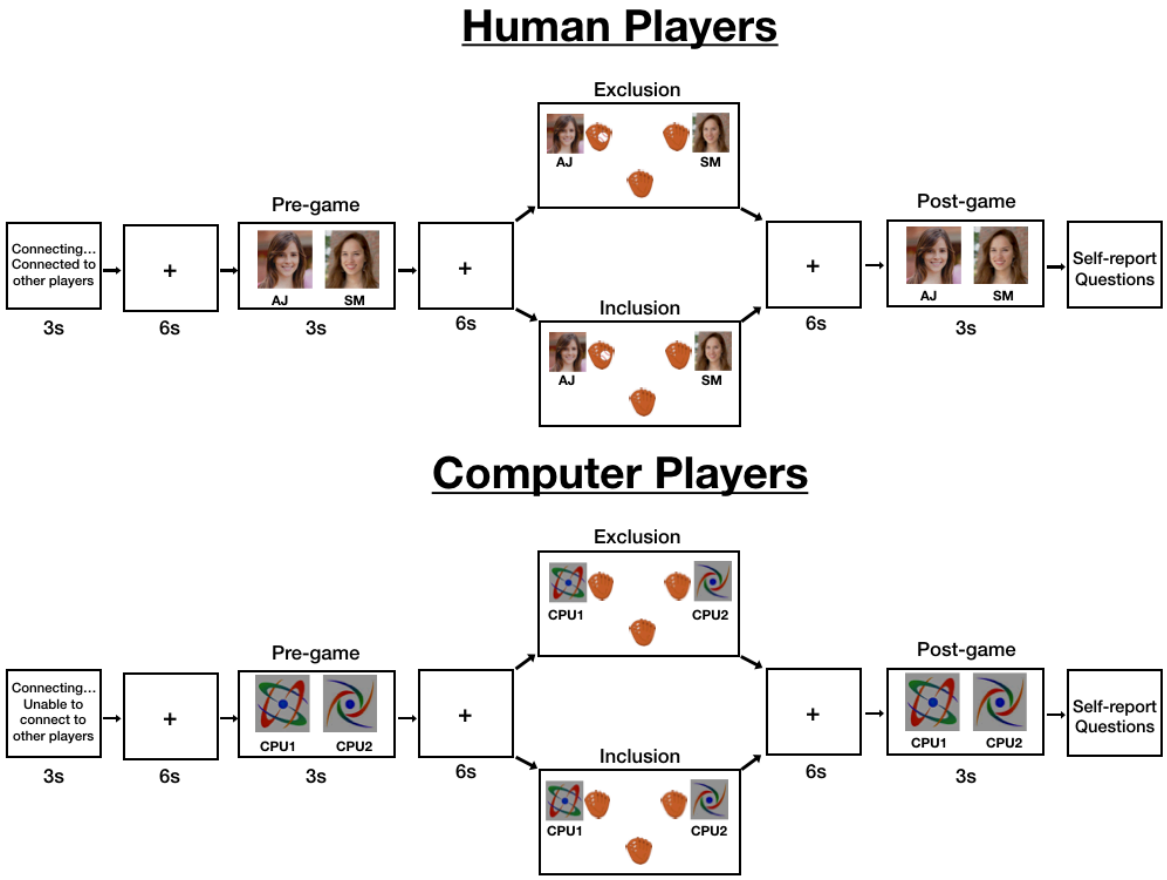

Figure 1. Depiction of experimental flow for human and computer player conditions in Experiment 1 and 2. Experimental flow was identical in Experiment 3 except abstract images were used for the human player condition as well.

After each game, participants were asked a series of questions about the game. First, a question was shown at the top of the screen asking participants, "If you had the chance to play again, would you want to play with this pair?" Participants indicated their choice by pressing the corresponding key for their answer (right key for playing again; left key for not playing again). Participants then indicated how much they liked the players on a 7-points scale (1 = *strongly dislike* to 7 = *strongly like*). They were also asked what percentage of ball tosses they thought they received during this game on a 10-point scale (0% to 100%). Then, participants' self-reported distress levels were assessed using the Basic Needs scale (Zadro et al., 2004).

Participants were asked to rate the following questions on a 7-point scale that assessed their mood ("I enjoyed playing this round" / "I felt angry playing this round"), sense of belonging ("I felt rejected by other players this round" / "I felt as though I connected or bonded with one or more players during this round"), sense of control ("I felt frustrated in this round" / "I felt in control during this round"), self-esteem ("I felt good about myself during this round" / "I felt inadequate during this round"), and sense of meaningful existence ("I felt my performance had some effect on the direction of this round" / "I felt ignored this round"). One question was presented randomly from each question pair. Negatively worded questions were reverse coded.

After completing all eight games, participants completed a 18-item Rejection Sensitivity Questionnaire (RSQ; Downey & Feldman, 1996), a demographic questionnaire, and were debriefed. The RSQ was administered to determine if individual differences in sensitivity to rejection correlate with the extent of arousal indexed in pupil dilation. Individuals scoring high in rejection sensitivity have been found to more readily perceive rejection from the ambiguous behaviors of others than those who are low in rejection sensitivity (Ayduk, Gyurak, & Luerssen, 2009; Romero-Canyas & Downey, 2005; Romero-Canyas, Downey, Berenson, Ayduk, & Kang, 2010). Furthermore, rejection sensitivity has been found to relate to neural and physiological responses and may mediate the relationship between physiological and behavioral responses to social exclusion (Berenson et al., 2009; Downey, Mougios, Ayduk, London, & Shoda, 2004; Kross, Egner, Ochsner, Hirsch, & Downey, 2007).

Pupil Preprocessing

Blinks were replaced with linear interpolations with interpolation time window of 100ms before and after the blink. A 10-point moving average smoothing filter was applied to the data and any outliers (data points beyond 3 SD) were removed. To calculate the relative change in pupil dilation from pre-game to post-game, we calculated the difference between the average *pre-game* pupil and average *post-game* pupil and divided this difference by the average *pre-game* pupil (see Hepach et al., 2012). The relative increase in pupil size from *pre-* to *post-game* was then averaged for each trial and participant according game and player type.

Results & Discussion

Pupil. A repeated-measures ANOVA was conducted with block order, game type, and player type as within-subject factors and mean relative change in pupil size as the dependent variable. There were no effects except a significant three-way interaction among block order, game type, and player type ($F(1, 46) = 6.158$, $p = .017$, $\eta_p^2 = .118$) and a significant two-way interaction between block order and player type ($F(1, 46) = 13.976$, $p = .001$, $\eta_p^2 = .233$), suggesting block order influenced pupil dilation. Block order effects were explored further by analyzing relative pupil change according to block order.

In the first block, the relative change in pupil size was greater after exclusion games than inclusion games ($F(1, 46) = 5.729$, $p = .021$, $\eta_p^2 = .111$) indicating that pupil size increased when viewing exclusive than inclusive players. However, there was no effect of player type ($F(1, 46) = .309$, $p = .581$, $\eta_p^2 = .007$) or interaction ($F(1, 46) = .469$, $p = .497$, $\eta_p^2 = .010$). See Figure 2. In the second block, there were no significant effects of game, player, or interaction ($Fs < .452$). See Table 1 for means and standard errors from the first block and Table 2 for the second block.

Figure 2. Box plots of the average relative change (from pregame to postgame) in pupil dilation as a function of exclusion or inclusion game type across experiments. Experiment 1 is the result from the first block. The boxes indicate the distribution of values lying between the first and fourth quartiles. The solid or dotted lines inside the boxes indicate the median value. Lines extending from the boxes capture values beyond 1.5 SD and the dots represent values beyond 1.5 SD.

Null effects in the second block appeared to be due to participants suspecting all players were computerized after playing the first block: When asked if participants found anything suspicious, 33 participants reported suspecting the human players were not real players (see supplementary analyses for results based on this suspicion).

In sum, relative pupil dilation was greater after exclusion than inclusion during the first block before participants reported being suspicious of the players in the second block. Greater pupil dilation after exclusion compared to inclusion in the first block occurred regardless of whether players were humans or computers. This indicates that pupil size may be capturing an arousal response that occurs when viewing exclusive individuals but not when viewing inclusive individuals.

Self-report. There were also significant block order effects in participants' self-reports except in the ball toss manipulation check question, player choice, control question, and existence question (see supplementary analyses). To further investigate these significant three-way interactions, ANOVA models were conducted for each block. Results from the first block are presented in Table 3 and second block in Table 4.

The manipulation check question confirmed that overall participants correctly reported receiving the ball more during inclusive than exclusive games. However, participants reported receiving more tosses from the human players than computer players after exclusion games and thought they received more tosses from computer players than human players after inclusion games in the second block. Participants preferred to play with players again after inclusive than exclusive games, regardless of block order or player type.

Participants reported more positive ratings after inclusion than exclusion in the Basic Needs scale. In the first block, participants reported greater liking, higher mood, and feeling more connected with human players than computer players. However, this main effect of player type disappeared in the second block. Participants also showed a significant interaction between player type and game type in their liking, belonging, and self-esteem response across both blocks. In the first block, participants reported higher liking, belonging, and self-esteem toward exclusive human players compared to exclusive computer players, but little difference between their ratings of inclusive human players versus inclusive computer players. In the second block, participants rated exclusive computer players more positively than exclusive human players, but rated inclusive humans players more positively than inclusive computer players.

The only no significant correlation between self-report ratings and relative pupil dilation after exclusion was in the second block: Participants who reported receiving less ball tosses after exclusion games were more likely to show greater relative pupil dilation toward exclusive players (r (48) = -.328, p = .023). There were no significant correlations between RSQ and relative pupil dilation after exclusion in the first block (r (48) = -.044, p = .764) or second block (r (48) = .038, p = .798).

As expected, self-reported measures showed consistently more positive attitudes after inclusion than exclusion. Unlike pupil dilation, player type affected some self-report measures such that human players were generally rated more positively than computer players, especially after exclusion than inclusion games. Self-reported measures and individual differences in rejection sensitivity did not show a strong relation to pupil dilation, suggesting pupil dilation may reflect the "quick" and "crude" exclusion detection process rather than the response magnitude to social exclusion.

Experiment 2

Experiment 2 investigated whether relative pupil dilation would also increase when participants were not involved in the social exclusion interaction, but rather, simply witnessed social exclusion.

Participants

Forty-six undergraduate students (30 female; M_{age} = 19.48 years, SD = 1.13) participated. Participants consisted of the following racial categories: 56.52% White, 17.39% Asian, 10.87% Black, 8.70% bi- or multi-racial, 6.52% Latinx. Because previous research suggests observing social exclusion elicits distress at similar effect sizes as experiencing it (Wesselmann et al., 2013), we aimed for the same sample size as Experiment 1. An additional ten participants were excluded from the final sample due to experimenter error (2), participants failing to follow instructions (3), and failure with calibration (5).

Design & Procedure

The apparatus, materials, design, and procedure were identical to Experiment 1 with a few modifications. To avoid arousing suspicion as in Experiment 1, the design was altered to present player type as a between-subjects factor. Participants were randomly assigned to either human or computer players and watched two inclusion and two exclusion games in random order. Participants were instructed to watch games that were played by a former research participant and to take this participant's perspective by “trying your best to imagine that you are in [this participant’s] shoes.” After each game, participants were given the same questions from Experiment 1, but were instructed to answer the questions from the former participant’s perspective.

Results & Discussion

Six participants reported suspecting the human players were not real people; because there was no difference in pupil dilation or self-report ratings between suspicious and non-suspicious participants (*Fs* > .383), all participants were included in the subsequent analyses.

Pupil. The average relative change in pupil size decreased less after exclusion games than inclusion games ($F(1, 44) = 5.477$, $p = .024$, $\eta_p^2 = .111$). See Figure 2. Although pupil size tended to decrease during post game viewing of the players, pupil size decreased relatively less after exclusion than inclusion, suggesting a more sustained arousal response to exclusive players compared to inclusive players. There was no significant effect of player type ($F(1, 44) = 1.388$, $p = .245$, $\eta_p^2 = .031$) or interaction between player and game type ($F(1, 44) = 1.098$, $p = .300$, $\eta_p^2 = .024$). See Table 5 for means and standard errors. Thus, pupil dilation was sustained more after viewing exclusive than inclusive players regardless of whether players were humans or computers.

Self-report. Participants reported that the former research participant received the ball significantly less during exclusion compared to inclusion games regardless of player type. Participants also consistently reported more positive ratings after inclusion than exclusion, regardless of player type. The only effect of player type was on player liking: participants reported that the former research participant would like human players more than computer players. See Table 6 for ANOVA results. Self-report measures and RSQ were unrelated to pupil dilation after exclusion (*rs* < .223).

Comparing Experiment 1 and 2. Comparing relative change in pupil size between Experiments 1 and 2 indicated that there were no significant effects (*Fs* > .715; see supplementary analyses). Thus, pupil dilation did not differ according to whether participants experienced exclusion first hand or witnessed exclusion. Comparing self-report responses between Experiments 1 and 2 indicated that participants generally reported feeling more positive in Experiment 1 than Experiment 2 (see supplementary analyses).

Experiment 3

Experiment 3 investigated whether the lack of difference in pupil reactivity to computer versus human players in Experiment 1 and 2 might be due to participants not interacting in person with the human players. Interacting with individuals in real life may heighten participant's pupil reactivity to exclusion from human players and lessen participants' suspicions about the nature of the human players.

Participants

Eighty undergraduate students (59 female; M_{age} = 19.75 years, *SD* = 1.32) participated. Participants consisted of the following racial categories: 49.38% White, 35.80% Asian, 6.17% Black, 3.70% Latinx, 2.47% bi- or multi-racial, 1.23% other. According to the effect size we obtained from Experiment 1, a sample size of 80 should provide 90.90% power to detect our hypothesized effects in a between-subject ANOVA analysis.

