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Development of Communication in Infants: Implications for Stimulus Relations Research

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Abstract Early forms of stimulus–response relations are learned by infants to communicate with caregivers. The infant communication abilities begin with the learning of eye gazing, joint attention, social referencing, and naming, among others. Learning to engage in these early communication skills facilitates the development of more advanced phenomena seen in equivalence class formations and derived relational responding research. This article discusses evidence of early communication skills that are often required for the emergence of other, more complex forms of stimulus–stimulus relations. We emphasize the importance of establishing these types of operants early in infancy and their implications for developmental research on stimulus relations.

Keywords Infants · Stimulus equivalence · Naming · Derived relational responding · Joint attention · Social referencing

This article discusses early social abilities that are suggested from a behavioral development approach (Pelaez, 2009). We report what could be considered the first types of stimulus–response relations learned in infancy and build toward the establishment of essential building blocks for social development and communication. The primary aim of this article is to discuss research findings that outline a developmental progression from simple to more complex infant learning of stimulus relations. This developmental progression is not always linear, and some communication skills may develop in tandem, but the basic outline here is one of increasing complexity.

We begin by presenting research findings on the development of infant eye contact with caregivers, first explaining an infant's progression from a controlled eye gaze to

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learning more complex behaviors such as joint attention (sharing interest with caregivers) as a required skill for the conditioning of social referencing as a form of relational responding (i.e., the infant using the caregiver's facial emotional cues to determine whether or not to approach an ambiguous or novel object). These three early skills are seen as involving the learning of stimulus–response relations. We then explore them as potential precursors to more complex skills, such as those involved in naming (Pelaez, 2009). The assumption is that learning to derive more complex stimulus–stimulus relations (such as stimulus equivalence or combinatorial entailment) would be greatly facilitated by learning controlled eye gazing, joint attention, and social referencing as basic forms of communication. Finally, we discuss the intersections of these early communication abilities with stimulus equivalence research in infancy.

Establishing Early Stimulus–Response Relations for Communication

Learning and development begin during the prenatal period (Gewirtz & Pelaez-Nogueras, 1992a; Novak & Pelaez, 2004; Pelaez & Monlux, 2017). By noting the delay or absence of social skills during early infancy and intervening with operant learning principles, one can possibly mitigate the severity of later developmental delays (Neimy, Pelaez, Carrow, Monlux, & Tarbox, 2017). In the following sections, we discuss the first forms of what we call "relational operants" that set the stage for learning later social communication.

Eye Gaze in Infancy

Without an infant's attention, we are limited in the skills that can be taught to that infant. When a baby is born, his or her vision—specifically the neural pathways that process sight in the brain—are still developing (albeit at a rapid pace). In a matter of weeks, an infant can progress from having nearsighted vision to being able to discriminate and recognize facial features from across the room (Dobson & Teller, 1978). Although eyesight is still in development at birth, eye contact is one of the earliest operant responses an infant acquires, and this is an important building block toward the establishment of later communicative skills (Mundy & Newell, 2007; Pelaez & Monlux, 2017).

The development of early social behaviors such as attending and eye contact play a formative role in the later acquisition of communicative and more complex social behaviors such as joint attention and social referencing (Novak & Pelaez, 2004; Pelaez, 2009). By 12 months of age, typically developing infants have learned stimulus–response relations that reflect their ability to modulate their responses toward ambiguous and novel stimuli by using the emotional reactions that others display as cues (Moses, Baldwin, Rosicky, & Tidball, 2001). For example, when an infant encounters a new or ambiguous toy and seems unsure how to react to this, she orients toward the mother (i.e., searches for cues in the mother's expression) and then uses the mother's cues as a basis for her own response to the toy. Learned relations such as those shown in social referencing seem to be a form of relational responding that requires eye gazing and joint attending as precursors (Pelaez, 2009; Pelaez, Virués-Ortega, & Gewirtz, 2012).

