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A systematic review of behaviour analytic processes and procedures for conditioning reinforcers among individuals with autism, developmental or intellectual disability

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A systematic review of behaviour analytic processes and procedures for conditioning reinforcers among individuals with autism, developmental or intellectual disability

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Abstract

Autism Spectrum Disorder is diagnosed when individuals demonstrate repetitive behaviours and restricted interests, especially in relation to social stimuli, that make it difficult for them to access socially reinforcing environments. Consequently, in most cases, behaviour analytic interventions initially have to focus on the establishment/conditioning of effective reinforcers. A systematic review was conducted of the literature on conditioned reinforcement that identified 33 relevant articles (published between 2002 and 2017). This article reports on the content analysis and quality of evidence and offers a summary of the findings reported in these papers. Four lines of research were identified: classical conditioning, operant conditioning, observational learning, and comparison studies. Differences and similarities are reported concerning procedures, type of stimuli to be conditioned, responses measured, reported effectiveness, and quality of evidence. Recommendations for future research and clinical practice are provided.

Keywords: conditioning reinforcer, operant, classical, pairing, discrimination, observational

Conditioning of neutral stimuli as reinforcers that can contribute to operant selection of new behaviour is one of the most ubiquitous processes in both applied and experimental behavioural research. Access to reinforcers guides learning in everyday activities and interactions, leading to the development of crucial repertoires (e.g., language acquisition). Stimulus changes that derive their reinforcing properties from an individual's learning history are called conditioned (or secondary, or learned) reinforcers. Examples of conditioned reinforcers include attention, eye contact, verbal praise, and tokens to be exchanged for various other reinforcers (e.g. food, leisure time). Generalised conditioned reinforcers have acquired their reinforcing properties "as a result of having being paired with many unconditioned and conditioned reinforcers" (Cooper, Heron, & Heward, 2019, p. 264).

Skinner (1953) provided an early conceptual description of conditioned reinforcers and the first practical applications with token economies date back to the 1950s (see Boerke & Reitman, 2014 for a general and historical overview). Since then, though, there has been little consensus on the most effective and efficient procedures for conditioning previously neutral stimuli into functional reinforcers (Axe & Laprime, 2017), particularly for children diagnosed with developmental and/or intellectual disabilities and autism who frequently lack social motivation. These children's behaviour often are sensitive to restricted and/or non-social reinforcers, which can contribute to the establishment of challenging behavioural repertoires early in their development. As they grow older and developmental delay becomes more apparent, making effective interventions essential, the need for effective reinforcers becomes even more significant. These issues are not new, in fact, the need for effective ways to establish conditioned reinforcement when teaching children with autism has been apparent for a long time (Lovaas et al., 1966) and the need to synthesise the existing literature has been identified repeatedly (Axe & Laprime, 2017; Leaf et al., 2016; Petursdottir & Lepper, 2015; Shillingsburg, Hollander, Yosick, Bowen, & Muskat, 2015).

In the main, at least one of three behavioural principles is used to establishing conditioned reinforcers: (1) classical conditioning, where neutral stimuli are paired with natural or otherwise established reinforcers (e.g., stimulus-stimulus pairing, SSP), (2) operant conditioning, where neutral stimuli become discriminative stimuli for target responses (e.g. operant discrimination training, ODT), and (3) observational learning, where conditioned reinforcers are established via vicarious reinforcement.

SSP procedures mirror the basic behavioural principle of classical conditioning, also known as Pavlovian or respondent conditioning, where a neutral stimulus is presented together with an unconditioned stimulus and thereby acquires its discriminative properties. In this procedure, "instead of signaling the consequences of responding, a stimulus simply signals the presentation of some other stimulus" (Catania, 2007, p. 198). Both existing reviews on conditioning reinforcers (Petursdottir & Lepper, 2015; Shillingsburg et al., 2015), collectively reporting on 14 studies (NB; 12 of these were the same papers), focused on different applications of SSP to condition neutral auditory stimuli as reinforcers and analysed their effects on subjects' vocal repertoires. They examined procedures in two main streams: (1) response-contingent pairing (RCP) in which the subject is expected to emit a response that then is followed by the simultaneous presentation of a neutral stimulus paired with a known reinforcer, and (2) response independent pairing (RIP), in which pairings of neutral and either conditioned or unconditioned stimuli occur on a time-based schedule independent of the subject's behaviour.

Both Petursdottir and Lepper's (2015) and Shillingsburg et al.'s (2015) reviews highlight that the SSP literature presents an impressive differentiation in terms of target behaviours and procedural variations. Shillingsburg et al. (2015) summarised these as (1) target sounds, (2) number of sounds emitted per pairing, (3) type of pairing procedure, (4) number of pairings per minute, (5) control for adventitious reinforcement (i.e. withholding reinforcement, if the child emitted the target sound during pairing trials), and (6) type of preferred item paired. They identified four pairing procedures under the generic description of SSP: (1) simultaneous, (2) trace, (3) delay presentations

that require no response from the subject, and (4) discrimination training that requires a response from the subject. Petursdottir and Lepper (2015) also provided an overview of the main procedural variations in SSP (i.e., RCP and RIP) and investigated discrimination training procedures. Based on the mixed results of their literature review, they invited researchers to keep exploring "discrimination training and response-contingent pairing as alternative to response independent stimulus pairing procedures that have predominated in the literature on establishing speech sounds as reinforcers" (Petursdottir & Lepper, 2015,p. 228).

Operant discrimination training (ODT) procedures (Lepper, Petursdottir, & Esch, 2013) or stimulus discrimination (S_D) procedures (Isaksen & Holth, 2009) are firmly grounded in the operant conditioning literature (for a review, see Bell & McDevitt, 2014). Despite minor procedural variations, the common characteristics of these procedures is that the stimulus to be conditioned as a reinforcer is contingent on a response from the participant. The protocol consists of conditioning a neutral stimulus as an S_D for a response that produces an unconditioned reinforcer and then building up a behaviour chain (Holth, 2005), as exemplified in Carbone et al.'s (2013) study on eye contact, where an analysis is offered of how "following frequent exposure to the variables that control the mand response, a behavioral chain occurs" (p. 150). In this behavioural chain, deprivation of the object acts as a motivating operation that increases the reinforcer effectiveness of the listener's gaze (eye contact) for different kinds of approach behaviour and eventually also functions as a discriminative stimulus for the emission of a mand.