Design & Procedure

Participants were randomly assigned to four possible conditions: (1) human inclusion, (2) human exclusion, (3) computer inclusion, and (4) computer exclusion. Participants assigned to the human player conditions encountered two female undergraduate confederates in the waiting room. After the participants and confederates provided consent and were given instructions about the study, confederates were led to another room to presumably be set up for the study and participants were led to the test room with the eye tracker. Participants assigned to the computer player condition did not encounter any confederates and were told they would play with computerized players. In both the human and computer player conditions, participants viewed abstract images to represent the players. This was done to prevent confounds that might arise in interpreting effects of player type. The game format was identical to Experiment 1 except that participants played two games of the same type (e.g., either two inclusive or two exclusive games). Piloting suggested that having participants experience inclusion and exclusion from the same confederates caused carryover effects (i.e., once confederates were exclusive, they were always seen as exclusive even if they were inclusive in the subsequent game), so participants experienced only one game type. Pupil size and self-reports were averaged across the two trials per participant.

Results & Discussion

None of the participants who experienced the computer player conditions reported being suspicious of the motivation behind the experiment. Of the 40 participants assigned to the human player conditions, 11 participants reported suspecting human players were computerized and 6 participants reported suspecting exclusion was intentional (i.e., confederates were instructed to exclude the participant). There were no significant differences in relative change in pupil size according to the three different response patterns to suspicion (*Fs* < .452) and thus the following analyses were conducted including all participants.

Pupil. A between-subjects ANOVA was conducted with game type and player type as a between-subject factor and mean relative change in pupil size as the dependent variable. There was a significant main effect of game ($F(1, 76) = 4.428$, $p = .039$, $\eta_p^2 = .055$) indicating that the average relative decrease in pupil dilation was less after exclusion than inclusion. There was no significant main effect of player type ($F(1, 76) = .181$, $p = .671$, $\eta_p^2 = .002$) or interaction ($F(1, 76) = .011$, $p = .917$, $\eta_p^2 < .001$). See Table 7 for means and standard errors. In sum, pupil dilation was more sustained for exclusive than inclusive players regardless of player type.

Self-report. Participants' self-reports were similar to previous experiments, with consistently more positive ratings after inclusion than exclusion games (see Table 8). Player type affected only the liking, player choice, control, and self-esteem questions. Participants reported significantly liking, choosing to play with, greater control, and higher self-esteem in human player than computer player conditions regardless of game type. The only player and game type interactions was in player choice: Participants were more likely to choose to play again with human than computer players after exclusion than after inclusion. Again, self-report ratings and RSQ did not significantly correlate with pupil dilation after exclusion (*rs* > .215).

General Discussion

Pupil dilation was more sustained when viewing exclusive players compared to inclusive players, regardless of whether players were social or non-social entities and whether exclusion was witnessed or experienced first-hand. This finding suggests physiological arousal is indeed highly sensitive to exclusion but also "crude" in the sense that it does not discriminate across different contexts of exclusion.

These results may initially seem to contradict Sleegers et al.'s (2017) finding that pupil size decreased in response to exclusion. However, this contradiction may be due to the present study measuring pupil size when viewing exclusive individuals immediately after the game instead of during the game as Sleegers et al. did. As suggested in other pupillometry studies (e.g., Price et al., 2013), pupil reactivity to viewing an exclusive individual may be an initial heightened threat response rather than a numbing response. It is also possible that a numbing response would be observed if pupil size was measured across a longer period than the 3 second window measured in the current study. Future studies should therefore explore how pupil reactivity changes across longer time courses when viewing socially exclusive individuals.

An unexpected pattern to note is that pupil size tended to decrease in post-game viewing of the players compared to pre-game viewing regardless of game type – although pupil size decreased relatively less after exclusion than inclusion. Participants viewed these players before the game and throughout the game; as such, the general decrease in pupils when viewing these players post-game may reflect low task demand or less processing effort in pupil reactivity (see Just, Carpenter, & Miyake, 2003 and van der Wel & van Steenbergen, 2018 for review and discussion) or even a well-studied habituation effect in physiology (Thompson & Spencer, 1966; cf. Snoweden et al., 2016). Nonetheless, exclusive individuals resulted in a more sustained pupil dilation than inclusive individuals, which is a consisten response pattern for emotionally arousing stimuli compared to neutral stimuli (Bradley et al., 2008; Snoweden et al., 2016).

The lack of differentiation in pupil dilation between social and non-social exclusion supports the idea of a "crude" ostracism detection system (Williams & Nida, 2011). Despite using non-social stimuli (i.e., abstract images) like Driscoll et al. (2017) to represent non-social players, pupil reactivity still occurred after exclusion by non-social players. Further, introducing participants to real-life individuals using confederates did not increase pupil dilation. However, participants tended to rate human players more positively than non-human players. Participants also showed larger self-report rating differences between exclusion and inclusion for human players than computer players across three experiments. These results suggest that the social nature of players do affect participants' self-reported ratings. Conscious decisions captured in self-report appears to show modulation based on the social nature of exclusion as found in Driscoll et al. (2017). In contrast, physiological arousal appears to occur regardless of the social nature of exclusion. Furthermore, pupil reactivity to exclusion was unrelated to self-report ratings of social pain and individual differences in rejection sensitivity, suggesting physiological arousal may occur regardless of individual differences in processing social exclusion.

Pupil reactivity to exclusion also did not differ between observing and experiencing exclusion, replicating previous work on vicarious ostracism (Wesselmann et al., 2013). It is striking that physiological arousal to exclusive individuals occurred even when individuals were not directly involved in exclusion. Taken together, these results suggest that physiological arousal as indexed in pupil dilation is a reflexive response that occurs without much cognitive processing as hypothesized by Williams (2009).

The present study is the first to demonstrate that the social pain response — as indexed by pupil dilation — occurs even in non-social interactions and is not limited to first-hand experience. This result supports the idea that pupil reactivity may reflect the hypothesized "quick" and "crude" ostracism detection system. Social pain from exclusion appears to reflect the high sensitivity to detect any instances of exclusion.

Table 1. Mean and standard errors for pupil dilation and self-report measures in Experiment 1 first block.

M (*SE*)	Inclusion	Exclusion	Human	Computer	Inclusive Human	Inclusive Computer	Exclusive Human	Exclusive Computer
Pupil	-.020 (.008)	.001 (.008)	-.006 (.009)	-.013 (.009)	-.019 (.011)	-.020 (.011)	.007 (.011)	-.006 (.011)
Ball Toss (%)	45.73 (1.23)	19.48 (1.00)	33.02 (1.31)	32.19 (1.31)	45.83 (1.74)	45.63 (1.74)	20.21 (1.41)	18.75 (1.41)
Player Choice	.84 (.05)	.20 (.05)	.56 (.05)	.48 (.05)	.90 (.06)	.79 (.06)	.23 (.07)	.17 (.07)
Player Liking	5.03 (.12)	3.24 (.12)	4.28 (.10)	3.99 (.10)	4.96 (.17)	5.10 (.17)	3.60 (.17)	2.88 (.17)
Mood	5.24 (.12)	3.15 (.15)	4.39 (.12)	4.00 (.12)	5.29 (.16)	5.19 (.16)	3.48 (.21)	2.81 (.21)
Belonging	4.47 (.11)	2.12 (.14)	3.48 (.13)	3.10 (.13)	4.35 (.16)	4.58 (.16)	2.60 (.19)	1.63 (.19)
Control	4.82 (.07)	3.69 (.08)	4.26 (.08)	4.25 (.08)	4.75 (.10)	4.90 (.10)	3.77 (.11)	3.60 (.11)
Existence	4.27 (.13)	2.16 (.13)	3.31 (.14)	3.12 (.14)	4.35 (.18)	4.19 (.18)	2.27 (.18)	2.04 (.18)
Self-Esteem	5.10 (.08)	3.50 (.12)	4.43 (.10)	4.18 (.10)	5.06 (.11)	5.15 (.11)	3.79 (.17)	3.21 (.17)

Table 2. Mean and standard errors for pupil dilation and self-report in Experiment 1 second block.

M (*SE*)	Inclusion	Exclusion	Human	Computer	Inclusive Human	Inclusive Computer	Exclusive Human	Exclusive Computer
Pupil	.012 (.010)	.005 (.008)	.001 (.010)	.015 (.010)	.009 (.014)	.015 (.014)	-.006 (.011)	.016 (.011)
Ball Toss (%)	42.60 (1.29)	20.73 (1.12)	31.15 (1.49)	32.19 (1.49)	40.63 (1.82)	44.58 (1.82)	21.67 (1.58)	19.79 (1.58)
Player Choice	.85 (.05)	.22 (.06)	.52 (.06)	.55 (.06)	.88 (.06)	.83 (.06)	.17 (.08)	.27 (.08)
Player Liking	5.08 (.12)	3.05 (.13)	4.13 (.09)	4.01 (.09)	5.38 (.16)	4.79 (.16)	2.88 (.19)	3.23 (.19)
Mood	5.19 (.10)	3.17 (.18)	4.21 (.13)	4.15 (.13)	5.44 (.14)	4.94 (.14)	2.98 (.25)	3.35 (.25)
Belonging	4.49 (.12)	2.17 (.13)	3.34 (.13)	3.31 (.13)	4.75 (.17)	4.23 (.17)	1.94 (.18)	2.40 (.18)
Control	4.75 (.09)	3.75 (.09)	4.31 (.09)	4.19 (.09)	4.81 (.13)	4.69 (.13)	3.81 (.13)	3.69 (.13)
Existence	4.42 (.14)	2.49 (.15)	3.35 (.15)	3.55 (.15)	4.31 (.20)	4.52 (.20)	2.40 (.21)	2.58 (.21)
Self-Esteem	4.97 (.10)	3.66 (.13)	4.30 (.10)	4.32 (.10)	5.21 (.13)	4.73 (.13)	3.40 (.18)	3.92 (.18)

Table 3. ANOVA results of self-report measures in Experiment 1 first block.

	Main effect of game type			Main effect of player type			Interaction		
	$F(1, 46)$	p	η_p^2	$F(1, 46)$	p	η_p^2	$F(1, 46)$	p	η_p^2
Ball Toss	4333.925	< .001*	.904	.203	.655	.004	.246	.622	.005
Player Choice	92.481	< .001*	.668	1.449	.235	.031	.096	.758	.002
Player Liking	83.653	< .001*	.645	4.231	.045*	.084	4.988	.030*	.098
Mood	108.112	< .001*	.702	5.008	.030*	.098	1.951	.169	.041
Belonging	173.677	< .001*	.791	4.505	.039*	.089	11.439	.001*	.199
Control	110.767	< .001*	.707	.009	.923	< .001	2.098	.154	.044
Existence	161.659	< .001*	.778	1.066	.307	.023	.035	.852	.001
Self-Esteem	112.190	< .001*	.709	3.452	.070	.070	4.844	.033*	.095

Table 4. ANOVA results of self-report measures in Experiment 1 second block.

	Main effect of game type			Main effect of player type			Interaction		
	$F(1, 46)$	p	η_p^2	$F(1, 46)$	p	η_p^2	$F(1, 46)$	p	η_p^2
Ball Toss	355.396	<.001*	.885	.243	.624	.005	6.318	.016*	.121
Player Choice	97.809	<.001*	.680	.160	.691	.003	1.288	.262	.027
Player Liking	90.508	<.001*	.663	.859	.359	.018	4.820	.033*	.095
Mood	80.659	<.001*	.637	.124	.727	.003	3.780	.058	.076
Belonging	186.921	<.001*	.803	.031	.862	.001	8.303	.006*	.153
Control	65.910	<.001*	.589	.890	.350	.019	<.001	1.000	<.001
Existence	91.119	<.001*	.665	.921	.342	.020	.003	.959	<.001
Self-Esteem	57.795	<.001*	.557	.021	.887	<.001	8.387	.006*	.154

Table 5. Mean and standard errors for pupil dilation and self-report in Experiment 2.

M (*SE*)	Inclusion	Exclusion	Human	Computer	Inclusive Human	Inclusive Computer	Exclusive Human	Exclusive Computer
Pupil Dilation	-.029 (.007)	-.009 (.007)	-.012 (.007)	-.025 (.009)	-.017 (.009)	-.040 (.010)	-.007 (.010)	-.011 (.011)
Ball Toss (%)	.46 (.18)	.23 (.11)	.33 (.16)	.37 (.19)	.43 (.24)	.50 (.28)	.22 (.14)	.25 (.17)
Player Choice	.95 (.03)	.31 (.05)	.64 (.04)	.62 (.04)	.94 (.04)	.95 (.04)	.33 (.07)	.29 (.08)
Player Liking	5.45 (.12)	3.11 (.15)	4.47 (.11)	4.09 (.13)	5.61 (.16)	5.29 (.19)	3.33 (.19)	2.90 (.23)
Mood	5.13 (.12)	2.58 (.15)	3.92 (.11)	3.79 (.13)	5.26 (.15)	5.00 (.18)	2.58 (.19)	2.58 (.23)
Belonging	4.79 (.11)	2.20 (.13)	3.49 (.10)	3.50 (.12)	4.69 (.14)	4.90 (.17)	2.30 (.17)	2.11 (.20)
Control	4.75 (.11)	2.47 (.15)	3.62 (.11)	3.59 (.13)	4.89 (.15)	4.61 (.17)	2.35 (.20)	2.58 (.24)
Existence	4.24 (.12)	2.35 (.14)	3.32 (.13)	3.26 (.16)	4.24 (.16)	4.24 (.18)	2.41 (.18)	2.29 (.21)
Self-Esteem	5.14 (.10)	2.94 (.14)	4.01 (.08)	4.07 (.10)	5.15 (.12)	5.13 (.15)	2.87 (.18)	3.00 (.21)

Table 6. ANOVA results from self-report measures in Experiment 2.