Gazing toward the caregiver is critical for an infant learning gestural communication, thus making it an important early relational operant. Without first establishing eye contact, the infant will have difficulty displaying controlled eye-gaze shifts such as from unknown stimuli to the caregiver's face (i.e., referencing for cues). An infant referencing the caregiver's signals with respect to an ambiguous or unfamiliar event appears to facilitate early communication. Displaying poor or no eye contact with others (typically caregivers) is one of the hallmark criteria that result in a formal diagnosis of autism spectrum disorder (ASD; Klin, Shultz, & Jones, 2015; Whalen & Schreibman, 2003). Studies have shown that infants at risk of ASD or other developmental delays may show a tendency to orient to other stimuli in the environment, such as toys or the mouths of others as opposed to their eyes (Jones & Klin, 2013), rather than making eye contact. In fact, a positive correlation has been found between children with ASD and the frequency of object–adult gaze switching at 20 months and later language delays and social skill deficits at 42 months (Charman, 2003). In effect, the delay or absence of sustained infant eye contact with caregivers indicates that the infant may be developmentally delayed with respect to a number of skills. This can result in associated delays in language and/or the absence of learning new stimulus–stimulus relations.

A simple conditioning strategy for increasing infant eye contact, particularly with infants at risk of developmental delays, has undergone the *synchronized reinforcement procedure* that uses contingent maternal delivered social stimuli during face-to-face interactions (Pelaez-Nogueras et al., 1997; Pelaez-Nogueras et al., 1996b). These interventions use a multimodal package of reinforcing stimuli composed of an adult smiling while simultaneously touching and cooing contingent to the infant making the eye contact response. The stimulus (Sr) is withheld until the infant initiates eye contact (R) with the caregiver and then is provided continuously until the infant disengages eye contact (or looks away). Synchronized reinforcement is an effective operant conditioning procedure to teach early social skills before or when notable deficits occur, hopefully mitigating future developmental delays.

Within the synchronized reinforcement paradigm, different combinations of social reinforcers can be individualized to the infant's specific preferences (e.g., touch with "motherese," touch alone, or even different types of touch). Researchers have evaluated this procedure with both infants at risk and typically developing infants under the age of 6 months with positive behavior gains. They have demonstrated increases in the duration of infant-directed eye contact (and gaze at the female experimenter) as well as infants' positive affect responses (smiles and vocalizations) by using reinforcement packages that are composed of contingent touch, imitation, motherese speech (cooing), smiling, and gentle touch of the infant's legs and arms (Pelaez, Virués-Ortega, & Gewirtz, 2011a; Pelaez, Virués-Ortega, & Gewirtz, 2011b; Pelaez et al., 2012; Pelaez-Nogueras, Field, Cigales, Gonzalez, & Clasky, 1994; Pelaez-Nogueras, Field, Hossain, & Pickens, 1996a; Pelaez-Nogueras & Gewirtz, 1997; Pelaez-Nogueras, Gewirtz, et al., 1996b).

When a multimodal reinforcement package includes touch stimuli in general, it is more effective at increasing infant eye contact as opposed to compound stimuli that do not include contingent touch (Pelaez-Nogueras, Field, et al., 1996a; Pelaez-Nogueras, Gewirtz, et al., 1996b). Although most of these experiments were conducted in laboratories, these findings ARE being replicated in more natural environments, such

as the caregiver's home (Neimy et al., 2017). The multimodal reinforcement procedure allows researchers to compare different densities and modalities of paired social stimuli (i.e., touch, smiling, motherese, and vocal imitation; see (Pelaez & Monlux, 2017), for further details on operant conditioning procedures).