SSP and ODT tend to be considered as exclusive alternative accounts of the process of conditioning reinforcers, and some studies include comparisons of their relative efficacy and participants' preference (Lepper et al., 2013). However, Donahoe and Palmer (2004) repeatedly questioned the view that classical and operant procedures involve two different kinds of learning or that they required two different fundamental theoretical treatments. They recognised that both procedures select environment-behavior relations and appealed for "a moment-to-moment analysis [that] calls for a unified theoretical treatment of the conditioning process, with the environmental

control of responding as the cumulative outcome of both procedures." (Donahoe, Palmer, & Burgos, 1997, p.198).

The third line of research regarding conditioned reinforcers focuses on observational learning (Greer & Singer-Dudek, 2008) also referred to as observational conditioning, or the establishment of reinforcers as a result of observation (Singer-Dudek & Oblak, 2013). This procedure engages both the participant and a peer in a simple task (e.g., matching), in which the participant is prevented from observing the peer's response, however, does observe the peer receiving an item (i.e., stimulus) contingent on completion of the task. The observation of vicarious reinforcement results in the previously neutral stimulus being conditioned as a potential reinforcer for the participant for both acquisition and maintenance of responses.

The fourth line of research within the conditioned reinforcer literature comprises comparison studies (Rader et al., 2014). This research also covers procedural modifications that are necessary to produce reliable and durable effects (e.g., Lepper & Petursdottir, 2017). Some of these studies report procedural variations of one conditioning procedure, where, for example, the effectiveness of variations in the number of presentations of the target sound are evaluated (e.g., Miliotis et al. (2012) examined one versus three presentations). Other studies compare different procedures such as classical and operant conditioning (e.g., Holth et al., 2009), making it difficult to draw definitive conclusions as to the relative efficacy and effectiveness of specific procedures.

This research is further complicated by the range of methods used to assess the effectiveness of the conditioning procedure. In the studies that explicitly examine the effects of conditioning, the new response method assesses the effect of the newly established conditioned reinforcer on novel responses (Taylor-Santa, Sidener, Carr, & Reeve, 2014) and the extinction method assesses resistance to extinction of behaviours when reinforced with conditioned reinforcers (Jerome & Sturmey, 2014). The new response and the extinction testing methods typically produce fleeting effects, both in experimental (Kelleher & Gollub, 1962; Williams, 1994) and applied (Esch, Carr, &

Grow, 2009) settings. In fact, Hackenberg (2018) pointed out that "comparisons of the two procedures for establishing conditioned reinforcers would be greatly enhanced if conducted under steady-state conditions, such as with extended chained and concurrent chained schedules, in which added stimuli continue to be paired with terminal reinforcers" (p. 401).

Given the complexity and the fragmentation of the evidence, the present paper systematically reviewed research conducted between 2002 and 2017 to first, distinguish studies by the procedures used (i.e., classical or operant conditioning, observational learning, and comparison studies); second, organise the evidence in terms of the population served, conditioning procedures employed, stimuli used as conditioned reinforcers, and methods utilised to verify the effectiveness of the conditioning procedures; third, compare procedures and outcomes as they relate to different stimuli; and fourth, evaluate the quality of the evidence presented in the papers.

Method

The title search was conducted using three computerised databases, PsychINFO, ERIC and Medline, following PRISMA guidelines (Liberati et al., 2009). Two reviewers were involved in the search, review, and analysis of the papers. Due to the breadth of the topic, initial searches were conducted using relevant keywords and filters. Preliminary results were both too numerous to manage and too distant from the target topic. The term Pair* input in ERIC, for example, led to the inclusion of many studies focusing on the involvement of classmates for teaching children in regular classrooms, while in Medline the term Condition* captured irrelevant medical conditions. After repeated searches, both reviewers agreed that PsychINFO was the most useful database, and this was used for the subsequent final search.

The following inclusion criteria were applied to all studies: (1) the study was published in an English-language peer-review journal, applied to a human population, and presented original data; (2) conditioning procedures were explicitly stated; (3) participants presented a diagnosis of autism

and/or DD and/or ID; and (4) the study was published between January 2002 and December 2017. All studies that did not meet the inclusion criteria were excluded; this also applied to literature reviews, conceptual papers, and papers reporting on the experimental analysis of behaviour.

Truncation was added to the following keywords: Condition* OR Pair* AND Reinforc*. The systematic search identified 84 records; nine additional records were identified via a manual search of references, including those from a systematic literature review focusing on procedural variations of token systems (Ivy, Meindl, Overley, & Robson, 2017). After removal of two duplicates, both independent readers screened the title and abstract of all remaining 91 articles against the inclusion criteria.

Following this screening process, the raters agreed to exclude 65 articles, maintaining 26 papers for a detailed evaluation consisting of reading the full text and scanning references. The latter identified an additional 12 records, bringing the total of full-text studies to be assessed for eligibility to 38. Of these, five were excluded following review. Consequently, 33 studies that met the original inclusion criteria were included in the qualitative synthesis. Content analysis and quality of evidence assessment (Romeiser Logan, Hickman, Harris, & Heriza, 2008) of each record are reported in Tables 1-7, while Figure 1 provides a flowchart of the review process.

Data coding

Data were summarised in the following categories:

1. Main references (author, title, year of publication) and participant characteristics (age, gender and main diagnosis),
2. Purpose (research question and stimuli to be conditioned). ‘Stimuli to be conditioned’ referred to the sources of previously neutral stimulation that were to acquire reinforcing properties after the conditioning process and experimental preparation, such as visuals, objects, tokens, social, or speech sounds. Visual stimuli included images, pictures, visual symbols (e.g., plus sign used by Ardoin, Martens,

Wolfe, Hilt, & Rosenthal, 2004). Objects were small items like strings, disks, books and toys. Speech sounds referred to vocal stimuli presented by the experimenter.