	Main effect of game type			Main effect of player type			Interaction		
	$F(1, 44)$	p	η_p^2	$F(1, 44)$	p	η_p^2	$F(1, 44)$	p	η_p^2
Ball Toss	119.918	< .001*	.816	3.175	.082	.067	1.569	.217	.034
Player Choice	96.449	< .001*	.687	.129	.721	.003	.131	.719	.003
Player Liking	118.434	< .001*	.729	5.274	.026*	.107	.074	.787	.002
Mood	220.888	< .001*	.804	.818	.370	.015	.393	.533	.007
Belonging	150.157	< .001*	.773	.556	.460	.012	.402	.529	.009
Control	119.234	< .001*	.730	1.493	.228	.033	1.493	.228	.033
Existence	143.294	< .001*	.765	.091	.764	.002	.130	.720	.003
Self-Esteem	122.174	< .001*	.735	.189	.666	.004	.134	.716	.003

Table 7. Mean and standard errors for pupil dilation and self-report measures in Experiment 3.

M(*SE*)	Inclusion	Exclusion	Human	Computer	Inclusive Human	Inclusive Computer	Exclusive Human	Exclusive Computer
Pupil	-.04 (.006)	-.02 (.006)	-.03 (.006)	-.03 (.006)	-.04 (.04)	-.04 (.034)	-.02 (.036)	-.02 (.051)
Ball Toss (%)	46.00 (.157)	10.50 (.157)	26.63 (.157)	29.88 (.157)	43.25 (.223)	48.75 (.223)	10.00 (.223)	11.00 (.223)
Player Choice	.725 (.045)	.125 (.045)	.575 (.045)	.275 (.045)	.950 (.063)	.500 (.063)	.200 (.063)	.050 (.063)
Player Liking	4.788 (.140)	2.738 (.140)	4.088 (.140)	3.438 (.140)	5.150 (.198)	4.425 (.198)	3.025 (.198)	2.450 (.198)
Mood	5.375 (.145)	3.188 (.145)	4.425 (.145)	4.138 (.145)	5.600 (.204)	5.150 (.204)	3.250 (.204)	3.125 (.204)
Belonging	4.738 (.129)	2.225 (.129)	3.650 (.129)	3.313 (.129)	5.050 (.182)	4.425 (.182)	2.250 (.182)	2.200 (.182)
Control	4.813 (.139)	2.650 (.139)	3.938 (.139)	3.525 (.139)	5.175 (.196)	4.450 (.196)	2.700 (.196)	2.600 (.196)
Existence	4.475 (.169)	2.450 (.169)	3.563 (.169)	3.363 (.169)	4.675 (.240)	4.275 (.240)	2.450 (.240)	2.450 (.240)
Self-Esteem	5.138 (.142)	3.663 (.142)	4.613 (.142)	4.188 (.142)	5.400 (.200)	4.875 (.200)	3.825 (.200)	3.500 (.200)

Table 8. ANOVA results for self-report in Experiment 3.

	Main effect of game type			Main effect of player type			Interaction of game type and player type		
	$F(1, 76)$	p	η_p^2	$F(1, 76)$	p	η_p^2	$F(1, 76)$	p	η_p^2
Ball Toss	254.140	< .001*	.770	2.130	.149	.027	1.021	.316	.013
Player Choice	89.705	< .001*	.541	22.426	< .001*	.228	5.607	.020*	.069
Player Liking	107.584	< .001*	.586	10.816	.002*	.125	.144	.705	.002
Mood	114.475	< .001*	.601	1.977	.164	.025	.632	.429	.008
Belonging	189.864	< .001*	.714	3.426	.068	.043	2.486	.119	.032
Control	121.325	< .001*	.615	4.415	.039*	.055	2.534	.116	.032
Existence	71.417	< .001*	.484	.697	.407	.009	.697	.407	.009
Self-Esteem	54.324	< .001*	.417	4.510	.037*	.056	.250	.619	.003

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Supplementary Analyses

Experiment 1

Self-report. Tables 9 and 10 report the results of the repeated-measures ANOVA conducted with block order, game type, and player type as within-subject factors and self-report responses as the dependent variables.

Table 9. Two-way and three-way interactions of block, game, and player for self-report in Experiment 1 both blocks combined.

	Interaction between block and game			Interaction between block and player			Interaction between game and player			Three-way interaction among game, player, block		
	$F(1, 23)$	p	η_p^2	$F(1, 23)$	p	η_p^2	$F(1, 23)$	p	η_p^2	$F(1, 23)$	p	η_p^2
Ball Toss (%)	7.271	.013*	.240	.340	.565	.015	7.811	.010*	.254	1.178	.289	.049
Player Choice	.020	.888	.001	.794	.382	.033	1.959	.175	.078	.203	.656	.009
Player Liking	1.641	.213	.067	1.007	.326	.042	.037	.848	.002	4.748	.040*	.171
Mood	.134	.718	.006	.939	.343	.039	.296	.591	.013	4.840	.038*	.174
Belonging	.027	.872	.001	1.540	.227	.053	.652	.428	.028	10.527	.004*	.314
Control	1.013	.325	.042	.258	.617	.011	1.137	.297	.047	.956	.338	.040
Existence	.825	.373	.035	1.308	.264	.054	.059	.811	.003	.004	.948	<.001
Self-Esteem	2.989	.097	.115	1.080	.309	.045	1.108	.303	.046	7.256	.013*	.240

Table 10. Main effects of block, game, and player for self-report in Experiment 1 both blocks combined.

	M (*SE*)		Main effect of block			Main effect of game			Main effect of player		
	Block 1	Block 2	$F(1, 23)$	p	η_p^2	$F(1, 23)$	p	η_p^2	$F(1, 23)$	p	η_p^2
Ball Toss	3.26 (.10)	3.17 (.11)	.686	.416	.029	761.827	< .001*	.971	.015	.905	.001
Player Choice	.52 (.04)	.54 (.04)	.223	.641	.010	144.086	< .001*	.862	.571	.458	.024
Player Liking	4.14 (.07)	4.07 (.06)	.844	.368	.035	143.585	< .001*	.862	3.409	.078	.129
Mood	4.19 (.07)	4.18 (.07)	.036	.851	.002	124.608	< .001*	.844	3.787	.064	.141
Belonging	3.29 (.09)	3.33 (.09)	.148	.704	.006	300.488	< .001*	.929	3.117	.091	.119
Control	4.26 (.05)	4.25 (.05)	.005	.946	< .001	108.275	< .001*	.825	.686	.416	.029
Existence	3.21 (.09)	3.45 (.10)	4.209	.052	.155	159.357	< .001*	.874	< .001	1.000	< .001
Self-Esteem	4.30 (.05)	4.31 (.06)	.024	.878	.001	137.775	< .001*	.857	1.487	.235	.061

Suspicion. There was an overall main effect of suspicion on pupil dilation ($F(1, 44) = 6.477$, $p = .015$, $\eta_p^2 = .128$), suggesting that participants who were suspicious that the human players were actually computerized players showed greater relative increase in pupil dilation ($M = .011$, $SE = .007$) than participants who were not suspicious ($M = -.018$, $SE = .009$). There were no other effects of suspicion on pupil dilation (*ps* > .364).

Comparing Experiment 1 and 2

Table 11 reports the ANOVA model results of comparing the pupil and self-report measures from Experiment 1 and 2.

Table 11. Comparing results between Experiment 1 to Experiment 2.

	M(*SE*)		Main effect of experiment			Interaction between experiment and game			Interaction between experiment and player			Three-way interaction among experiment, game, and player		
	Exp 1	Exp 2	$F(1, 90)$	p	η_p^2	$F(1, 90)$	p	η_p^2	$F(1, 90)$	p	η_p^2	$F(1, 90)$	p	η_p^2
Pupil Change														
Ball Toss	32.60 (.11)	34.85 (.11)	2.081	.153	.023	2.194	.142	.024	2.951	.089	.032	.492	.485	.005
Player Choice	.52 (.03)	.63 (.03)	5.714	.019*	.060	.015	.904	< .001	5.714	.019*	.060	.224	.637	.002
Player Liking	4.14 (.08)	4.28 (.08)	1.826	.180	.020	3.523	.064	.038	.166	.685	.002	1.706	.195	.019
Mood	4.19 (.08)	3.85 (.09)	7.830	.006*	.080	2.513	.116	.027	1.132	.290	.012	2.034	.157	.022
Belonging	3.29 (.08)	3.50 (.09)	2.874	.093	.031	.859	.356	.009	2.557	.113	.028	2.537	.115	.027
Control	4.26 (.07)	3.61 (.07)	42.998	< .001*	.323	24.544	< .001*	.214	.008	.928	<.001	3.165	.079	.034
Existence	3.21 (.10)	3.29 (.10)	.331	.567	.004	.951	.332	.010	.242	.624	.003	.013	.911	<.001
Self-Esteem	4.30 (.07)	4.04 (.07)	7.965	.006*	.081	5.829	.018*	.061	2.673	.106	.029	2.670	.106	.029

Chapter 3: Social Exclusion Detection in Children

Feeling excluded from a group is a common human experience that starts in childhood. This basic human need to belong or connect with others is argued to be universal and thought to have an evolutionary basis (Baumeister & Leary, 1995; Coon, 1946; Panksepp, 2003). Because being part of a group has extensive evolutionary benefits (Brewer, 2007; Buss & Kenrick, 1998), it has been argued that this desire to connect with others and sensitivity to exclusion is a skill that is present from birth (Spoor & Williams, 2006; Williams, 2007). But when does one become conscious of being excluded by others? Infants appear to quickly form attachments to their caregivers and show distress when they are separated from caregivers (Ainsworth, Blehar, Waters, & Wall, 2015; Bowlby, 1969). In fact, if caregivers are unresponsive, infants react with alarm and distress (Tronick, Als, Adamson, Wise, & Brazelton, 1978), suggesting that the ability to detect disruptions in social connections exists early in life.

However, children may not begin to understand social disconnections or exclusion from people other than caregivers until later in life. During the preschool years, from roughly 3 to 6 years of age, children start to engage more in group dynamics and start to become members of social groups. Classic studies on children's play suggest during the preschool years children transition from predominately playing alone (i.e., solitary play) to playing with others (i.e., group play) (Parten, 1932; Smith, 1978). Such shifts in play behavior suggest that children are transitioning to connecting to others besides their caregivers and becoming more aware of group dynamics.

Critically, around 5 years of age, children start to exhibit relational aggression, which is behavior intending to exclude or hurt others through non-physical manipulation, threat, or damage to close relationships and social status (Crick, 1995; Crick, Casas, & Mosher, 1997;

Crick & Grotpeter, 1995; Vlachou, Andreou, Botsoglou, & Didaskalou, 2011). Around this age, children also begin to identify bullies and victims of bullying in their classrooms. However, 3- to 4-year-old children tend to show greater difficulty recognizing relational and nonphysical forms of bullying (e.g., ignoring others) than physically aggressive forms of bullying (e.g., hitting others) (Crick, Casas, & Ku, 1999; Monks & Smith, 2006). Furthermore, younger children exhibit relatively simple and direct relational aggression, such as directly telling a peer they cannot play with them. Older preschoolers, in contrast, start to show more complicated relational aggression, such as disseminating malicious rumors (Crick et al., 1999). These findings suggest that explicit social exclusion, or exclusion that is verbalized, is detected easier and earlier in development than implicit social exclusion, or exclusion that is not necessarily verbalized. Such age-related differences in relational bullying and socially exclusive behaviors may be due to differences in verbal abilities as well as social, cognitive, and moral development that occur at this age (Crick, 1996; Crick et al., 1999; Killen & Rutland, 2011).

However, recent social cognitive research suggests even children who lack sophisticated verbal abilities – such as younger preschoolers and possibly even infants – could detect and reason about complex social interactions like social exclusion. One experimental investigation found that 4- to 5-year-old children could verbally report that exclusion occurred after watching geometric shapes silently keep one shape from being included in a circle (Song, Over, & Carpenter, 2015). However, due to the limited verbal abilities of younger children, more studies have focused on children's nonverbal responses to social exclusion to trace the developmental origin of social exclusion understanding. In these studies, children are typically primed by watching videos of abstract shapes that either exclude another shape or include another shape. After primed with exclusion, children were found to imitate an experimenter's actions more faithfully and draw individuals closer together than when primed with inclusion (Over & Carpenter, 2009; Song et al., 2015; Watson-Jones, Legare, Whitehouse, & Clegg, 2014; Watson-Jones, Whitehouse, & Legare, 2015). Such higher affiliative behaviors after exclusion compared to inclusion is hypothesized to be an adaptive response to the threat of feeling socially excluded; children may imitate more or draw people closer together because they want to ensure their social connection to the experimenter or friends after feeling excluded. Children this age thus may employ behavioral strategies to compensate for the negative effects of exclusion (Over & Carpenter, 2009; Watson-Jones et al., 2015).

Further support for this early emerging ability to detect social exclusion comes from research that finds infants are able to discriminate positive and negative social interactions. For example, beginning around 10 months of age, infants can track third-party social dominance relationships (Mascaro & Csibra, 2012, 2014; Thomsen, Frankenhuis, Ingold-Smith, & Carey, 2011). Six- and ten-month-old infants also preferentially reach for an agent that previously helped someone achieve their goal (i.e., a prosocial agent) over one who hindered it (i.e., an antisocial agent) (Hamlin, Wynn, & Bloom, 2007; Hamlin, Wynn, Bloom, & Mahajan, 2011). Fifteen-month-old infants also prefer individuals who distribute resources fairly over those who do not (Burns & Sommerville, 2014; Schmidt & Sommerville, 2011). Thus, infancy research suggests nonverbal measures, such as preferences, may reveal children's understanding of complex social relationships before they are able to verbally articulate it.

Preference measures are a common method for assessing socio-cognitive reasoning in both infancy and childhood research. Preference measures can be implemented from infancy through early childhood to test the same construct, such as preferences based on race (Kinzler & Spelke, 2011; Shutts, 2015). Further, infants' and children's preferences tend to be consistent with other measures, such as looking time, gaze expectations, and sharing behaviors (Geraci & Surian, 2011; Hamlin et al., 2007; Kuhlmeier, Dunfield, & O'Neill, 2014; Renno & Shutts, 2015). Using a preference measure, one recent study found that after watching a socially exclusive interaction, 3-year-old children – but not 2-year-olds – preferred agents who were excluded over agents who excluded others (Hwang, Marrus, Irvin, & Markson, 2017).