Parents are natural agents of change with regard to their own infants, with typical interactions containing requests for child behaviors ("Look at ___") as well as frequent multiple vocal and visual stimulus presentations with infants as young as 4 months old. As we will discuss later in this article, "it appears that most parents provide the kind of intensive trials involving multiple stimuli and response relationships for the development of a generalized behavior [and possibly] relational responding" (Novak & Pelaez, 2004), p. 263). Once eye contact has been established, it lays the foundation for developing joint attention (attending) in older children (Pelaez, 2009). Establishing eye gaze is not only a requirement for subsequent, more advanced skills but is also considered a *behavioral cusp* for the development of other stimulus–response relations such as those involved in social referencing, naming, and (potentially) perspective taking (McHugh, Barnes-Holmes, & Barnes-Holmes, 2009). Behavioral cusps involve behavior changes—sometimes simple, sometimes complex—that systematically cause other, further, not formally programmed meaningful behavior changes. Cusps are significant "either because of their breadth or because of their importance to the organism or its species" (Rosales-Ruiz & Baer, 1997), p. 537). An eye contact cusp, therefore, can involve small or large behavioral changes, but the significance lies in the additional stimulus–response relations that the learner may be exposed to once acquiring the skill. Sustained infant eye contact with others thus sets the stage for acquiring joint attention.

Joint Attention

Joint attention refers to an infant's ability to make eye contact with another individual, shift her gaze to some stimuli (that her communicative caregiver is simultaneously looking at), and regain eye contact with the same caregiver. This triangular relationship among stimuli, the adult, and the learner allows the adult and the learner to quickly jointly reference stimuli with or without physically pointing (e.g., with a finger) or showing (e.g., by elevating or placing the object in front of the infant's face). Joint attention plays an important role in the early learning of a variety of stimulus–stimulus relations, appears to be at the core of later language such as naming and cognitive development, and provides a basis for social referencing (Mundy & Newell, 2007; Pelaez, 2009). For example, young children with autism spectrum disorder typically show deficits in eye gaze, joint attention, and social referencing repertoires. They may also later lack the ability to learn new stimulus relations required for naming and other, more complex forms of communication such as perspective taking (Isaksen & Holth, 2009; Novak & Pelaez, 2011).

Joint attention typically emerges between 9 and 12 months of age and comprises controlled eye-gaze shifts between a target object and a familiar person, resulting in a shared experience (Pelaez, 2009). Isaksen and Holth (2009) developed a protocol that targets three primary joint attending skills: (a) responding to joint attention bids, (b) engaging in turn taking based on joint attention skills, and (c) initiating joint attention. After first teaching the parent's head nod as a conditioned social reinforcer, four

children with ASD participated in a training procedure in which turn taking and joint attention behaviors were increased when the social reinforcer was contingently provided. Parents reported that skills generalized across settings and had been maintained after a 1-month follow-up period.

According to Holth, Vandbakk, Finstad, Grønnerud, and Akselsen Sørensen (2009), the reinforcer being used is critical to both the acquisition and maintenance of joint attention. Of particular importance is the process by which a stimulus becomes a conditioned social reinforcer. These researchers compared two conditioning procedures to determine the difference between elicitation and reinforcement effects. The research compared a classical conditioning pairing procedure with an explicit operant discrimination procedure for establishing new generalized social reinforcers (head nod or smiles) in the teaching of joint attention (Holth et al., 2009). A stimulus that was previously neutral was either presented at the same time (paired) as an already-established reinforcer or was conditioned to be a discriminative stimulus for reinforcement and delivered only after an arbitrary response was displayed. Then, both previously neutral stimuli were tested for generalized conditioned reinforcement effects. Seven children participated in the procedure, and 5 of the 7 made more correct responses when viewing the previously neutral stimuli that gained control over the arbitrary response by a discrimination procedure than the previously neutral stimuli that had been paired.

In typically developing infants, the joint attention process appears to be facilitated and maintained largely by conditioned social reinforcers (Dube, MacDonald, Mansfield, Holcomb, & Ahearn, 2004; Whalen & Schreibman, 2003). However, for children with ASD, social stimuli (eye contact and smiles) are often less reinforcing (Holth et al., 2009; Novak & Pelaez, 2011). This could account for these deficits in joint attention, and this makes the research on how social stimuli acquire these reinforcing properties crucial. When a researcher simultaneously conditions the reinforcing properties of the stimuli while also increasing the rate of responding to that stimulus, he or she produces more learning opportunities. This view is in line with Dube and colleagues (2004) interpretation that within the joint attention behavior chain, adult attending functions as a primary reinforcer and that smiles, along with other signs of approval such as social praise, function as generalized conditioned reinforcers. The process of first conditioning a social stimulus such as a nod or a gestural expression as a discriminative stimulus for reinforcement, prior to targeting operant training of joint attending, may thus increase the potential for more complex learning.