3. Method (study outline) and main outcome (results and response measured). Reported results/effectiveness was presented according to conclusions of the authors of the original study. When authors did not qualify outcomes as positive, negative or mixed, they were classified as follows for the purpose of this review: positive when the desired change was observed across participants and target behaviours (e.g., Axe & Laprime, 2017), negative when the treatment produced no changes in the desired direction for any of the participants (e.g., Esch et al., 2005) or produced effects in the undesired direction, and mixed if the desired change was only observed for some participants or some target behaviours (e.g., vocalisations increased in one out of two participants, such as in Ward, Osnes, & Partington, 2007). The response measured was categorised either in terms of observable preference for previously neutral stimuli (as in Petursdottir, Carp, Matthies, & Esch, 2011) or in terms of changes in participants' behaviour (e.g., changes in toy play, academic performance or participants' vocalisations).
4. Quality of evidence. The 14 criteria outlined by Romeiser Logan et al. (2008) were used to assess the quality of the evidence, including a description of participants and setting, independent variable, dependent variable, design and analysis. Each criterion was rated either as "yes" or "no", and each "yes" was assigned one point. Hence counting all "yes" answers provides an overall score for the study's methodological strength. Concerning their overall methodological rigour, studies scoring 11-14 points were rated as 'strong' studies scoring between seven and 11 points were considered 'moderate', and studies scoring below seven were considered 'weak'.

Intercoders' agreement

Three coders independently rated the methodological strength of 10 sample studies according to the 14 criteria questions outlined by Romeiser Logan et al. (2008). Agreement was calculated on the total of 140 answers for these ten sample studies by dividing the number of agreements by the sum of agreements and disagreements and multiplying the result by 100 to obtain the percentage of total agreements. This process resulted in an initial consensus on the 87.14% that increased to 92,14% following further discussion between the assessors.

Results

Participants' characteristics

Most studies involved a small number of participants; overall, the 33 studies included 107 participants, most of whom had a diagnosis of autism and/or ID/DD. Two studies (Holth et al., 2009; Singer-Dudek & Oblak, 2013) also included typically developing participants (two and one participants, respectively). Some studies reported the diagnosis as pervasive developmental disorder or mental retardation. While this kind of lexicon may have been acceptable historically, this no longer is the case. However, for accuracy of reporting these specific papers in the analysis reported here, the original wording was retained. Participants' ages ranged from infancy to adulthood, with the majority of studies focusing on children younger than six years of age (Figure 2).

Participants' characteristics were sufficiently detailed to allow comparison between studies. Indicators of the level of functioning, though, differed significantly between the studies. Even though age, diagnosis, gender, and school placement were reported in all of the studies, more specific information, such as communicative and verbal competencies, academic performances, and functional living skills were reported in different ways in the studies, making it very difficult to summarise these type of data and to identify potential correlations between participants' level of functioning and intervention results.

Lines of research in the study of conditioned reinforcement

The studies covered four different lines of research:

1. pairing / SSP studies (n=16),
2. discrimination /ODT studies (n=4),
3. observational conditioning studies (n=5)
4. comparison studies (n=8).

Pairing/SSP studies. Of the 16 studies (Table 1), seven focused on increasing children's vocalisations, aiming to establish a repertoire of sounds upon which selection by consequences might operate (see Cividini-Motta, Scharrer, & Ahearn, 2017 for a recent review and a comparison of pairing procedures versus echoic teaching and mand training). Of the remaining nine studies, four examined the conditioning of images, and four focused on social stimuli, such as praise statements, recorded adult's voice and staff social attention. One study examined the conditioning of tokens (Moher, Gould, Hegg, & Mahoney, 2008).

In more than half of the SSP studies an active response from the participant was required to start the pairing trial (e.g., an observing response or an arbitrary motor response, such as hand raising), adding a contingency element to the pairing procedure. Pairing studies, therefore, were categorised as applying either a contingent (RCP) or a non-contingent (also called response independent, RIP) procedure, although in some instances it was difficult to distinguish which conditioning procedures had been used (i.e., operant or classical). Among RCP studies a distinction was made between studies that resembled traditional discrete trials, where the experimenter started the pairing trial based on a pre-programmed inter-trial interval that is contingent upon an observing response (e.g. Esch, Carr, & Grow, 2009) and studies in which the participant initiated the pairing trial (e.g. Moher et al., 2008).

Results were mainly discussed in terms of increases in participants' vocal repertoire or academic and curricular skills. A minority of studies proceeded to test directly newly acquired reinforcing properties (Axe & Laprime, 2017; Jerome & Sturmey, 2014) while one of the study

evaluated the establishment of preference through an SSP procedure (Petursdottir et al., 2011).

The ten response-contingent pairing (RCP) studies in which a response was required from the participant at the beginning of the pairing trial or the paired presentation of neutral and reinforcing stimuli was contingent upon any response are identified in Table 1 with a + before the first author's surname.

Discrimination/ODT Studies. Three of the four studies summarised in Table 2 focused on social behaviour. These studies conditioned a neutral social stimulus to become a discriminative stimulus for access to reinforcement for an arbitrary response, by blocking (Isaksen & Holth, 2009) or extinguishing (Carbone et al., 2013) the arbitrary response, if emitted in the absence of the stimulus to be conditioned. The remaining study (Taylor-Santa et al., 2014) conditioned neutral visual stimuli to become discriminative and then presented the new S_D as a consequence to test their reinforcing properties. Positive results were reported as responding increased during post-test only in the S_D condition, remaining low in the S-delta condition. Therefore the procedure was judged efficacious in conditioning neutral stimuli as reinforcers through the establishment of the stimulus itself as discriminative for responding. Taylor-Santa et al. (2014), as well as Lugo, Mathews, King, Lamphere, and Damme (2017) proceeded to directly test the acquired reinforcing value of the stimulus on the participants' behaviour, while the outcome measures in Carbone et al. (2013) comprised the clinical relevance of the increase in mands with eye contact only, and Isaksen and Holth (2009) focused solely on joint attention responses (Table 2).