However, precisely how reflective preferences are of children's underlying social cognitive reasoning remains an open question. For instance, as seen in infancy research, avoidance of socially exclusive individuals and preference for socially inclusive individuals may emerge earlier than verbal abilities to identify social exclusive versus inclusive individuals. On the other hand, preferences may closely track children's social exclusion detection, such that children who can verbally identify exclusive and inclusive agents also prefer inclusive agents over exclusive agents during the same developmental stage. In contrast, preferences may indicate more sophisticated social decisions – such as social desirability or concerns of reputation – than simple verbal detection and thus may emerge later in development than verbal detection. Thus, testing whether children's verbal report and preference measures converge or differentially will help elucidate the developmental trajectory of children's detection and understanding of social exclusion. It will also shed light on the relation between verbal report and social preference in capturing children's social cognitive reasoning, which is essential to understanding how laboratory-based measures reflect children's processing of real-life social interactions.

The aim of the present study is to clarify how social exclusion detection emerges in development using different experimental measures, which should shed light on the utility and relation among methodologies currently being used in social cognitive research. Specifically, the present study tested whether 3- to 6-year-old children show differences in their verbal reports, preferences, and sharing responses when they experience explicit exclusion compared to implicit exclusion. Further, two different paradigms, a child-friendly puppet paradigm (Experiment 1) and a cyberball paradigm (Experiment 2) were used to elicit social exclusion in children in the lab.

Hypotheses

We hypothesized that when exclusion and inclusion are explicit (i.e., verbalized), children at all ages would prefer to play and share more with individuals who included them rather than individuals who excluded them. This is based on earlier findings demonstrating that already around 6 to 10 months of age, children show an aversion to antisocial others and preference for prosocial others (Hamlin et al., 2007; Schmidt & Sommerville, 2011). We further hypothesized that children of all ages would correctly identify exclusion and correctly answer moral reasoning questions about what happened after explicit social exclusion, because preschool age children can detect verbalized exclusion behaviors (Crick et al., 1999; Killen & Rutland, 2011; Monks & Smith, 2006; Vlachou et al., 2011). We also hypothesized that there will be age-related difference in verbal measures, but not in nonverbal measures, such as preference and sharing behaviors. Specifically, children might distinguish between inclusive and exclusive individuals in their preferences and sharing behaviors before they are able to verbally report that exclusion occurred.

However, when exclusion and inclusion are implicit (i.e., not verbalized), we hypothesized that age-related differences in both nonverbal and verbal measures. Specifically, we predicted that after implicit exclusion children will be more likely to prefer and share more with inclusive individuals over exclusive individuals as they get older. We also hypothesized that with age, children will be more likely to correctly report that exclusion occurred after implicit social exclusion. We predicted that older preschool age children, i.e., 5- to 6-year-old children, would show consistently heightened response to exclusion compared to inclusion even in implicit interactions, as research suggests that by age 5, children are sensitive to exclusion and can verbally identify implicit exclusion (Song et al., 2015; Watson-Jones et al., 2015). However, little research has been done with 3- to 4-year-old children and studies suggest that children this age may not be as responsive to relational social exclusion as older children (Crick et al., 1997; Watson-Jones et al., 2014). Thus, we hypothesized that 3- to 4-year-old children would be able to detect exclusion in explicit interactions but not in implicit interactions.

Experiment 1a: Implicit Social Exclusion

Using an interactive puppet paradigm, Experiment 1a tested whether 3- to 6-year-old children show differing verbal and nonverbal responses after experiencing exclusion compared to inclusion when intentions of the agents are implicit and not verbally stated.

Method

Participants. Ninety-six children participated: 32 3-year-old children (15 females, M_{age} = 3;5, range = 3;0–3;10), 32 4-year-old children (17 females, M_{age} = 4;6, range = 4;0–4;11), and 32 5- to 6-year-old children (14 females, M_{age} = 5;8, range = 5;0–6;9). We chose a sample size of 32 for each age group based on previous research that used preference measures to investigate children's response to prosocial and antisocial agents (Burns & Sommerville, 2014; Hamlin et al., 2007, 2011; Hwang et al., 2017; Shutts, Banaji, & Spelke, 2010). Furthermore, a previous study reported a Cohen's *d* effect size of .38 for differences in children's imitation responses after nonverbal exclusion compared to inclusion (Watson-Jones et al., 2015). Another recent study investigating 4- to 5-year-old children's verbal ability to report if exclusion occurred after watching abstract shapes interact without verbal cues reported a *d* of .98 (Song et al., 2015).

Thus, we predicted a medium to large effect sizes (Cohen's *d* of .30 to .80) for the differences in responses between social exclusion and inclusion. G*Power software (Faul, Erdfelder, Buchner, & Lang, 2009) indicated that at an alpha of .05, our sample size of 96 should provide 90.69% to 99.99% power to detect our hypothesized effects.

Children were recruited from a database of families interested in participating in child development research in a mid-western United States metropolitan area and all were tested in the laboratory. The racial and ethnic composition of the children were 77.08% White, 15.63% Bi- or Multi-racial, 2.08% Other, 1.04% Black, 1.04% Hispanic, and 1.04% Asian. Children were from mostly middle-class families with an average yearly income bracket of $75,000 to $99,999, and all parents reported having some college education. Eight additional children participated in the study, but were excluded from analyses due to parental interference ($n = 1$), experimenter error ($n = 3$), or failure to complete the study ($n = 4$).

Materials. Stimuli included one ball (3 × 3.5 in) and four animal puppets (5 × 9 in), which were four identical hippopotamus puppets. Two of the puppets wore black shirts and the other two wore brown shirts. For half of the children, puppets with black shirts were exclusive, whereas for the other half of the children, puppets with brown shirts were exclusive.

Parents also filled out a form which asked for basic demographic information (as reported above) and were also asked to indicate whether their child had a sibling or not and estimate how many hours a week their child consistently attended preschool, daycare, classes, playgroups, or other social activities.

Design & Procedure. Children sat in front of a table (41.5 × 48 in) facing a curtain. Two puppeteers sat behind the curtains with the puppets on their hands so that children saw only the puppets and not the puppeteers. The four puppets were approximately 48 inches in front of the children and the positions of the puppets – whether brown hippopotamus puppets were on children's left or right side – were counterbalanced across children. If parents chose to come into the experiment room, they sat 3 feet directly behind the children and were instructed to not talk or influence their children during the session.

First, the experimenter waved hello to the puppets and introduced children to each pair. Children were encouraged to wave hello to the puppets. Puppets also replied by introducing themselves (i.e., "Hello! We are the black/brown hippos!"). After introductions, the experimenter said, "Why don't we play with the brown/black hippos first? Brown/black hippos, do you guys want to play a ball game with [child's name]?" After the puppets nodded, the experimenter gave the ball to one of the puppets. Children then played the ball game with one pair at a time. Which puppets – brown or black – played first was counterbalanced across children.

Children experienced two ball games, one inclusive and one exclusive. The order of the ball games (inclusive first or exclusion first) was counter-balanced across children. For both inclusion and exclusion games, the beginning interaction was identical: The puppet who received the ball always passed the ball first to its partner puppet; then this partner puppet passed the ball to the children. Children were then encouraged to throw the ball back to the puppets. In the inclusion game, the puppets continued to pass the ball equally to each other and to the children for another six tosses; children received the ball twice during this part of the game. Therefore, children received the ball for a total of three times in the inclusion game. In the exclusion game, the puppets stopped tossing the ball to the children and only tossed the ball to each other for another six tosses. Therefore, children received the ball only once in the exclusion game. Each game lasted approximately 40 seconds.

After children played the games with both pairs, a second experimenter who was blind to the roles of the puppets entered the room and asked children the *preference* question: "Now that you got to play with both pairs, which hippos do you like?" Children were encouraged to point to the pair they liked. Children were then asked the *detection* question: "Which ones did not want to play with you?" Children were again encouraged to point to indicate their answers. The preference question was always asked first and the detection question second to reduce potential carryover effects from the detection question influencing children's preferences. After children's choices, the exclusive pair apologized to the children and played a few tosses with the children to ensure children left on a positive note.

Results

Generalized linear mixed models (Baayen, Davidson, & Bates, 2008) were conducted using a step-up strategy for model building (see West et al., 2014) as this method of analysis is well-suited for binary outcomes, allowed us to treat age as a continuous variable, and to control for different factors simultaneously. Age and task type (preference vs. detection) were entered into the models as fixed effect predictors of children's binary responses. We also tested whether children had a sibling, the number of social activity hours per week, counter-balancing factors (order of the games (inclusion or exclusion first), color of the shirts (brown or black), positions of the puppets (left or right)), and children's sex (later referred to as *additional predictors*) improved the fit of the model beyond the main hypothesized predictors. As random effects, random intercepts were entered for participant ID to account for dependencies within participants. Analyses were performed in R using lme4 (Bates, Maechler, Bolker, & Walker, 2016) and lmerTest (Kuznetsova, Brockhoff, & Christensen, 2014). See Table 1 for β, standard errors, *z*, and *p* values of the best-fit models and Table 2 for the proportion of children's choices according to age group.

Table 1. Fixed effects of best-fit binomial logistic models predicting the probability of children's preference and detection after implicit exclusion (Experiment 1a) and explicit exclusion (Experiment 1b).

Exclusion Type	Predictors	β	*SE*	Wald *z*	*p*
Implicit	Intercept	-1.687	.782	-2.158	.031
	Task Type	.371	.307	1.207	.227
	Age	.033	.014	2.354	.019
Explicit	Intercept	-7.231	3.154	-2.293	.022
	Task Type	-1.061	.569	-1.866	.062
	Age	.200	.078	2.575	.010

Table 2. Proportion of children who preferred the inclusive puppets and correctly identified the exclusive puppets according to age group after implicit exclusion (Experiment 1a) and explicit exclusion (Experiment 1b).

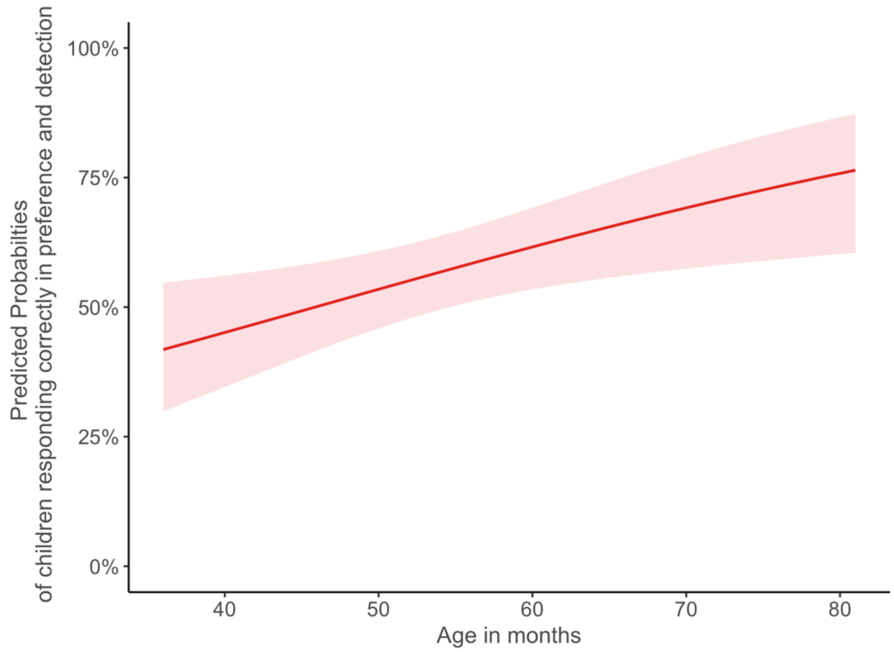
Exclusion Type		3-year-old	4-year-old	5- to 6-year-old
Implicit	Preference	18 (56.25%)	17 (53.13%)	23 (71.88%)
	Detection	10 (31.25%)	18 (56.25%)	23 (71.88%)
Explicit	Preference	16 (50%)	-	-
	Detection	23 (71.88%)	-	-

Note. $n = 32$ in each age group.

A model with the interaction between task type and age was not a significantly better fit than a model without the interaction (likelihood ratio tests, $\chi^2 = 2.678$, $df = 1$, $p = .102$). Additional predictors did not improve the model with the main predictors (*ps* >.118). The best-fit model revealed a significant main effect of age ($p = .019$), indicating that children were more likely to prefer the inclusive puppet and detect the exclusive puppet with age. However, there was no main effect of task type ($p = .227$), suggesting children did not differ in their performance between preference and detection. See Figure 1. Follow-up one-tailed binomial tests were conducted for each age group to determine at what age children preferred inclusive players and detected exclusion above chance.

Preference. Three-year-old children did not show a clear preference ($p = .597$). Four-year-old children also did not show a clear preference ($p = .860$). However, 5- to 6-year-old children significantly preferred the inclusive puppets over the exclusive puppets ($p = .020$).

Detection. Three-year-old children were unable to correctly identify the exclusive puppets above chance ($p = .990$). Four-year-old children also did not accurately detect exclusive puppets above chance ($p = .298$). In contrast, 5- to 6-year-old children were above chance at correctly identifying the exclusive puppets ($p = .010$).