Developmentally, joint attending responses may be considered relational operants that are necessary and precede social referencing responses. Both of these operants are an intricate part of the tapestry that comprises typical social development. These two different communication skills appear to be critical components in the development of socioemotional stimulus–response relations (Dube et al., 2004; Pelaez, 2009). They also result from discrimination training and other operant relations.

Social Referencing

As we have proposed elsewhere (Gewirtz & Pelaez-Nogueras, 1992b; Pelaez, 2009; Pelaez & Monlux, 2017; Pelaez et al., 2012), infant referencing responses both comprise and build off of joint attention skills. Both joint attention and social

referencing involve social stimulus–response relations in a chain where the caregiver's behavior can function as both a cue and a reinforcer for maintaining an infant gazing at the caregiver's face (DeQuinzio, Poulson, Townsend, & Taylor, 2016; Holth, 2005; Holth et al., 2009; Pelaez et al., 2012).

Specifically, the infant learner needs to be able to view the caregiver's emotional reactions (e.g., grimace or smile) and use them as discriminative stimuli that inform her own referential understanding in ambiguous or novel contexts (Moses et al., 2001). In Pelaez et al.'s (2012) experimental preparations, social referencing was described as a behavior chain in which two individuals (caregiver and child) were involved in an interaction in which (a) they both made eye contact; (b) they both shifted their gaze to an ambiguous or strange stimulus; (c) they both shifted their gaze back to one other, regaining eye contact (this is joint attention); (d) the caregiver displayed a facial cue (e.g., fearful face = A or happy face = B); and (e) the infant responded differentially to novel toys (approached the toys after the happy face or inhibited that approach after a fearful face). This conditional discrimination sequence was learned from different consequences delivered to the infant for reaching based on the caregiver's cues. In that study, when an infant jointly attended to the novel object, the infant either approached the ambiguous stimulus after referencing her mother's smiles (SD+) and received praise, touch, and pleasant tinkling chimes or did not approach (refrained from touching the toy) after her mother's fearful expression (SD−). After multiple training trials of stimulus–response–consequence relations, the infants learned to respond differentially to the two sets of cues. Items were used only once so that the relation being taught was based off of the cue and not the item itself. In this way, how to respond to stimuli could be reliably conveyed through the social referencing sequence without direct instruction with each novel stimulus/event.

The emotional and social aspects of referencing responses (the mother's fearful and happy or joyful expressions) can facilitate the young child's development of other stimulus relations (e.g., those involved in the understanding of the emotions of others). Displays of sympathy and empathy for others are social abilities that appear to require the learning of basic relational operants such as joint attending and referencing (Pelaez, 2009). From our behavior–analytic developmental perspective, social referencing is an example of early social knowledge and understanding of stimulus relations that often involves an emotional component (i.e., emotional expressions that function as signals; (Gewirtz & Pelaez-Nogueras, 1992b). To put it simply, the experienced learner, through operant conditioning, begins to orient to social cues (e.g., smiles or cringes) of another individual to determine whether social reinforcement or punishment is more probable when approaching the unfamiliar stimulus, event, or person. The adult's facial expression (either a fearful or happy face) becomes a triggering event that establishes (or alters) the meaning of the ambiguous event (e.g., the item, situation, object, or stranger). It functions as either a cue that signals reinforcement for reaching or an aversive cue that signals punishment for reaching (DeQuinzio et al., 2016; Pelaez et al., 2012).