Observational conditioning studies. This line of research focused on the emergence of conditioned reinforcers following observation of peers receiving neutral stimuli contingent on their behaviour (Greer & Singer-Dudek, 2008). In these studies, experimental preparation was varied in terms of stimuli to be conditioned, using neutral objects like strings or disks (Greer & Singer-

Dudek, 2008), books (Singer-Dudek, Oblak, & Greer, 2011), toys (Leaf et al., 2012), or social activities (Leaf et al., 2016). Three of the studies reported results in terms of the acquisition of reinforcing properties, tested by measuring the effect of access to the conditioned item on maintenance or acquisition of behaviours. In the two remaining studies, the authors evaluated preference but not the reinforcing value of the newly conditioned stimulus, e.g., item and/or activity (Table 3).

Comparison Studies. The eight studies (Table 4) compared different protocols and verified their relative efficacy when conditioning of different stimuli. Half of the examined studies reported mixed results when comparing RIP to RCP (Dozier, Iwata, Thomason-Sassi, Worsdell, & Wilson, 2012), RIP to ODT (Isaksen & Holth, 2009; Lepper et al., 2013) and to different procedures such as echoic and mand training (Cividini-Motta et al., 2017). Two additional studies failed to identify a better procedure when comparing RCP to ODT (Rodriguez & Gutierrez, 2017) and SSP to echoic training or a control condition consisting in enriched environment (Stock, Schulze, & Mirenda, 2008). Positive results were reported when comparing RCP to RIP (Lepper & Petursdottir, 2017) in favour of RCP and when trying to identify the optimal number of pairings in SSP (Miliotis et al., 2012). Lepper et al. (2013) was the only study to report on the conditioning of vocal stimuli. Two papers (Holth et al., 2009; Rodriguez & Gutierrez, 2017) examined ODT and SSP (either RIP or RCP) in terms of their relative effectiveness in conditioning previously neutral social stimuli such as smiles, clapping, and “hurray” by measuring subsequent increases in arbitrary motor responses.

Analysis of results

The analysis took account of the main characteristics of the studies in order to highlight consistencies across lines of research and identify patterns in the findings.

Neutral Stimuli employed. Figure 4 focuses on the neutral stimuli that were employed in

the different lines of research to establish new conditioned reinforcing stimuli. Pairing/SSP studies focused mainly on speech sounds; discrimination/ ODT studies focused on social stimuli, such as nods and praise; observational conditioning studies used objects, such as books, toys, and strings, except for Leaf et al. (2016) who focused on social stimuli. Comparison studies mainly employed speech sounds, although social stimuli, such as praise (Dozier et al., 2012) and computer-administered applauses, "yay" sounds, and smiles (Holth et al., 2009) were also examined. Only one study focused on the conditioning of tokens (Moher et al., 2008).

Dependent variables. Two kinds of dependent variables were used to measure the effectiveness of the newly conditioned reinforcer: (1) preference for the conditioned stimulus and (2) effect of the conditioned stimulus on one of three kinds of target behaviour: vocals; motor responses; and curricular objectives (Figure 5).

Two studies assessed the participants' preferences after conditioning the new reinforcer, but their results offered only preliminary evidence (Leaf et al., 2012; 2016). Both of these studies had used observational methods to establish the conditioned reinforcers. Other studies measured the effects of the newly conditioned reinforcers on participants' vocal repertoire (n=12); basic motor responses, such as hand clapping or stair stepping (Dozier, Iwata, Thomason-Sassi, Worsdell, & Wilson, 2012); complex activities, such as the number of learning trials to mastery in matching-to-sample tasks (Greer & Han, 2015), or appropriate toy and computer play (Longano and Greer, 2006).

Studies that focused on curricular targets, such as matching to sample tasks (Delgado, Greer, Speckman, & Goswami, 2009) and complex repertories, such as joint attention (Isaksen & Holth, 2009) mainly used classical or operant conditioning to establish conditioned reinforcers. None of these studies offered comparisons between conditioning methods. In contrast, comparative methods were reported in five of the studies that assessed the effects of conditioned reinfocers on child-emitted speech sounds and in three of the studies that measured simple motor responses. Eleven studies tested the effects of previously neutral stimuli (e.g., praise, staff attention, objects, or tokens)

directly on an arbitrary response that were already in the learner's repertoire, such as motor responses or vocals (Figure 5).

Conditioned reinforcer effectiveness. Figure 6 reports effectiveness by lines of research. Among pairing studies, RCP ones mostly reported positive results. RIP studies were mainly directed towards increasing vocalisations in non-vocal or minimally vocal children and reported mixed or negative results, except for Jerome and Sturmey (2014) who reported positive results when focusing on the conditioning of social stimuli.

Three of the four discrimination studies reported success. Eight of the 14 RCP and ODT studies reported positive results. All five observational conditioning studies reported positive results, although two of these measured only preference shift, thus limiting the significance of their findings. Having said this, all participants were reported as having mild to moderate language delays, or, if diagnosed with autism, be fully conversational and capable of observational learning.

Comparison studies were not included in Figure 6 since they did not evaluate separate procedures but rather described which procedure was superior in the conditioning process. Table 5 presents responses measured (e.g., motor responses or child emitted speech sounds), procedures compared, and relative success reported for the comparison studies.

Reported effectiveness and stimuli to be conditioned. Figure 7 combines data reported in Figures 4 and 6: reported effectiveness together with the different stimuli conditioned in each line of research. Analysing reported effectiveness regardless of the different stimuli to be conditioned can be misleading. For this reason, results from the first two graphs are presented side by side to permit a visual analysis and to simultaneously take account of the procedures applied (e.g., lines of research), stimuli to be conditioned (e.g., social or non-social stimuli) and results obtained regarding the effectiveness in conditioning the initially neutral stimulation. As an example, of the three RCP studies focusing on the conditioning of social stimuli and voices, one reported positive results (Axe & Laprime, 2017), one negative (Petursdottir et al., 2011) and the last one reported

mixed results (Greer, Pistoljevic, Cahill, & Du, 2011). Similar inconsistencies were observed in all the lines of research except observational conditioning: all five of these studies reporting positive results, although two only investigated shift of preference and did not test reinforcing properties at all.