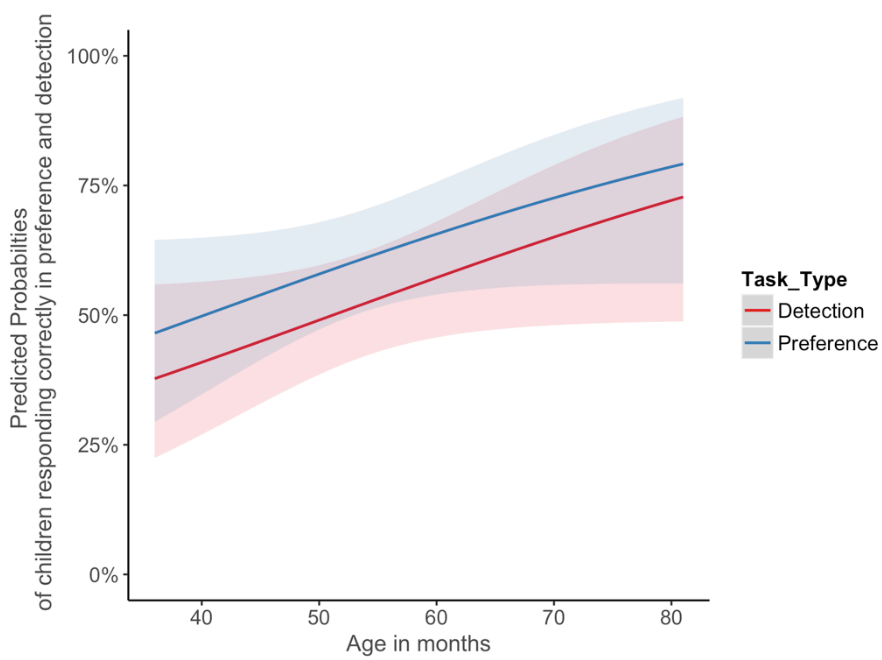


Figure 1. The upper figure represents the predicted probabilities of children preferring inclusive puppets and correctly identifying exclusive puppets from Experiment 1a collapsing across task type. The lower figure represents the same predicted probabilities separated into task type. The blue line represents the predicted probabilities of children preferring the inclusive puppets after implicit exclusion across age. The red line represents the predicted probabilities of children identifying the exclusive puppets after implicit exclusion across age. The shaded area around the line represent 95% confidence intervals calculated based on the predicted values and their standard errors from the best-fit model.

Discussion

When children were implicitly excluded, they were more likely to prefer inclusive puppets and better at verbally reporting exclusion with age. Five- to six-year-old children correctly identified which puppets were exclusive and preferred inclusive puppets above chance. In contrast, 3- and 4-year-old children did not show a clear preference for the inclusive puppets and were unable to correctly identify which puppets were exclusive. These findings suggest that 3- to 4-year-old children had more difficulty noticing nonverbal, implicit exclusion than 5- to 6-year-old children. This result also is in line with previous findings that younger preschool age children have difficulty processing relational bullying than older children. However, another possibility is that the task may have been more difficult for younger children than older children. The less developed verbal skills and memory of younger children may have caused them to underperform compared to older children. If task difficulty is the driving cause behind younger children's lower performance, then younger children should show difficulty detecting exclusion even when exclusion is explicit. To further test whether the nonverbal nature of implicit exclusion caused younger children to be less likely to detect exclusion – not necessarily the task itself being more difficult for younger children than older children – we conducted an identical puppet paradigm but with puppets verbally expressing that they are excluding the children.

Experiment 1b: Explicit Social Exclusion

Experiment 1b tested whether even the youngest age group, 3-year-old children, would be able to verbally identify exclusion and prefer inclusive puppets if exclusion was communicated verbally.

Method

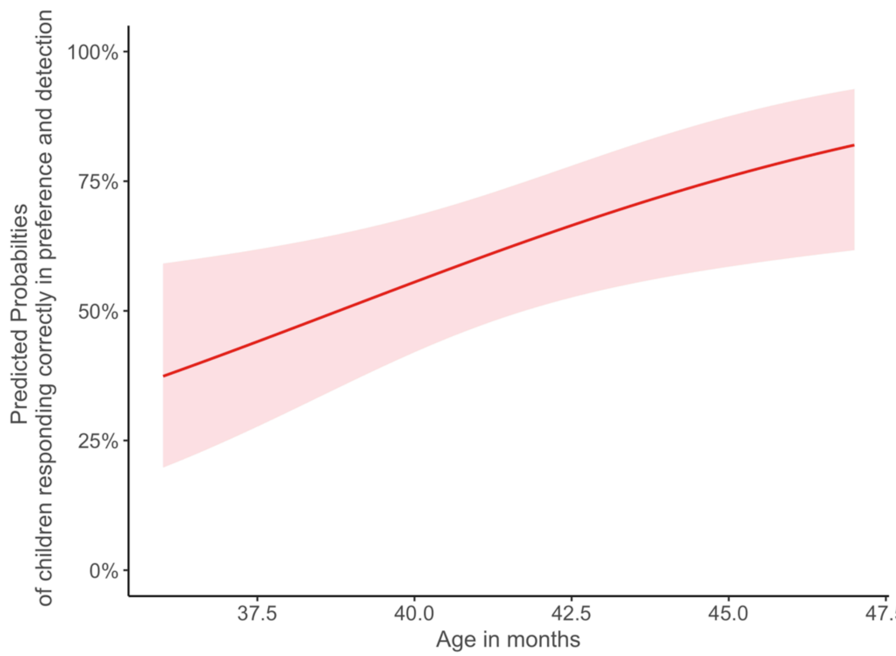
Participants. Thirty-two 3-year-old children participated (15 females, M_{age} = 3;5, range = 3;0–3;9). Children were recruited from the same database as Experiment 1a. The racial and ethnic composition of the children were 87.5% White, 6.25% Black, and 6.25% Bi- or Multi-racial. Children were from mostly middle-class families with an average yearly income bracket of $75,000 to $99,999 and all parents reported having some college education. Two additional children participated in the study, but were excluded from analyses due to failure to complete the study ($n = 2$).

Procedure. Children experienced the same set-up and design as Experiment 1a with two pairs of puppets, in which one pair was inclusive and the other pair exclusive. However, in this experiment, the puppets indicated their intention to include or exclude verbally. Specifically, after the first round of ball tosses (i.e., after receiving a ball toss from the children), the inclusive puppets each said, "Let's keep playing together," to the children and continued to pass the ball to the children as in the previous experiment. In contrast, the exclusive puppets each said, "We don't want to play with you anymore," to the children and only passed the ball to each other and never to the children. Children were asked the preference and detection question as in Experiment 1a.

Results

Because we hypothesized that children will prefer inclusive over exclusive puppets and would correctly identify exclusive puppets after explicit exclusion, the following binomial tests were conducted as one-tailed tests. After explicit exclusion, 3-year-old children did not show a clear preference between inclusive and exclusive puppets ($p = .570$). However, 3-year-old children were above chance at correctly identifying the exclusive puppets ($p = .010$).

Best-fit generalized linear models were constructed in the same manner as Experiment 1a. A model with the interaction between task type and age was not a significantly better fit than a model without the interaction (likelihood ratio tests, $\chi^2 = .976$, $df = 1$, $p = .323$). Additional predictors did not improve the model with the main predictors (*ps* >.182). The best-fit model revealed a significant main effect of age ($p = .010$), indicating that children were more likely to prefer the inclusive puppet and detect the exclusive puppet with age. There was a marginal main effect of task type ($p = .062$), suggesting children may show better verbal identification of exclusive puppets than preference for inclusive puppets after explicit exclusion. See Figure 2.



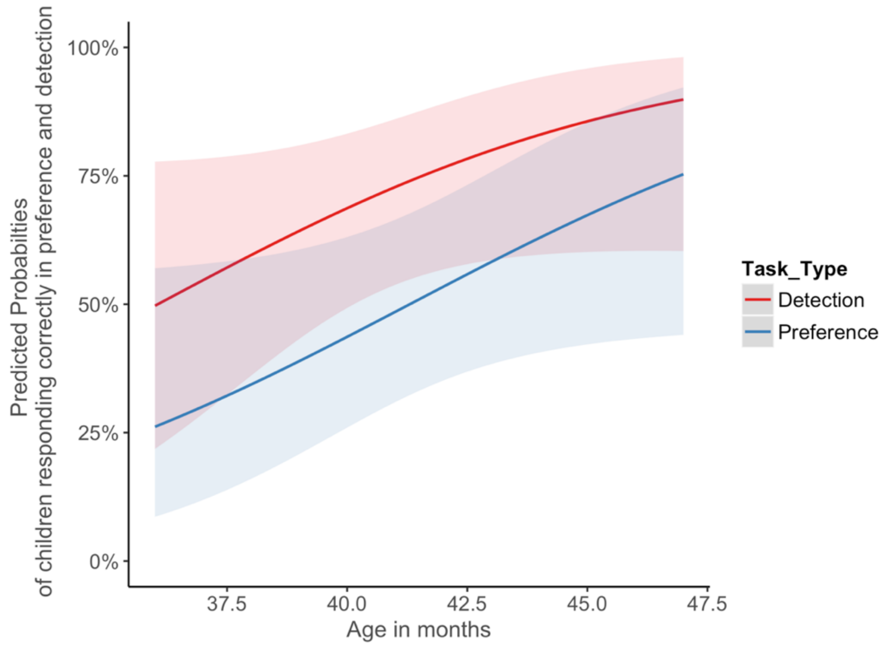


Figure 2. The upper figure represents the predicted probabilities of children preferring inclusive puppets and correctly identifying exclusive puppets from Experiment 1b collapsing across task type. The lower figure represents the same predicted probabilities separated into task type. The blue line represents the predicted probabilities of children preferring the inclusive puppets after explicit exclusion across age. The red line represents the predicted probabilities of children identifying the exclusive puppets after explicit exclusion across age. The shaded area around the line represent 95% confidence intervals calculated based on the predicted values and their standard errors.

Comparing Explicit vs. Implicit Exclusion. We compared whether children showed greater differentiation of inclusive and exclusive puppets in their preference and identification after experiencing explicit exclusion compared to implicit exclusions We limited the comparison to 3-year-old children as we did not test older children in explicit exclusion. A generalized mixed model was conducted with children's binary responses to the task as the dependent variable. The fixed effect predictors were task type (preference vs. detection), exclusion type (implicit or explicit), and age. Random intercepts for participant ID were entered as random effect to the model.

The best-fit model indicated a significant interaction between task type and exclusion type (p = .006, ß = -2.103, SE = .771, z = -2.728), but no other significant effects. Because we predicted that children would perform better in preference tasks than detection tasks, as well as better in explicit than implicit exclusion, follow-up one-tailed fisher's exact tests were conducted to further investigate this interaction. Three-year-old children's preference responses did not differ after explicit and implicit exclusion (p = .401), but children were more likely to correctly identify exclusive puppets after explicit exclusion than after implicit exclusion (p = .001). See Figure 3.

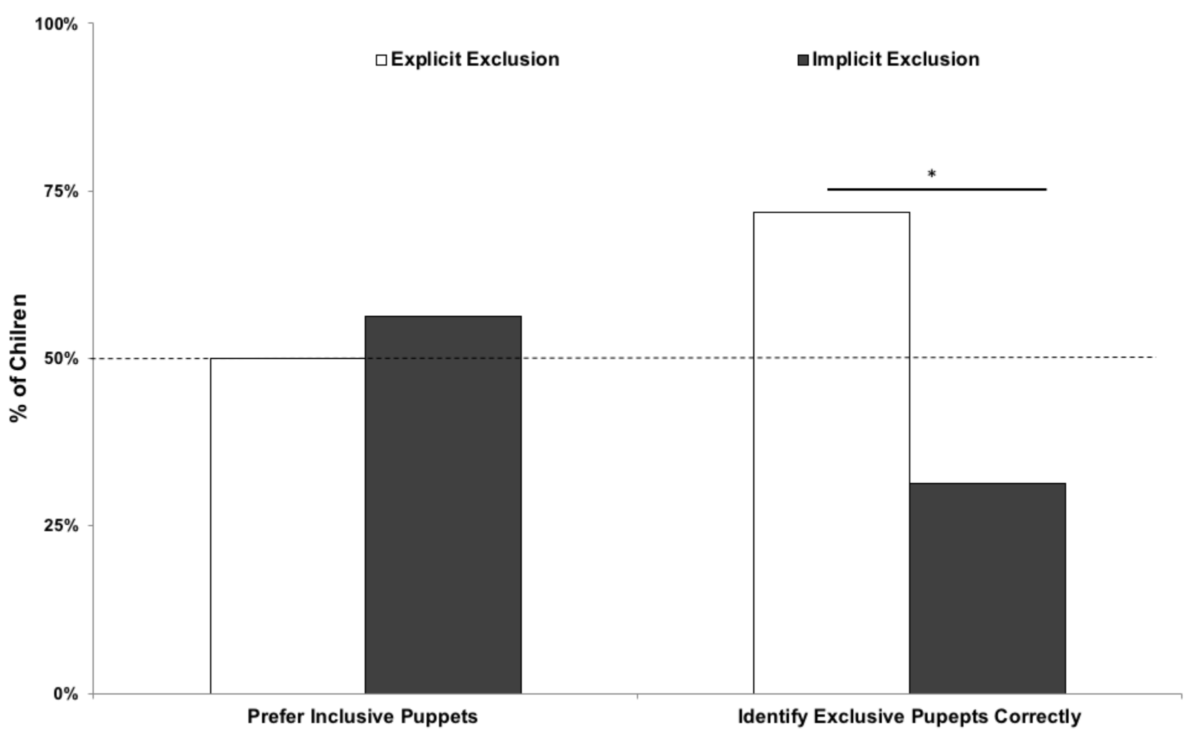


Figure 3. Percentage of 3-year-old children who preferred inclusive puppets and correctly identified exclusive puppets after implicit exclusion (Experiment 1a) and explicit exclusion (Experiment 1b). The asterisk denotes p =.001.

Discussion

After experiencing explicit social exclusion, 3-year-old children correctly identified the exclusive puppets above chance and did so significantly more after explicit than implicit social exclusion. However, 3-year-old children were not more likely to *prefer* the inclusive puppets over the exclusive puppets after explicit exclusion above chance. Crucially, children's preferences did not differ after explicit and implicit social exclusion.

These results suggest that 3-year-old children's unclear identification of implicit social exclusion was not solely due to difficulties associated with the task or memory demands, but rather due to 3-year-old children being unable to verbally identify implicit social exclusion. Thus, results of Experiment 1a and 1b suggest that children are able to identify explicit social exclusion earlier than implicit social exclusion in verbal measures, but not necessarily in preference measures.