Thus, in line with our behavior–analytic approach, it becomes feasible to establish the young learner's referential responses using the emotions displayed by others. In other words, once referencing has been established, it is likely that a whole array of more subtle emotional adult reactions and appropriate response patterns, such as fear and empathy in appropriate contexts, could be transferred to infants. This general approach has been adopted in a number of studies.

In Gewirtz and Pelaez-Nogueras's (1992b) initial experiment, 20 pairs of mothers with infants aged 9 to 12 months underwent a within-subjects reversal design procedure. In this experiment, ambiguous or arbitrary hand-to-face gestures were used to condition the infant's approach (or nonapproach) behavior to unfamiliar toys. Half of the infants were taught to approach toys that were unveiled after their mothers displayed a neutral face with fist to nose (i.e., an originally arbitrary stimulus = A) and were taught to avoid toys that were preceded by their mothers making a neutral face with their palms to their cheeks (i.e., arbitrary stimulus = D), whereas the other half was counterbalanced to approach and avoid the opposite ambiguous gestures. Correct infant approaches (B) on positive trials were reinforced by being paired with tinkling chimes (C), and incorrect infant approaches (E) on negative (aversive) trials were punished by being paired with an unpleasant noise and abrupt movement of the object (F). By conditioning (pairing) arbitrary gestures (palms to cheeks and fist to nose), the researchers were able to provide support to the notion that the stimulus–response–consequence relations learned in social referencing result from operant learning and are not an innate ability (Gewirtz & Pelaez-Nogueras, 1992b).

This original social referencing study was replicated by Pelaez et al. (2012) with 11 younger infants (4 to 5 months old). In this second experiment, however, instead of arbitrary, meaningless hand-to-face cues, the caregiver's natural emotional expressions of smiles and fearful faces were established as cues (SDs) for responding. In a repeated-measures reversal design, the mothers displayed their typical facial expressions of joy (A) to signal social reinforcement (B) for the infant reaching for a toy and fearful faces (D) signaling punishment (E) for reaching. Subsequently, researchers conducted another replication of the same procedure to teach infants of depressed mothers (infants "at risk") to reference facial emotional signals (Pelaez, Virués-Ortega, Field, Amir-Kiaei, & Schnerch, 2013). The later study found that infants of depressed mothers had lower baseline instances of correct responding to social referencing. After undergoing the operant conditioning procedure, the infants of depressed mothers showed similar results—higher correct rates of approaching objects preceded by the smiling cues and avoiding objects preceded by the frowning or fearful faces or cues.

Correct responding in social referencing requires an infant to demonstrate differentiated responding as the result of discrimination training (Pelaez, 2009). Specifically, the early learning of stimulus–response relations is critical: The smile or joyful face acquires the properties of S+ stimuli and signal that reinforcement (e.g., access to a fun toy) is available, whereas the frown or fearful face acquires the properties of S− stimuli that signal punishment (e.g., no access to a fun toy and unpleasant, loud sounds) is available but should be avoided (DeQuinzio et al., 2016; Pelaez et al., 2013; Pelaez et al., 2012). The stimulus–stimulus relation between the facial expression and the ambiguous stimuli is taught, and after that relation is learned, that relationship can generalize to untaught relations with other objects, stimuli, or people.

Typically developing infants do not require extensive drilling to learn the difference between positive stimuli, such as toys, or negative items that may cause harm, such as a hot stove; they appear to learn exemplars of each and generalize that relationship to other stimuli. One way in which such generalization may occur is through learning to name objects and events, an area to which we now turn.

Naming in Early Childhood

Typically, by the age of 12 months, an infant is not only able to display joint attention and social referencing with others but is also learning to point and name objects. Learning to relate a name to an object typically involves an infant tracking the eye gaze of the person naming the object to determine what he or she is naming. Then, repeating the name in the presence of the object typically involves looking from the object back to the caregiver to reference the caregiver's signals to confirm the name and furthermore determine how to respond in the presence of this object. The child would need to jointly attend to the object with the caregiver to identify the correct name. Once infants have established sufficient naming repertoires, these can become generative; that is, "(a) relatively novel naming relations can be developed without direct shaping, and (b) some naming responses can be maintained without reinforcement as long as other naming responses are reinforced" (Pelaez-Nogueras, 1996 pg. 300).