Stimuli to be conditioned, procedures and reported results. Table 6 summarises how the conditioning of different stimuli was addressed in different experiments. It also shows study results and identifies the procedures used in comparison studies and thereby identifies gaps in the literature and summarises research relevant to specific stimuli or experimental preparations. The inconsistency of terminology used across these studies posed a potential barrier to a thorough analysis; i.e., different terms were used to describe very similar procedures, including pairing procedure, non-contingent pairing, response independent pairing and stimulus pairing. Conversely, at times, procedures that were actually different were defined as pairing, as was the case for response-contingent and response independent stimulus-stimulus pairing procedures. Therefore, Table 6 also identifies the terminologies used in the different studies.

Quality of evidence. Tables 1 to 4 report ratings for each study against each of the 14 criteria for the quality of evidence as well as the overall rating of each study. Two studies were rated as methodologically strong; one on pairing (Jerome & Sturmey, 2014) and one on observational learning (Leaf et al., 2016). Two other studies were rated as weak (Ardoin et al., 2004; Longano & Greer, 2006), while the remaining 29 studies were rated as moderate. Ratings related to participants and independent variable (i.e., Questions 1 to 3) scored positively in all but two studies, while Question 6 (i.e., blind outcome assessor) and Questions 13 and 14 (i.e., statistical analysis) were rated negative in all studies.

Discussion

In order to organise the available evidence on the process of conditioning previously neutral stimuli to be used as reinforcers in applied contexts, a systematic review was conducted. The search identified 33 studies,16 of which pertained to research applying SSP procedures, in which, regardless of context (e.g., what the learner is doing) the neutral and reinforcing stimuli were presented repeatedly together (i.e., associated or paired). The pairing procedures described were contingent on a participant response (i.e., RCP) or non-contingent (i.e., RIP), although this distinction was not always made explicit and at times the participant response was described as “an observing prompt” (Rader et al., 2014; p.70). RIP procedures were described mainly in studies aiming to increase the vocal repertoire in minimally vocal children, while RCP, both in the form of both free-operant participant-initiated trials and discrete experimenter-initiated trials, examined conditioning of diverse stimuli. Of the six pairing studies reporting positive results, five applied RCP procedures. Three RCP studies focused on the conditioning of visual stimuli or objects, two on social stimuli and voices, while Moher et al.'s (2008) study was the only one examining the conditioning of tokens, even though tokens are said to be the most commonly used generalised conditioned reinforcer (Gillis & Pence, 2015).

Ten pairing studies reported either mixed (n= 3) or negative (n= 7; NB, five of these applied non-contingent procedures) results in conditioning speech sounds, social stimuli (Greer et al., 2011), voices (Rader et al., 2014), and visual stimuli (one RCP study; Ardoin et al., 2004).

Four ODT studies described operant discrimination training procedures in which the child was taught to emit an arbitrary response that was either easy (e.g., reaching for an edible; Lugo et al., 2017), new, or low in frequency (Taylor-Santa et al., 2014) and under the discriminative control of the previously neutral stimulus. In fact, the defining part of the ODT procedure was that the reinforced arbitrary response was emitted in the presence of a neutral (to be conditioned) stimulus that acquired discriminative properties during the training. Three of the four ODT studies reported positive results in terms of efficacy, although two of these (Carbone et al., 2013; Isaksen & Holth,

2009) focused on the clinical outcome rather than testing the reinforcing properties of the previously neutral stimulus. Stimuli to be conditioned were social in three of the studies, while they were visual in the fourth. More than half of the studies that required a response from the participant (i.e., RCP and ODT studies) reported positive results with very different populations and stimuli. These results deserve further consideration when planning new research to explore if contingent responses are necessary or, if not, what stimuli should be used and which populations would benefit.

Five studies used observational conditioning procedures, where the participant observed a consequence (e.g., delivery of neutral stimulus) of an out-of-sight response (e.g., matching-to-sample task) or they observed a peer interacting with the neutral stimulus in an engaging way while being prevented from contacting the same item. All observational conditioning studies reported positive results, either based on direct testing of newly acquired reinforcing properties (Greer & Singer-Dudek, 2008; Singer-Dudek & Oblak, 2013; Singer-Dudek et al., 2011) or on the basis that a successful shift in children's preference was evident through children's choices (Leaf et al., 2012, 2016). Four observational studies focused on the conditioning of neutral objects, such as plastic discs, strings, toothpicks, books, while in the remaining study (Leaf et al., 2016) the stimulus to be conditioned was a social activity. As "many different skills have to come together for observational learning to work" (Catania, 2007, p. 228), the basic process underlying these studies remains unclear, and the researchers recognized that "although the observational procedure was successful … numerous questions still need to be answered" (Leaf et al., 2016; p.8).

Participants in observational conditioning studies appeared to be less severely affected by social and communicative impairment than the participants of other studies. All were described as conversational partners able to participate in group teaching or attend mainstream classrooms. Clearly, participants' characteristics are relevant when examining the relative efficacy of different interventions. Commonly, as highlighted by Esch et al. (2009), participants in SSP studies were

minimally vocal, non-echoic, and their "speaker-listener repertoires have been described as largely non-functional" (p. 239). An absent listener repertoire is likely to compromise the salience of vocal stimuli and consequently constitutes an obstacle for pairing to occur. It is likely that the difference in participants' listener repertoires contributed to the inconsistency of results. Participants in observational studies tended to be described as vocal, capable of following at least one-step instructions and emitting at least one-word utterances as mands and tacts, if not fully conversational. Observational conditioning, therefore, can be described as a complex phenomenon requiring advanced verbal capabilities (Catania, 2007). The findings reported here are consistent with Normand and Knoll (2006) who concluded that "it is unclear whether the verbal repertoire of the individual influences responsiveness to the procedure" (p. 84). In fact, both Normand and Knoll (2006) and Miguel (2002) highlighted that participants with higher verbal capabilities seemed to derive the lowest benefit from the pairing procedure. This requires acknowledging not only that "systematically pairing a stimulus of weaker value with already effective reinforcers establishes the requisite history of contiguity to condition it as a reinforcer" (Esch, Carr, & Grow, 2009, p. 225) but also that although temporal contiguity is a necessary condition for the transfer of properties to occur, it may not be sufficient (Donahoe & Palmer, 2004). The present study supports the notion that it is essential to identify the necessary conditions for pairing to happen and adds participant repertoires to the list of identifiable conditions.