However, before making strong conclusions, it is important to note that Experiment 1 tested children on only one trial, which may have limited children's opportunity to show their true understanding. Furthermore, design of Experiment 1 only allowed a direct comparison of exclusive versus inclusive individuals, instead of assessing children's responses separately to exclusive individuals versus inclusive individuals. For instance, if children choose an inclusive individual over an exclusive individual, it is unclear if this reflects a preference for inclusive individuals or an avoidance of an exclusive individual. In contrast, comparing an exclusive individual against a neutral individual would allow us to determine whether children are actively avoiding exclusive individuals; comparing an inclusive individual against a neutral individual would also clarify if children show a preference for inclusive individuals over a neutral individual. Lastly, although puppets have shown to be treated as agents by children (e.g., Hamlin et al., 2011; Johnson, Slaughter, & Carey, 1998), puppets are not the same as human agents. Thus, children's preferences observed in Experiment 1 may have been distorted due to the nature of the puppets.

To address these limitations and further explore the relations among age, task types, and explicit versus implicit exclusion, Experiment 2 tested whether the patterns we observed in Experiment 1 generalizes to human agents, different tasks, and across more trials. Experiment 2 expanded upon Experiment 1 by testing children in multiple trials of social exclusion and inclusion interactions with human agents. Children were given a choice of choosing to either play again with previous players who were either exclusive or inclusive against neutral players. Experiment 2 also incorporated more measures of children's social behavior towards exclusive and inclusive agents by adding a sharing task, as well as more measures of children's verbal reporting of exclusion by adding a moral evaluation task, to further clarify the relation between verbal report measures and nonverbal social measures.

Experiment 2

Experiment 2 investigated whether 3- to 6-year-old children show different preferences, sharing, identification, and moral evaluation responses after exclusion and inclusion when intentions of the agents were explicit (i.e., verbally stated) versus implicit (i.e., not verbally stated).

Method

Participants. In total, 112 3- to 6-year-old children participated. In the implicit condition, 32 3- to 4-year-old children (M_{age} = 48.63 months; SD = 6.66) and 32 5- to 6-year-old children (M_{age} = 68.90 months; SD = 6.41) participated. In the explicit condition, 24 3- to 4-year-old children (M_{age} = 45.09 months; SD = 7.51) and 24 5- to 6-year-old children (M_{age} = 68.43

months; *SD* = 6.87) participated. Seven additional participants participated, but were excluded from analyses due to program error.

Sample size for each condition was conducted separately. For the implicit condition, a previous study using cyberball with 5- to 6-year-old children reported a Cohen's *d* effect size of .38 for differences in children's imitation responses after nonverbal exclusion compared to inclusion (Watson-Jones et al., 2015). Another recent study investigating 4- to 5-year-old children's verbal ability to report if exclusion occurred after watching abstract shapes interact without verbal cues reported an effect size of .98 (Song et al., 2015). Thus, we predict medium to large effect sizes (Cohen's *d* of .30 to .80) for the differences in responses between social exclusion and inclusion in this experiment. G*Power software (Faul et al., 2009) indicated that our sample size of 64 will provide 99.99% power at an alpha of .05 for detecting our hypothesized effects.

For the explicit condition, Experiment 1b in the current study demonstrated that even 3-year-old children can correctly that report exclusion occurred after they were explicitly and verbally excluded and resulted in a Cohen's *d* effect size of .81 for 3-year-old children preferring inclusive agents over exclusive agents and a *d* of 1.36 for correctly identifying exclusive agents after experiencing explicit exclusion. Thus, we expected a large effect size (Cohen's *d* of .80) for the differences in response between social exclusion and inclusion in this experiment. G*Power software (Faul et al., 2009) indicated that our sample size of 48 in explicit exclusion will provide 99.44% power at an alpha of .05 for detecting our hypothesized effect.

Children were recruited and tested in a quiet area in the laboratory, their preschool, or a local science center in a Midwestern city in the U.S. In all locations, children were seated in front of a laptop with parents or caregivers, who if present, were seated behind them and instructed not to influence their children. The racial and ethnic composition of the children were 70.30% White, 12.50% Bi- or Multi-racial, 9.38% Black, 3.13% Hispanic, 3.13% Asian, and 1.56% not reported. Children were from middle-class families with an average yearly income bracket of $75,000 to $99,999 with parents reporting on average having a college degree or higher.

Materials.

Cyberball. One of the most widely used experimental method to study adults' response to social exclusion is cyberball, and there has been great interest in using cyberball with children (Scheithauer, Alsaker, Wölfer, & Ruggieri, 2013; Zadro et al., 2013). Cyberball has been used successfully with school age children, who report lower moods and more threats to their need to belong after an exclusive game than an inclusive game, replicating findings from adults (Abrams, Weick, Thomas, Colbe, & Franklin, 2011; Hawes et al., 2012; Watson-Jones et al., 2015). We developed an age-appropriate cyberball paradigm for preschool age children on Psychopy (Peirce, 2007) that was presented on a touch-screen laptop. In this version of cyberball, children saw pictures of two children, one on the left side and the other on the right side, each with accompanying baseball gloves. On the screen was also a baseball glove in the center of the screen with children's names below. A ball appeared always in possession of the other two players at the beginning of the game. Children could only toss the ball to other players when the ball was in their glove. To toss the ball, children had to touch the picture of the player they wanted to toss the ball to.

Games consisted of two types: inclusion and exclusion. In the inclusive game, children received one third of the total ball tosses (i.e., 3 out of 9 total tosses). In the exclusive game, children received only one ball toss from the other players and then received no more ball tosses for the remainder of the game. Children played four games: two inclusion and two exclusion games. The game order was counter-balanced across participants but designed to ensure the games alternate between exclusion and inclusion as piloting suggested receiving two exclusion games in a row caused high rates of disengagement from the experiment by children.

Children were randomly assigned to either the implicit or explicit condition. In the implicit condition, players did not talk to the children. However, in the explicit condition, players talked to the children. Specifically, in the inclusive game, after receiving the first ball toss, children heard the other players each say, “Let’s keep playing together!” twice (i.e., in total four times) to communicate that the other players want to include the children in the game. In the exclusive game, children heard the other players each says, “We don’t want to play with you!” twice to communicate that they want to exclude children from the game. Four 10- to 5-year-old children (two boys and two girls) recorded these short voice clips for use in the study; each child recorded both the inclusive and exclusive voice clips. To prepare children for the explicit condition, children were told the other players will occasionally talk to them during the game. All other aspects of the study were identical between implicit and explicit conditions.

Demographic Questionnaire. Basic socio-demographic information was collected through the same questionnaire as in Experiment 1.

Design & Procedure.

Children first played a warm-up cyberball game with cartoon characters to familiarize them with the controls of the game. Children were tossed the ball twice out of five tosses in this familiarization game. The experimenter demonstrated that touching the photograph of a character will send the ball to that character. Children then practiced playing the cyberball game and practiced the preference, sharing, identification, and moral evaluation tasks with the cartoon characters. All children successfully completed the familiarization game.

After the familiarization game, children were told they would be connected to other children players and would play four ball tossing games with different players. Children then saw photographs of two other children, whom the experimenter introduced as other children who were going to play the game with them. The other players always matched children in gender. Once the children were ready, the experimenter started the game and children proceeded to play the first game. The end of the game was signaled by the words "The End" appearing on the screen, a chime, and instructions that the game has ended. Each game lasted approximately 1 minute.

Immediately after playing the game, children saw four photographs: two photographs of the players children just played with (*previous players*) and two photographs of players children have not played with (*new players*). The experiment was designed to always test children's responses toward players they interacted with versus players they have not interacted with, rather than contrasting inclusive players with exclusive players. This comparison allowed us to look at how children judge each type of players separately and reduce the working memory load children would need to remember each pairs' actions. The photographs of the players were matched in attractiveness, emotional expressions, and friendliness by adult raters and were counter-balanced across participants. The experimenter reminded children which players they just played with and which ones were new players. She then administered the preference, sharing, detection, and moral evaluation task. The order of the tasks was counter-balanced across participants.

Preference Task. Children were asked to choose which pair of players they would like to play with next. They were asked to indicate their choice by touching the photographs of the players they would like to play with next. After children indicated their preference, they were asked why they liked the pair they chose.

Sharing Task. Children saw three stickers appear on the screen and a basket in front of each pair. Children were instructed to distribute the stickers between the two pairs by touching the basket of the pair they want to give each sticker to. After children finished distributing the stickers, they were asked why they chose to give more stickers to one of the pairs.

Identification & Moral Evaluation Tasks. For the identification and moral evaluation tasks, the experimenter pointed to the previous players and asked children the following questions. In the *identification* question, children were asked, "Did these players share or not share the ball with you?" For the *moral evaluation* question, children were asked, "Were these players nice or mean?" The order of the words (share or not share; nice or mean) were counter-balanced between participants. Children then proceeded to the next game until all four games were completed. For each game, children saw different players from the previous games to ensure no carry-over effects.

Coding. All dependent variables were a series of binary choices except the sharing task. In the preference task, children could either choose to play with the previous players again (coded 1) or play with new players (coded 0) for each game. For the sharing task, children could give 0 to 3 stickers to previous player. In the reasoning task, for the detection question, children could either respond that the previous players shared (coded 1) or did not (coded 0). For the moral reasoning question, children could either respond previous players were nice (coded 1) or mean (coded 0).

Results

As in Experiment 1, generalized linear mixed models (Baayen et al., 2008) were conducted using a step-up strategy for model building (see West et al., 2014). Binomial probability distributions were used to analyze preference, identification, and moral evaluation tasks. Poisson distribution were used for the sharing task as the dependent variable ranged from 0 to 3. Our main hypothesized variables of condition (explicit vs. implicit), game type (inclusion vs. exclusion), children's age in months, and interaction of these terms were entered into the models as fixed effect predictors. Age was centered at the mean value of 57.56 months to help model convergence. As random effects, random intercepts were entered for participant ID to account for dependencies within participants. We also tested whether children had a sibling, the number of social activity hours per week, testing location, trial number, task order, and children's sex improved the fit of the model beyond the main hypothesized predictors; none of these factors improved the main model. See Table 3 for the results of models.

Table 3. Fixed effects of best-fit models predicting the probability of children's preference, sharing, detection, and moral evaluation in Experiment 2.

Task	Predictors	β	*SE*	Wald *z*	*p*
Preference	Game	1.570	.385	4.073	.0005
	Age	.017	.016	1.085	.278
	Condition	.054	.418	.129	.897
	Age x Condition	-.004	.034	-.109	.913
	Game x Condition	-.899	.834	-1.078	.281
	Game x Age	.056	.030	1.847	.065
	Game x Age x Condition	-.172	.094	-1.832	.067
Sharing	Game	.425	.089	4.783	< .001
	Age	-.010	.003	-2.844	.004
	Condition	.239	.091	2.641	.008
	Age x Condition	-.009	.007	-1.320	.187
	Game x Condition	-.297	.189	-1.572	.116
	Game x Age	.021	.007	2.872	.004
	Game x Age x Condition	-.010	.015	-.708	.479
Identification	Game	6.616	.978	6.763	< .001
	Age	-.098	.028	-3.546	.0004
	Condition	-.367	.631	-.582	.561
	Age x Condition	.004	.086	.046	.964
	Game x Condition	.388	1.246	.312	.755
	Game x Age	.325	.080	4.071	.00005
	Game x Age x Condition	.025	.158	.157	.875
Moral Evaluation	Game	4.699	.583	8.056	< .001
	Age	-.063	.024	-2.687	.007
	Condition	1.314	.591	2.224	.026
	Age x Condition	.047	.068	.683	.495
	Game x Condition	-2.710	1.041	-2.604	.009
	Game x Age	.272	.056	4.841	< .001
	Game x Age x Condition	-.112	.119	-.940	.347

Preference Task. There were no significant effects, except a significant main effect of game type ($p = .008$) on children's preference. This result suggests that children significantly preferred previous players after inclusive games than exclusive games, regardless of age or whether exclusion was implicit or explicit. See Figure 4.

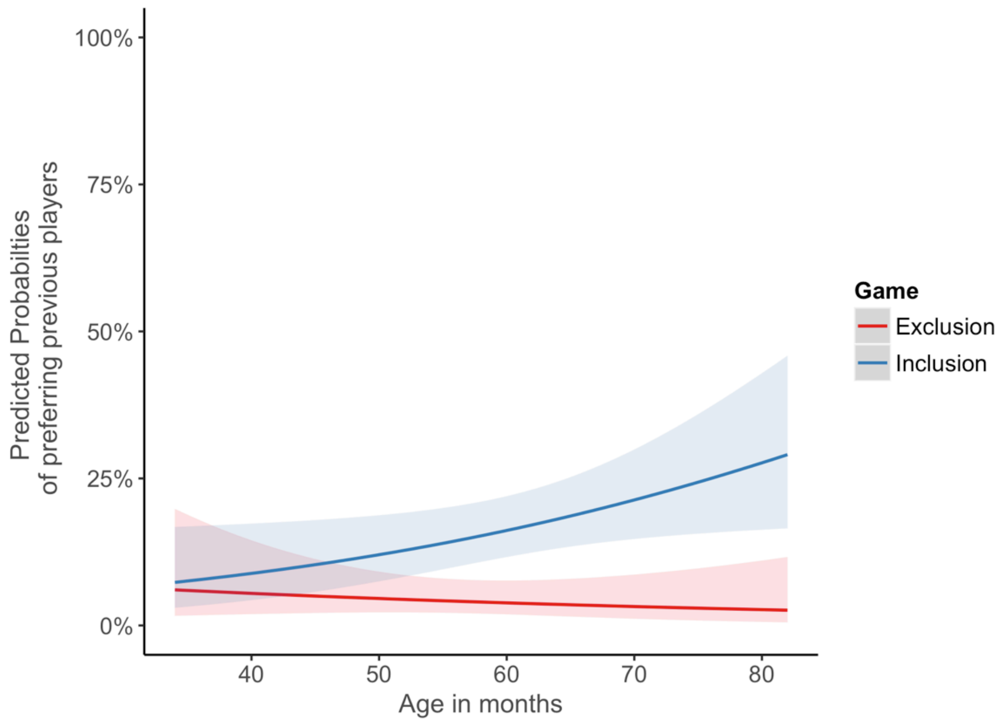


Figure 4. Children's preference task performance in Experiment 2. Blue line represents the predicted probabilities of preferring previous player after *inclusive* games. Red line represents the predicted probabilities of preferring previous player after *exclusive* games. The shaded area around each line represents 95% confidence intervals calculated based on the predicted values and their standard errors.