The original work by Horne and Lowe (1996) is important because the authors offered a research model and theoretical basis for beginning to conduct experimental analyses of early forms of verbal behavior (e.g., naming) in young children. Indeed, the procedures examined by Horne and Lowe (1996) to assess linguistic relations have permitted further examination in natural settings. If an experimental analysis of naming could reveal conditioning histories that produce naming behavior and systematic observation could reveal similarities in natural settings, then we would have, at the very least, a semblance of an understanding of other language skills (Pelaez-Nogueras, 1996). It appears that a young child's ability to name an object is frequently a precursor that can facilitate stimulus equivalence relations, as defined by Sidman and colleagues (see (Sidman, 1994), for a book-length treatment of stimulus equivalence research). Bidirectionality seems to occur when naming involves a behavioral relation that evokes (and itself is evoked by) classes of events. This suggests an overlap with the bidirectional nature of a relation of symmetry in an equivalence class. We know that as early as 6 months of age, infants begin to respond to some symbolic language cues, as with the type of infant social referencing discussed earlier (learning the facial expressions or gestures of caregivers). By the time infants reach the age of 12 months, their receptive language can typically be well above 100 words (Novak & Pelaez, 2004).

Research has also shown instances of infants forming some stimulus–stimulus classes, understanding referencing behavior, or separating objects into categories before being able to name them (see Pelaez-Nogueras, 1996), for a review). In fact, expressive vocabulary does not usually catch up until about the age of 18 months. It is conceivable that at least basic forms of derived stimulus relations, such as those involved in equivalence classes, could occur before expressive naming develops (Pelaez-Nogueras, 1996). For example, Luciano, Becerra, and Valverde (2007) successfully established stimulus equivalence relations in a nonverbal infant prior to the infant displaying naming. The notion that equivalence class formation requires naming during match-to-sample training is thus open-ended. According to Pilgrim, "as long as naming can have any possible effect on equivalence performances, inferences about naming can be made no matter what the test outcome" (Pilgrim, 1996), p. 285).

Until this point, we have tried to provide a review of the learning of eye gazing, joint attention, social referencing, and naming as important behavioral skills for infant communication. We have suggested that these early social skills can result from the

learning of stimulus–stimulus relations and that these abilities seem to develop before the learning of more complex forms of communication (e.g., perspective taking). We believe that it is important to clarify that we are not suggesting that these early forms of communication are the only (or absolutely necessary) precursors for equivalence class formation (as in symmetry and transitivity) and derived relational responding (DRR) more generally (as in mutual and combinatorial entailment). We believe that these early abilities are important foundations for the learning of other, more complex stimulus–response relations such as those seen in stimulus equivalence research.

Even though many of the studies discussed herein suggest that normally developing infants have already developed joint attention, social referencing, and naming by the age of 1 year, there is limited evidence regarding the role played by joint attention and referencing in equivalence class formation. Furthermore, there are other communication abilities that may also act as precursors for the formation of equivalence relations that we did not discuss in this article (e.g., tacts, mands, interverbals). We believe that it is important to discuss infant research literature that deals with the early formation of stimulus–stimulus relations and to identify the intersections of these early communication abilities with the full development of equivalence classes and DRR. Therefore, in the next section, we identify stimulus equivalence research with infants and attempt to provide evidence for some of the prerequisite behavioral repertoires.

From the literature examined, one can conclude that without the skill of naming, normally developing infants require more time or training to master stimulus–response relations to criterion. Some evidence suggests that expressive naming can be seen as a related operant that might not always be needed for the appearance of some stimulus equivalence relations; however, the evidence points toward naming being able to facilitate the emergence of stimulus–stimulus classes. Our main emphasis thus far has been that joint attention and referencing skills facilitate the learning of naming. But we now turn to the intersections of these early abilities with stimulus equivalence.