The present search yielded eight studies that reported the comparison of different procedures, comparing either different procedures or different protocols of the same procedure (i.e., number of pairings as in Miliotis et al., 2012). The results of these studies were inconsistent and thus conclusions cannot be drawn that drive clinical practice towards well-established procedures. Given the diversity of studies and their remarkably different approaches, no procedure can claim an absolute superiority in terms of efficacy of the conditioning procedure or methodological rigour.

Overall, there is promising evidence regarding procedures that require participants to actively respond in the pairing trial. Compared to RIP, both RCP and ODT procedures either showed better results (Dozier et al., 2012; Holth et al., 2009) or were equally effective but preferred by participants (i.e., ODT procedures; Lepper et al., 2013). These results were consistent in different sets of stimuli; social stimuli administered via computer (Holth et al., 2009), praise (Dozier et al., 2012), and speech sounds (Lepper & Petursdottir, 2017; Lepper et al., 2013). Positive results for ODT, though, were not replicated in Rodriguez and Gutierrez's study (2017), which reported "that the respondent procedure (pairing) resulted in more robust and enduring effects than the operant procedure (discriminative stimulus procedure)" (p. 159).

Measurement constituted an additional source of variability among all studies, making it even more difficult to compare results since this ranged from direct measurement of reinforcing effects in studies examining effects of conditioning on arbitrary motor responses to complex measures that are especially prone to introducing confounding variables, such as the acquisition of curricular objectives. Procedural variations across the studies made it difficult to draw any final conclusion. Taken as a whole, the literature reviewed here indicated a general superiority of procedures that required participants to emit a response (i.e., response-contingent pairing and operant discrimination training procedures) as compared to pure pairing procedures in which the presentation of neutral and reinforcing stimuli was not contingent on a response from the participant.

Limitations

This review is subject to two main limitations. First, it relies entirely the search of a single database and manual searches, and consequently, some relevant research may have been missed. Second, although two independent researchers completed the quality assessment, evaluation of

results as positive, mixed or negative derives uniquely from what the studies themselves reported and not from any other external/objective criteria.

Despite these limitations, the literature reviewed here provided some evidence to support procedures that include the learner's active response in pairing trials, such as RCP and ODT. This finding is consistent with the previously documented notion of the value of primary reinforcers to which neutral stimuli can be conditioned (Kelleher & Gollub, 1962; Lepper & Petursdottir, 2017). These elements, especially if considered together with the inconsistent results obtained through the alternative RIP procedures in the SSP studies, may be considered sufficient to shift clinical practice towards procedures that involve operant conditioning and build on the well documented multiple functions of stimuli (e.g. discriminative and reinforcing) in behavioural chains (Bullock & Hackenberg, 2015; Kelleher & Gollub, 1962).

Recommendations and conclusions

While further research is needed to identify the most efficient manner to condition neutral stimuli as reinforcers, both in terms conceptual foundations and procedural variations, the strengths and weaknesses of the studies reviewed here offer clear recommendations for future research. Given the complexity of the numerous variables involved delineating successful procedures for conditioning new reinforcers for the applied field, it is essential to firmly ground further research on a coherent conceptual analysis. Similar recommendations can also be found in the recent review on tokens published by Ivy and colleagues (Ivy et al., 2017), who pointed out that only about half (i.e., 50) of the studies they reviewed detailed the conditioning procedure. In the majority of these studies the conditioning process relied on verbal rules, despite recommendations cautioning that "substitutability of instructions and contingencies cannot always be assumed" (Hackenberg, 2018, p.399). Future researchers need to report complete procedural details together with the rationale for their use, and they must anchor these descriptions to a coherent theoretical description that is

grounded in basic research. Capitalising on these recommendations will ensure that future research reaches generalisable and parsimonious conclusions.

In the present review, differentiating clearly between operant and respondent procedures was difficult due to the remarkable variability of experimental procedures, participants' levels of functioning and pre-requisite skills, and target outcomes. This variability obscured the basic processes involved and impeded an assessment of the generality of findings. Further research is necessary to capitalise on the evidence thus far and ensure clearer results. The suggestion that "Skinner's commitment to a moment-to-moment analysis of behaviour compels a rejection of a fundamental distinction between the conditioning processes instantiated by respondent and operant procedures" (Donahoe et al., 1997, p. 198) should drive further research.

Further research is necessary also for procedures related to observational conditioning since questions remain open, both in relation to the necessary pre-requisite skills (e.g., verbal repertoires, imitative behaviour, tacting and rule-governed behaviour; Palmer, 2012; Catania, 2007)) and the mechanisms underlying observational conditioning as a special case of observational learning. Future research also should ensure detailed descriptions these issues to allow comparisons between studies and increase external validity.

In addition, in clinical practice, it is crucial to take into account also of the necessary response effort, for example, in procedures that focus on increasing vocalisations in totally non-vocal children response effort would be higher than in similar studies with minimally vocal children. Previous reviews examined the effects of different target sounds and highlighted that lack of research on the relative effectiveness of pairing novel sounds as opposed to pairing sounds that are already in the participants' repertoire. It appears that no direct comparison has been conducted yet that takes into account the baseline frequency of vocalisations (Shillingsburg et al., 2015). Furthermore, the intrinsic characteristics of the sounds to be conditioned also should be controlled in future studies.

An additional methodological issue that merits further consideration is the measurement of the newly acquired reinforcing properties following the conditioning procedures. It is essential to establish if the testing method employed is one of the variables influencing the reinforcing properties of stimuli. Future research therefore needs to rely on a “steady-state condition” (Hackenberg, 2018, p.401) when measuring reinforcing effects.

In sum, this review adds to the existing body of literature by examining and summarising the body of research regarding the conditioning of different stimuli as reinforcers including a mixture of conditioning procedures and types of stimuli. It is, to date, the only systematic literature review conducted on this topic that includes all studies published in the specified timeframe (between 2002 and 2017) and irrespectively of the nature of examined stimuli. Consequently, it adds to and updates existing literature reviews (Petursdottir & Lepper, 2015; Shillingsburg et al., 2015) that have included studies published earlier and focused solely on the conditioning of speech sounds.