Sharing Task. There were significant main effects of game type ($p < .001$), age ($p = .005$), and condition ($p = .008$) on children's sharing patterns. As expected, children significantly shared more stickers with previous players after inclusive games than exclusive games. Children also shared more with previous players after implicit games than explicit games. With age, children were less likely to share more stickers with previous players. Importantly, there was a significant interaction between game and age ($p = .004$). This interaction suggests that with age, children tended to give more stickers to previous players after inclusive games than exclusive games. There were no other significant interactions. See Figure 5.

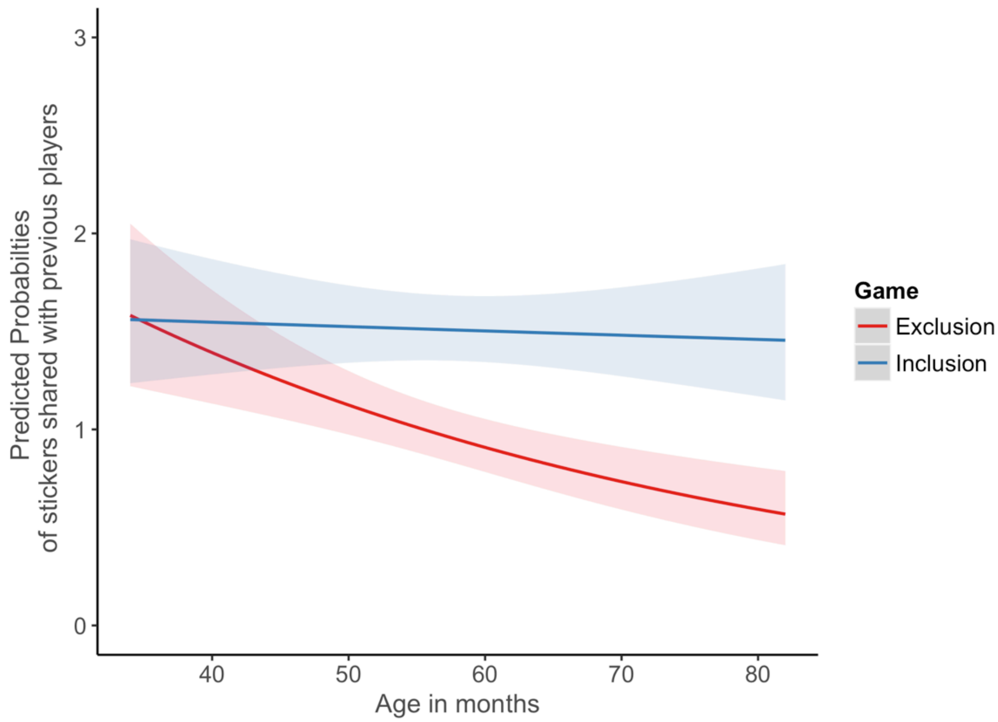


Figure 5. Children's sharing task performance in Experiment 2. Blue line represents the predicted probabilities of stickers shared with previous player after *inclusive* games. Red line represents the predicted probabilities of stickers shared with previous player after *exclusive* games. The shaded area around each line represents 95% confidence intervals calculated based on the predicted values and their standard errors.

Identification Task. There were significant main effects of game type ($p < .001$) and age ($p = .0004$) on children's identification. Children were significantly more likely to report previous players shared after inclusive games than exclusive games. With age, children were less likely to report previous players shared. Crucially, there was a significant interaction between game and age ($p < .001$), suggesting that with age, children were more likely to correctly report previous players shared after inclusive games than exclusive games. There were no other significant interactions. See Figure 6.

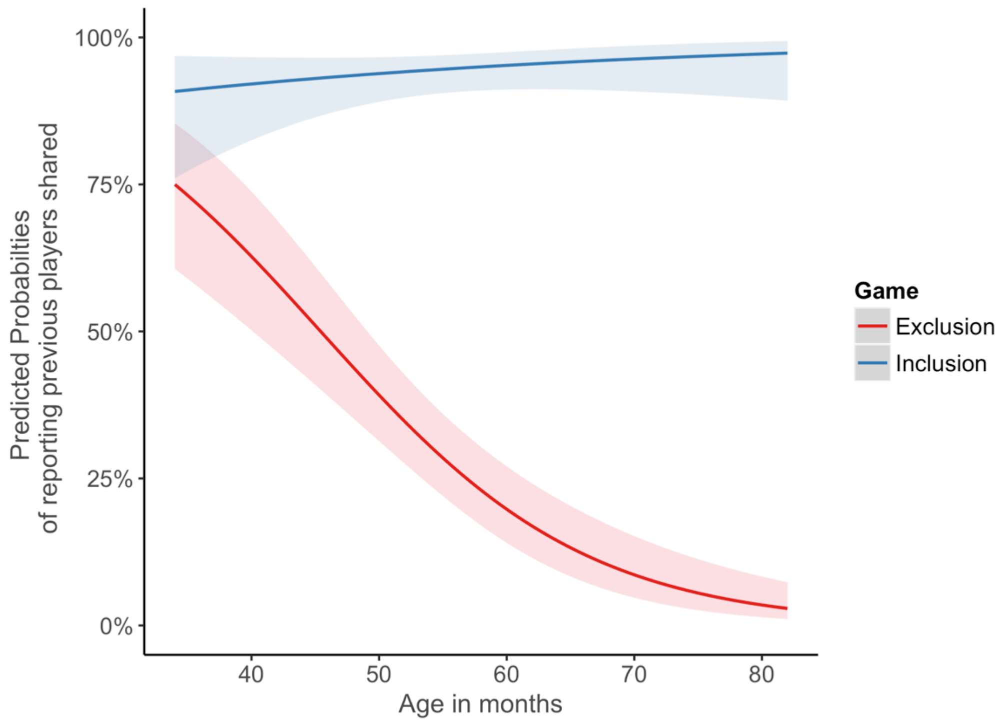


Figure 6. Children's detection task performance in Experiment 2. Blue line represents the predicted probabilities of children reporting previous players shared after *inclusive* game. Red line represents the predicted probabilities of children reporting previous players shared after *exclusive* game. The shaded area around each line represents 95% confidence intervals calculated based on the predicted values and their standard errors.

Moral Task There were significant main effects of game type ($p < .001$), age ($p = .007$), and condition ($p = .026$) on children's moral evaluation. Children were significantly more likely to report previous players were nice after inclusive games than exclusive games. With age, children were less likely to report previous player were nice. Although children overall were more likely to report previous players were nice after implicit games than explicit games, there was a significant interaction between game and condition ($p = .009$). This interaction indicates that children did not differ in their evaluation of previous players according to whether inclusion was implicit or explicit, but children were more likely to report previous players were mean after explicit exclusion than implicit exclusion. There was also a significant interaction between age and condition (p < .001) indicating that with age, children were more likely to report players were nice after implicit games than explicit games. See Figure 7.

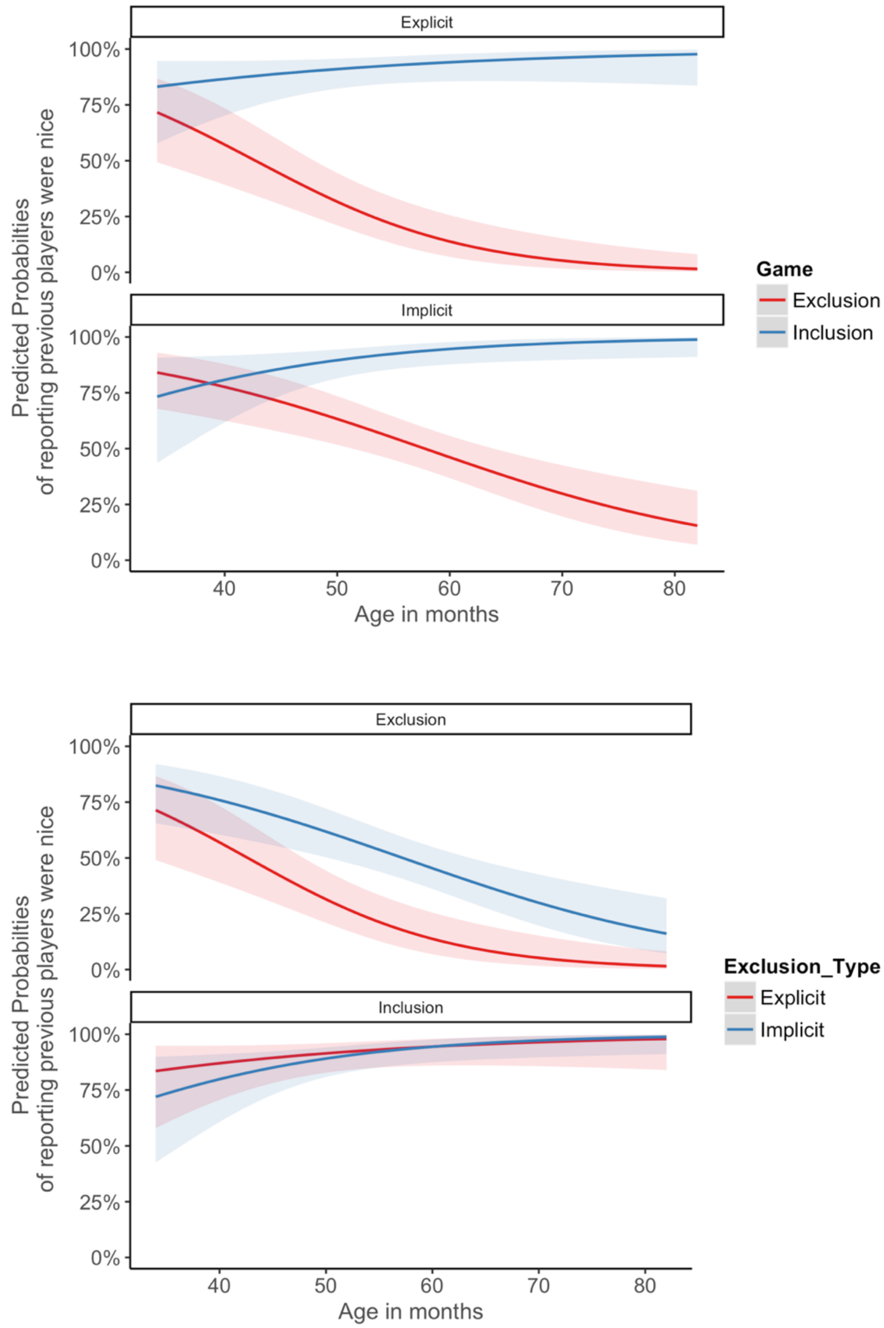


Figure 7. Children's moral evaluation task performance in Experiment 2. The upper figure represents children's moral evaluation grouped according to condition. The lower figure represents children's moral evaluation grouped according to game type.

Comparing across Tasks. To determine whether children's performance in the four tasks differed, generalized mixed models were conducted with condition (explicit vs. implicit), task type (preference, sharing[2], detection, and moral evaluation), age, game type (exclusion vs. inclusion), and interaction of these terms as main fixed effect predictors. Random intercepts for participant ID were entered as random effects to the model.

A model with a four-way interaction among condition, task type, age, and game was not a significantly better than a model without the four-way interactions (likelihood ratio tests, χ^2 = 3.240, *df* = 3, *p* = .356). A series of likelihood ratio tests of the different three-way interactions indicated that the three-way interaction among game, age, and task type was the only three-way interaction term that significantly improved fit beyond a model with two-way interactions. Follow-up comparisons of the three-way interaction among game, age, and task-type indicated that children's distinction of inclusive and exclusive players in the sharing task was significantly different from the moral evaluation and detection task across age; there were no other differences among tasks. Although there were other significant two-way interactions and main effect differences among the tasks, the sharing task was the only task that differed from the other tasks according to game and age. This difference appears to be due to sharing patterns between inclusive and exclusive players emerging later in age than the detection and evaluation tasks.

Discussion

Children across all ages treated inclusive agents more positively than exclusive agents in the different tasks. Although children showed age-related changes in the sharing, identification, and moral evaluation tasks, children did not show any age-related differences in the preference

[2] Children's sharing pattern was re-coded to a binary variable to match the outcome of the other tasks. Children who shared more stickers with previous player were categorized as 1, whereas children who shared less stickers with previous player were categorized as 0.

task. Children significantly preferred previous players after inclusive than exclusive games, regardless of age and whether intentions were implicit or explicit. Such lack of age-related development in the preference tasks suggest children's preferences are a robust indicator of children differentiating inclusive and exclusive individuals even at the youngest preschool age. Strikingly, this result also suggests even young children could detect implicit, nonverbalized social exclusion and avoid those who implicitly exclude them.

Children could also verbally identify exclusive players regardless of whether the players communicated their intentions verbally or not. Children were more likely to report previous players did not share after exclusive games than inclusive game. However, unlike in their preferences, children did increase in their correct reporting of exclusion with age as hypothesized.

In contrast, children's sharing patterns and moral evaluation were modulated by age and the implicit or explicit nature of the interactions. With age, children improved in their discrimination of inclusive and exclusive players in their sharing patterns: they shared more stickers with previously inclusive players than previously exclusive players as they got older. Interestingly, children overall tended to share more stickers with previous players after implicit games than explicit games. This greater sharing with previous players in implicit games may reflect children's strong tendency to reciprocate (Engelmann, Over, Herrmann, & Tomasello, 2013; Olson & Spelke, 2008; Tomasello & Vaish, 2013). Because players' intentions were more ambiguous in implicit games than explicit games, children may have been more open to continuing connections with familiar individuals who had ambiguous intentions than familiar individuals who were unambiguously exclusive toward them.