Intersections of Early Communication Abilities with Stimulus Equivalence and DRR

Researchers have suggested the possibility that stimulus equivalence classes or basic relational frames (e.g., coordination) could progress in young developing children with limited receptive language abilities or understanding even before expressive language skills such as naming are demonstrated (Luciano et al., 2007; Pelaez-Nogueras, 1996). In this section, we discuss possible intersections between the skills we outlined previously with stimulus equivalence and DRR. We report a few studies that suggest that infants with more developed communication skills (i.e., naming) require fewer trials to complete conditional discrimination training before demonstrating an understanding of stimulus equivalence classes (e.g., Pelaez, Gewirtz, Sanchez, & Mahabir, 2000). From earlier studies, we know that young children who are verbal (already displaying expressive language) will do better on stimulus equivalence tasks than infants who do not have these communication skills (e.g., Devany, Hayes, & Nelson, 1986; Lipkens, Hayes, & Hayes, 1993).

Equivalence class formation in infants is the basis for later concept formation and categorization (Pelaez et al., 2000). The study of equivalence phenomena in infants and

toddlers (younger participants) is important because it can provide developmental information about the precursors required for training (Pelaez, 2009). For example, several researchers have been able to successfully establish stimulus equivalence relations in infants as young as 21 months with limited expressive and receptive language (Auguston & Dougher, 1992; Devany et al., 1986; Pelaez et al., 2000). Pelaez et al. (2000) systematically replicated the Devany et al. (Devany et al., 1986) study with nine infants between 21 and 25 months of age. Pelaez et al. were able to establish equivalence relations (i.e., combined symmetry and transitivity) in 8 out of the 9 participants (scores between 80% and 100%) by breaking down the relations. Specifically, researchers taught one relation at a time, such as A = B, to mastery (9 consecutively correct out of 10 trial sessions) before training a new relation of A = C (then D = E and D = F) and introducing the mixed trials. For training, either A or D was presented as the sample, and B, E, C, or F were the comparisons. After the mixed trials, symmetry was evaluated by switching the sample stimuli (i.e., now B was the sample and A was the correct comparison). Once the symmetry relation was demonstrated, a further conditional discrimination task was presented whereby in the presence of A, C was to be selected, followed by additional mixed trials. Finally, once these tasks had been presented, the transitivity equivalence test was presented by providing a comparison stimulus (i.e., B) and determining if the participant correctly related it to another stimulus that had not been trained (i.e., B = C with A = B and A = C being directly trained).

All nine infants were able to show derived stimulus relations (symmetry and transitivity) at criterion levels, and it was noted that several of the participants were pointing and naming the stimuli even though this was not a required part of the procedure (i.e., saying "duck" when shown an arbitrary shape that resembled a duck). The results of these early studies suggest that even though we do not know if expressive language necessarily precedes the ability to successfully perform stimulus equivalence (e.g., symmetry), having some communication abilities (e.g., joint attention, pointing and naming) does seem to facilitate full equivalence class formation (combined symmetry and transitivity; (Devany et al., 1986; Lipkens et al., 1993; Luciano et al., 2007; Pelaez et al., 2000).

The core infant communication abilities discussed thus far appear to follow a developmental progression and are interrelated (in that they build upon each other). In addition, they seem to facilitate the ability to form equivalence relations. Joint attention (attending) and social referencing, phenomena that typically appear early in life by the age of 12 months, often precede other, more advanced forms of communication such as naming. Stimulus equivalence and DRR appear to be critical to the functional analysis of language, given that stimulus–stimulus relations function bidirectionally and involve individual stimuli that can comprise classes of stimuli (Hayes et al., 2001; Hughes & Barnes-Holmes, 2014; Rehfeldt, 2011). This sentiment was similarly expressed by Horne and Lowe (1996): "A child, through learning listener behavior and then echoic responding, learns bidirectional relations between classes of objects or events and his or her own speaker-listener behavior, thus acquiring naming" (p. 185). It stands to reason that the bidirectional relations present in DRR build off of the bidirectional relations present in joint attention and social referencing, and all of these may develop from controlled gaze shifting. Without being able to follow a point or orient to a class of stimuli and then gaze shift to the comparison stimuli, the relation

can break down for the young learner. Of course, more research on these precursor abilities of infants is needed to determine exactly how these early social relational operants are built into, or intersect with, DRR.