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A systematic review of behaviour analytic processes and procedures for conditioning reinforcers among individuals with autism, developmental or intellectual disability

Abstract

Autism Spectrum Disorder is diagnosed when individuals demonstrate repetitive behaviours and restricted interests, especially in relation to social stimuli, that make it difficult for them to access socially reinforcing environments. Consequently, in most cases, behaviour analytic interventions initially have to focus on the establishment/conditioning of effective reinforcers. A systematic review was conducted of the literature on conditioned reinforcement that identified 33 relevant articles (published between 2002 and 2017). This article reports on the content analysis and quality of evidence and offers a summary of the findings reported in these papers. Four lines of research were identified: classical conditioning, operant conditioning, observational learning, and comparison studies. Differences and similarities are reported concerning procedures, type of stimuli to be conditioned, responses measured, reported effectiveness, and quality of evidence. Recommendations for future research and clinical practice are provided.

Keywords: conditioning reinforcer, operant, classical, pairing, discrimination, observational

Conditioning of neutral stimuli as reinforcers that can contribute to operant selection of new behaviour is one of the most ubiquitous processes in both applied and experimental behavioural research. Access to reinforcers guides learning in everyday activities and interactions, leading to the development of crucial repertoires (e.g., language acquisition). Stimulus changes that derive their reinforcing properties from an individual's learning history are called conditioned (or secondary, or learned) reinforcers. Examples of conditioned reinforcers include attention, eye contact, verbal praise, and tokens to be exchanged for various other reinforcers (e.g. food, leisure time). Generalised conditioned reinforcers have acquired their reinforcing properties "as a result of having being paired with many unconditioned and conditioned reinforcers" (Cooper, Heron, & Heward, 2019, p. 264).

Skinner (1953) provided an early conceptual description of conditioned reinforcers and the first practical applications with token economies date back to the 1950s (see Boerke & Reitman, 2014 for a general and historical overview). Since then, though, there has been little consensus on the most effective and efficient procedures for conditioning previously neutral stimuli into functional reinforcers (Axe & Laprime, 2017), particularly for children diagnosed with developmental and/or intellectual disabilities and autism who frequently lack social motivation. These children's behaviour often are sensitive to restricted and/or non-social reinforcers, which can contribute to the establishment of challenging behavioural repertoires early in their development. As they grow older and developmental delay becomes more apparent, making effective interventions essential, the need for effective reinforcers becomes even more significant. These issues are not new, in fact, the need for effective ways to establish conditioned reinforcement when teaching children with autism has been apparent for a long time (Lovaas et al., 1966) and the need to synthesise the existing literature has been identified repeatedly (Axe & Laprime, 2017; Leaf et al., 2016; Petursdottir & Lepper, 2015; Shillingsburg, Hollander, Yosick, Bowen, & Muskat, 2015).

In the main, at least one of three behavioural principles is used to establishing conditioned reinforcers: (1) classical conditioning, where neutral stimuli are paired with natural or otherwise established reinforcers (e.g., stimulus-stimulus pairing, SSP), (2) operant conditioning, where neutral stimuli become discriminative stimuli for target responses (e.g. operant discrimination training, ODT), and (3) observational learning, where conditioned reinforcers are established via vicarious reinforcement.

SSP procedures mirror the basic behavioural principle of classical conditioning, also known as Pavlovian or respondent conditioning, where a neutral stimulus is presented together with an unconditioned stimulus and thereby acquires its discriminative properties. In this procedure, "instead of signaling the consequences of responding, a stimulus simply signals the presentation of some other stimulus" (Catania, 2007, p. 198). Both existing reviews on conditioning reinforcers (Petursdottir & Lepper, 2015; Shillingsburg et al., 2015), collectively reporting on 14 studies (NB; 12 of these were the same papers), focused on different applications of SSP to condition neutral auditory stimuli as reinforcers and analysed their effects on subjects' vocal repertoires. They examined procedures in two main streams: (1) response-contingent pairing (RCP) in which the subject is expected to emit a response that then is followed by the simultaneous presentation of a neutral stimulus paired with a known reinforcer, and (2) response independent pairing (RIP), in which pairings of neutral and either conditioned or unconditioned stimuli occur on a time-based schedule independent of the subject's behaviour.

Both Petursdottir and Lepper's (2015) and Shillingsburg et al.'s (2015) reviews highlight that the SSP literature presents an impressive differentiation in terms of target behaviours and procedural variations. Shillingsburg et al. (2015) summarised these as (1) target sounds, (2) number of sounds emitted per pairing, (3) type of pairing procedure, (4) number of pairings per minute, (5) control for adventitious reinforcement (i.e. withholding reinforcement, if the child emitted the target sound during pairing trials), and (6) type of preferred item paired. They identified four pairing procedures under the generic description of SSP: (1) simultaneous, (2) trace, (3) delay presentations

that require no response from the subject, and (4) discrimination training that requires a response from the subject. Petursdottir and Lepper (2015) also provided an overview of the main procedural variations in SSP (i.e., RCP and RIP) and investigated discrimination training procedures. Based on the mixed results of their literature review, they invited researchers to keep exploring "discrimination training and response-contingent pairing as alternative to response independent stimulus pairing procedures that have predominated in the literature on establishing speech sounds as reinforcers" (Petursdottir & Lepper, 2015,p. 228).

Operant discrimination training (ODT) procedures (Lepper, Petursdottir, & Esch, 2013) or stimulus discrimination (S_D) procedures (Isaksen & Holth, 2009) are firmly grounded in the operant conditioning literature (for a review, see Bell & McDevitt, 2014). Despite minor procedural variations, the common characteristics of these procedures is that the stimulus to be conditioned as a reinforcer is contingent on a response from the participant. The protocol consists of conditioning a neutral stimulus as an S_D for a response that produces an unconditioned reinforcer and then building up a behaviour chain (Holth, 2005), as exemplified in Carbone et al.'s (2013) study on eye contact, where an analysis is offered of how "following frequent exposure to the variables that control the mand response, a behavioral chain occurs" (p. 150). In this behavioural chain, deprivation of the object acts as a motivating operation that increases the reinforcer effectiveness of the listener's gaze (eye contact) for different kinds of approach behaviour and eventually also functions as a discriminative stimulus for the emission of a mand.