Children also showed an influence of explicit versus implicit exclusion on their moral evaluations of the players – but only after exclusion games. With age, children were more likely to evaluate players as meaner after explicit exclusion games than implicit exclusion games. This greater tendency to evaluate players as meaner after explicit exclusion is again due to players' intentions being more ambiguous after implicit exclusion than explicit exclusion. However, children did not show a difference in moral evaluation after inclusion games, regardless of whether players communicated their intentions implicitly or explicitly. Children robustly labeled players as nice after inclusive games than exclusive games overall and their correct identification improved with age.

Lastly, contrary to our hypotheses, children did not appear to show earlier discrimination of exclusive and inclusive agents in nonverbal tasks compared to verbal tasks. Across development, children's sharing pattern was the only task that differed from the verbal tasks in its discrimination of exclusive and inclusive agents. However, this difference appears to be due to sharing patterns between inclusive and exclusive players emerging later in age than the verbal tasks. Furthermore, children's preference patterns did not emerge earlier than children's verbal identification and moral evaluation. Children's performances across age in these tasks also did not differ according to whether exclusion was explicit or implicit. This lack of difference among tasks suggests that preference, sharing, identification, and detection tasks were equally good at capturing children's discrimination of inclusive and exclusive players across development.

General Discussion

The present study sought to clarify whether preference measures may reveal young children's processing of social exclusion at an earlier developmental stage than verbal report measures. Although relational aggression and verbal understanding of exclusive behaviors are observed to emerge in preschool age (Crick et al., 1997; Killen & Rutland, 2011), findings from recent socio-cognitive research suggests even infants demonstrate sophisticated processing of positive and negative social interactions from nonverbal measures, such as preference behaviors (Burns & Sommerville, 2014; Hamlin et al., 2007, 2011). Thus, tracing how children's ability to notice and respond to social exclusion using corroborative measures provides an opportunity to compare and contrast the utility of these laboratory-based measures, as well as answer theoretical questions concerning when the sensitivity to social exclusion emerges in development.

The present results show that the ability to detect and respond to social exclusion may be present in children as young as 3 years, but becomes more sophisticated with development. Across different paradigms and tasks, preschool age children showed consistent age-related development in their ability to detect and respond to exclusion. Five- to 6-year-old children reliably demonstrated detection of exclusion in all task domains, whereas 3- to 4-year-old children showed less consistent performance. In all tasks, older children performed above chance at distinguishing inclusive agents from exclusive agents. In contrast, younger children showed more difficulty performing above chance on both verbal and nonverbal tasks.

Surprisingly, children were not better at detecting exclusion when it was communicated verbally (explicit exclusion) than exclusion when it was communicated nonverbally (implicit exclusion). Across Experiments 1 and 2, children showed little difference between explicit and implicit social exclusion. Although children were marginally more likely to verbally detect explicit exclusion than implicit inclusion in Experiment 1, children's preferences did not differ between explicit and implicit exclusion in Experiment 1. Experiment 2 further supported this lack of difference in explicit and implicit exclusion in other domains: children showed no difference in their verbal identification of exclusion between implicit and explicit exclusion. Furthermore, differences observed in sharing patterns and moral evaluation of the players across explicit and implicit exclusion appeared to be due to judgements based on how clearly players' intentions were communicated, rather than differences in the detection of social exclusion compared to inclusion. Children appeared to be more generous and more likely to evaluate players positively when the players' intentions were not verbalized rather than when players' intentions were explicit.

Contrary to our predictions, preference measures did not consistently distinguish children's detection of exclusion at an earlier developmental point than verbal measures. In Experiment 1, 3-year-old children did not show a significant preference for inclusive puppets over exclusive puppets after implicit or explicit exclusion. In fact, children's performance did not differ between preference and verbal identification. In addition, children in Experiment 2 showed no difference in preference and verbal measures: preferences did not differ from verbal measures in capturing children's distinction of inclusion and exclusion. Results suggest that preference measures closely track children's underlying response to social exclusion but may not necessarily emerge earlier than what children can communicate verbally.

The similar developmental trajectory of preference and verbal report was surprising, as preference tasks have been argued to be a useful measure of preverbal children's social cognition. It is possible that in Experiment 2, children's preference for novelty may have subdued children's preference for inclusive agents and avoidance of exclusive agents. The forced-choice preference measure pitted a novel, neutral player against an exclusive or inclusive player in Experiment 2, but children showed a strong tendency to choose new players after all games. Such preference for novelty may have caused less distinction between exclusive versus neutral agents or between inclusive versus neutral agents. However, children still showed a significant distinction of exclusive versus inclusive agents in Experiment 2, suggesting that across different comparisons and designs, young children do show a preference for inclusive agents and avoidance of exclusive agents.

Another possible explanation for why preferences did not emerge earlier than verbal report may be that there are many factors that contribute to preference for an agent beyond the assessment of the agents' behavior or character. When asked why they chose certain agents, many children responded they did so due to physical characteristics, such as the color of the puppets and, in the case of pictures of children, hair color. These physical characteristics were experimentally controlled and counterbalanced, but nonetheless could have influenced children's preference responses. It may be that preference and sharing behavior toward inclusive and exclusive agents also require children to become more skilled at weighing more relevant factors (e.g., behavior, disposition) over less relevant factors (e.g., physical characteristics). Taken together, the present findings suggest that preference measures reflect children's detection of social exclusion but preference for inclusive agents and avoidance of exclusive agents do not emerge earlier in development than verbal identification of exclusion.

To better understand the relation between children's preferences and verbal responses, further work should explore how individual differences in cognitive and social abilities affect young children's exclusion detection, especially concerning the differences in detecting verbalized (explicit) versus nonverbalized (implicit) social exclusion. For instance, children with developmental disorders and impairments in social capacities, such as Autism Spectrum Disorder and Williams Syndrome, might show a reduced ability to detect and respond to explicit versus implicit social exclusion compared to typically developing children (Järvinen, Korenberg, & Bellugi, 2013; Klein-Tasman, Li-Barber, & Magargee, 2011). Typically developing school age children who have high rejection sensitivity – a disposition to expect, readily perceive, and overreact to social rejection – are found to show higher distress responses after ambiguous exclusion than those with low rejection sensitivity (Downey, Lebolt, Rincón, & Freitas, 1998; Rubin, Bukowski, & Bowker, 2015). It is possible that even in younger children, individual variations in rejection sensitivity may affect children's responses toward inclusive and exclusive agents. The amount of peer and group play experience may also predict children's response to social exclusion. Our measure of such social experience was limited and therefore no significant relations were found between social experience and response to social exclusion, but a more comprehensive measure of social experiences and social abilities may better capture individual differences in social exclusion detection.

To conclude, the present findings answers both theoretical and applied questions behind children's understanding of social exclusion. Our results demonstrate that children as young as 3-year of age readily detect social exclusion, regardless of whether exclusion is explicit or implicit. This ability to detect and process social exclusion earlier in childhood than previously thought highlights the importance of addressing relational aggression in early childhood. The present study also emphasizes the importance of applying multiple methods when assessing children's social cognitive abilities. Children's preferences for inclusive over exclusive agents closely track their correct verbal report and assessments of the agents and there appears to be little age-related differences in verbal and nonverbal measures in capturing children's detection of exclusion. In fact, discerning exclusive and inclusive players in sharing behavior appears to occur slightly later in childhood than verbally reporting exclusion, suggesting children's decisions to treat agents differently according to their past interactions may emerge more slowly in development. This relationship between nonverbal measures and verbal measures has important methodological implications for the field of developmental social cognition as well as practical and clinical implications of bullying and atypical social development.

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Chapter 4: Conclusion

The present work aimed to directly test the theoretical claims about how we as human detect social exclusion using both physiological and behavioral methods across different life stages. Because being excluded from a group is a common human experience that starts in early childhood, this basic human need to belong or connect with others is argued to be universal and thought to have an evolutionary basis. In fact, it has been argued that the ability to detect being excluded may be present from birth and occurs rapidly with little cognitive processing. Study 1 tested whether this rapid detection of exclusion is reflected in pupil dilation and how discerning this signal is of the social nature of exclusion. Study 2 tested how social exclusion detection emerges across the preschool years using both verbal and nonverbal measures.

Study 1 found that adults show consistent pupil reactivity to viewing exclusive individuals compared to inclusive individuals. Although pupil dilation generally decreased when viewing players' pictures a second time, when the players were exclusive in the cyberball game (i.e., did not share the ball with the participants) pupil dilation decreased less than when players were inclusive. This sustained pupil dilation to exclusive individuals compared to inclusive individuals suggests that exclusive individuals elicit more of an arousal response than inclusive individuals. Further, this arousal response to exclusive individuals occurred regardless of whether the players were human players or computerized non-human entities. In fact, the magnitude of pupil dilation to exclusion was not correlated to self-reported distress levels or individual differences in rejection sensitivity. Pupil dilation also occurred even when viewing third-party social exclusion, suggesting sensitivity to exclusion occurs even when participants did not necessarily experience exclusion themselves.

The indifference of pupil dilation to the social nature of exclusion or individual differences suggests pupil dilation reflects the initial detection of ostracism. This finding supports the idea that pupil dilation, or the initial physiological arousal to encountering exclusion, is part of the reflexive response hypothesized in the Temporal Need Threat model (Williams, 2009). According to Williams, reflexive responses occur without much cognitive processing. Pupil dilation occurred in response to exclusion even from non-social entities and was not necessarily related to later occurring cognitive appraisal processes that are captured in self-report ratings or individual differences in personality. Thus, pupil dilation appears to capture the reflexive response to encountering social exclusion. Study 2 also provides support for the idea that the ostracism detection system is "quick" and "crude" (Haselton & Buss, 2000). Pupil dilation occurred within three seconds of participants viewing exclusive individuals, supporting the idea that detecting ostracism is "quick." Furthermore, pupil dilation occurred even for exclusive computer players, who do not have any bearings in real life, suggesting that the initial detection of ostracism may indeed be "crude" – responding to even miniaml signals of exclusion.

Thus, physiological arousal to exclusion appears to be captured in pupil dilation. Pupil dilation thus may be a promising indicator of ostracism detection. Study 1 not only empirically tested and clarified the mechanism behind the ostracism detection system, but also provides a promising methodology to investigate social exclusion detection in future research. Pupillometry is a noninvasive and relatively cost-effective methodology that can be easily applied to study the cognitions of children and infants because it is more comfortable for participants (i.e., require less restrictive measures) than other physiological measures, such as heart rate or neuroimaging (Geangu et al., 2011; Hepach et al., 2012). Furthermore, it is a nonverbal measure, which is advantageous for investigating preverbal infants as well as nonverbal clinical populations. Thus, the finding that pupil dilation indexes arousal in response to social exclusion in adults holds great promise for applying pupillometry to test social exclusion detection in young children in future work.

Study 2 found that children as young as 3 years of age could detect social exclusion, but there is developmental change in the ability to respond to social exclusion. Specifically, 5- to 6-year-old children could verbally report and evaluate exclusive agents above chance as well as prefer and share more with inclusive agents than exclusive agents. In contrast, 3- to 4-year-old children were not always above chance in correctly distinguishing exclusive agents from inclusive agents in these verbal and nonverbal tasks.

Contrary to expectations from previous research on social cognitive reasoning in infancy, young children's nonverbal responses (i.e., preferences and sharing behavior) did not necessarily reflect detection of exclusion at an earlier age than their verbal responses. Children's preferences closely matched their verbal distinction of exclusive and inclusive agents and both preferences and verbal reasoning appeared to mature at a similar rate across development. Further, challenging the extant observational research on relational bullying in preschool age children, children did not detect exclusion communicated verbally (explicit exclusion) at an earlier age than exclusion that is communicated nonverbally (implicit exclusion). Children were also able to detect implicit exclusion equally well as explicit exclusion with no age differences in their detection. Such finding suggests that children show remarkably early emerging ability to notice when one is left out – even earlier than suggested from observational research.

Study 2 demonstrates that the ability to detect social exclusion emerges in the preschool years, but there is little difference in detecting explicit versus implicit exclusion and this detection can be measured equally well using both verbal and nonverbal measures. Assessing whether children's verbal report and nonverbal behavior converge or differ elucidates the developmental trajectory of children's detection of social exclusion as well as the relation between verbal report and nonverbal measures in capturing children's social cognitive reasoning. Study 2 also deepens our understanding of how verbal report and preferences change across age and how theses laboratory-based measures reflect children's processing of real-life social interactions.

Taken together, the findings of Study 2 suggest that the ability to detect and process social exclusion emerges early in childhood and has implications for how to address relational aggression early in childhood. Tracing the typical developmental trajectory of detecting and responding to social exclusion across different modalities has important clinical implications as well. Results of Study 2 can provide a baseline trajectory to which individual children's progress can be compared for potentially diagnostic and treatment purposes. In fact, future work is planned to assess how children with Autism Spectrum Disorder respond to social exclusion in the measures used in Study 2 as well as using eye-tracking and pupil dilation. Thus, Study 2 has methodological implications for the field of developmental social cognition as well as more applied and real-world implications for bullying and atypical social development.

In sum, the present body of research clarified the physiological component behind ostracism detection and the developmental trajectory of social exclusion detection in early childhood. The present work establishes pupillometry as a useful nonverbal measure to index detection of social exclusion and found support for the theoretical claim that detection of social exclusion is crude but quick. Further, based on the studies reported here, pupillometry will have wide-ranging application for investigations with nonverbal populations, especially young children and infants. Because even young preschool age children discriminate between exclusion and inclusion across verbal and nonverbal modalities, investigating children's physiological responses would be a promising step toward elucidating the ostracism detection system. Continued efforts in this area will help improve our understanding of social cognitive development and contribute to clinical efforts toward better characterizing and treating social difficulties in early childhood.