By using innovative computer technologies such as touch screens, researchers can more easily teach conditional discriminations (Pelaez, 2009). Indeed, iPads and other tools can be useful for preverbal infants to learn the response prerequisites for the formation of stimulus classes (using adaptations of the multiple-exemplar training). Touch-screen technologies can also be used to determine if stimulus classes can be demonstrated in infants with receptive language skills but minimal or no expressive language skills (Pelaez, 2009). Once all the appropriate response prerequisites are mastered, evidence suggests that a young child with minimal expressive language skills can demonstrate the formation of arbitrary stimulus classes (e.g., (Luciano et al., 2007).

Indeed, The Luciano et al. (Luciano et al., 2007) experiment expanded on previous equivalence research by testing for generalized listening behavior across longer delays with novel stimuli and by teaching visual–visual relations. The 15-month-old participant Gloria first demonstrated symmetry with a visual–visual relation and was able to derive receptive audiovisual relations after a time delay of 2 h (without naming in her repertoire). These findings are noteworthy due to the age of the participant and the fact that DRR appeared to have been established prior to the infant displaying independent naming behavior. Furthermore, when Luciano et al. (Luciano et al., 2007) described their procedures for teaching naming, the importance of eye contact and joint attention is made clear:

> The mother took an object (A1) out of the bag, held it up at the level of Gloria's eyes, and asked her to look at the object. If Gloria did not look at the object or moved away, the trial was stopped, and the mother waited until Gloria looked at her again. (Luciano et al., 2007, p. 360)

This is a crucial aspect of the research because a trial could not have begun until eye contact was established (joint attending and referencing were also probable). The procedure thus relied on a triangular relationship among the object presented, the adult experimenter's signals or cues, and the contingencies following the infant responses.

Conclusion

From a developmental behavior–analytic approach, each of the infant skill components discussed herein can be established through operant conditioning procedures. Although all the early communication abilities outlined in this article may not necessarily emerge in the order proposed, deficits or delays in any of these early forms of communication will likely result in slower acquisition of more developmentally advanced abilities. Infant eye contact, gaze shifting, joint attention, social referencing, and naming are crucial for communication. We have suggested that prior to developing full stimulus equivalence classes and other, more complex derived relational operants, the learning of early communication stimulus–response relations occurs (Pelaez, 2009). Researchers may benefit from setting up new studies that consider the proposed developmental

progression of increasingly more complex stimulus–stimulus relations. Without these skills, an infant is limited in being able to use the ongoing cues (stimulus signals) of others to determine how to respond.

Further research also needs to be conducted using larger randomized samples of infants and longitudinal designs to determine the exact sequences and progressions of the early learning of these stimulus–stimulus relations. In this article, we have provided some ideas for further research that would involve testing and establishing the behavioral prerequisite operants in infants for the development of more complex forms of communication. We suspect that these communication abilities are critical for understanding the relation between language development and increasingly complex cognitive tasks. The logistical and methodological challenges of conducting such experimental research with large samples of infants of different ages and various levels of receptive and expressive language skills are enormous. The prospective research findings, however, would have far-reaching implications. A systematic approach that seeks to determine the interplay among controlled infant eye-gaze shifting, joint attending, referencing, and naming and their role in facilitating the formation of equivalence classes and other derived stimulus relations could be extremely useful. Insofar as the formation of equivalence and other relational classes is critical for typical language development, further research into these areas could result in better targeted interventions for language-delayed individuals.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they do not have any conflicts of interest.

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