SSP and ODT tend to be considered as exclusive alternative accounts of the process of conditioning reinforcers, and some studies include comparisons of their relative efficacy and participants' preference (Lepper et al., 2013). However, Donahoe and Palmer (2004) repeatedly questioned the view that classical and operant procedures involve two different kinds of learning or that they required two different fundamental theoretical treatments. They recognised that both procedures select environment-behavior relations and appealed for "a moment-to-moment analysis [that] calls for a unified theoretical treatment of the conditioning process, with the environmental

control of responding as the cumulative outcome of both procedures." (Donahoe, Palmer, & Burgos, 1997, p.198).

The third line of research regarding conditioned reinforcers focuses on observational learning (Greer & Singer-Dudek, 2008) also referred to as observational conditioning, or the establishment of reinforcers as a result of observation (Singer-Dudek & Oblak, 2013). This procedure engages both the participant and a peer in a simple task (e.g., matching), in which the participant is prevented from observing the peer's response, however, does observe the peer receiving an item (i.e., stimulus) contingent on completion of the task. The observation of vicarious reinforcement results in the previously neutral stimulus being conditioned as a potential reinforcer for the participant for both acquisition and maintenance of responses.

The fourth line of research within the conditioned reinforcer literature comprises comparison studies (Rader et al., 2014). This research also covers procedural modifications that are necessary to produce reliable and durable effects (e.g., Lepper & Petursdottir, 2017). Some of these studies report procedural variations of one conditioning procedure, where, for example, the effectiveness of variations in the number of presentations of the target sound are evaluated (e.g., Miliotis et al. (2012) examined one versus three presentations). Other studies compare different procedures such as classical and operant conditioning (e.g., Holth et al., 2009), making it difficult to draw definitive conclusions as to the relative efficacy and effectiveness of specific procedures.

This research is further complicated by the range of methods used to assess the effectiveness of the conditioning procedure. In the studies that explicitly examine the effects of conditioning, the new response method assesses the effect of the newly established conditioned reinforcer on novel responses (Taylor-Santa, Sidener, Carr, & Reeve, 2014) and the extinction method assesses resistance to extinction of behaviours when reinforced with conditioned reinforcers (Jerome & Sturmey, 2014). The new response and the extinction testing methods typically produce fleeting effects, both in experimental (Kelleher & Gollub, 1962; Williams, 1994) and applied (Esch, Carr, &

Grow, 2009) settings. In fact, Hackenberg (2018) pointed out that "comparisons of the two procedures for establishing conditioned reinforcers would be greatly enhanced if conducted under steady-state conditions, such as with extended chained and concurrent chained schedules, in which added stimuli continue to be paired with terminal reinforcers" (p. 401).

Given the complexity and the fragmentation of the evidence, the present paper systematically reviewed research conducted between 2002 and 2017 to first, distinguish studies by the procedures used (i.e., classical or operant conditioning, observational learning, and comparison studies); second, organise the evidence in terms of the population served, conditioning procedures employed, stimuli used as conditioned reinforcers, and methods utilised to verify the effectiveness of the conditioning procedures; third, compare procedures and outcomes as they relate to different stimuli; and fourth, evaluate the quality of the evidence presented in the papers.

Method

The title search was conducted using three computerised databases, PsychINFO, ERIC and Medline, following PRISMA guidelines (Liberati et al., 2009). Two reviewers were involved in the search, review, and analysis of the papers. Due to the breadth of the topic, initial searches were conducted using relevant keywords and filters. Preliminary results were both too numerous to manage and too distant from the target topic. The term Pair* input in ERIC, for example, led to the inclusion of many studies focusing on the involvement of classmates for teaching children in regular classrooms, while in Medline the term Condition* captured irrelevant medical conditions. After repeated searches, both reviewers agreed that PsychINFO was the most useful database, and this was used for the subsequent final search.

The following inclusion criteria were applied to all studies: (1) the study was published in an English-language peer-review journal, applied to a human population, and presented original data; (2) conditioning procedures were explicitly stated; (3) participants presented a diagnosis of autism

and/or DD and/or ID; and (4) the study was published between January 2002 and December 2017. All studies that did not meet the inclusion criteria were excluded; this also applied to literature reviews, conceptual papers, and papers reporting on the experimental analysis of behaviour.

Truncation was added to the following keywords: Condition* OR Pair* AND Reinforc*. The systematic search identified 84 records; nine additional records were identified via a manual search of references, including those from a systematic literature review focusing on procedural variations of token systems (Ivy, Meindl, Overley, & Robson, 2017). After removal of two duplicates, both independent readers screened the title and abstract of all remaining 91 articles against the inclusion criteria.

Following this screening process, the raters agreed to exclude 65 articles, maintaining 26 papers for a detailed evaluation consisting of reading the full text and scanning references. The latter identified an additional 12 records, bringing the total of full-text studies to be assessed for eligibility to 38. Of these, five were excluded following review. Consequently, 33 studies that met the original inclusion criteria were included in the qualitative synthesis. Content analysis and quality of evidence assessment (Romeiser Logan, Hickman, Harris, & Heriza, 2008) of each record are reported in Tables 1-7, while Figure 1 provides a flowchart of the review process.

Data coding

Data were summarised in the following categories:

1. Main references (author, title, year of publication) and participant characteristics (age, gender and main diagnosis),
2. Purpose (research question and stimuli to be conditioned). ‘Stimuli to be conditioned’ referred to the sources of previously neutral stimulation that were to acquire reinforcing properties after the conditioning process and experimental preparation, such as visuals, objects, tokens, social, or speech sounds. Visual stimuli included images, pictures, visual symbols (e.g., plus sign used by Ardoin, Martens,

Wolfe, Hilt, & Rosenthal, 2004). Objects were small items like strings, disks, books and toys. Speech sounds referred to vocal stimuli presented by the experimenter.

3. Method (study outline) and main outcome (results and response measured). Reported results/effectiveness was presented according to conclusions of the authors of the original study. When authors did not qualify outcomes as positive, negative or mixed, they were classified as follows for the purpose of this review: positive when the desired change was observed across participants and target behaviours (e.g., Axe & Laprime, 2017), negative when the treatment produced no changes in the desired direction for any of the participants (e.g., Esch et al., 2005) or produced effects in the undesired direction, and mixed if the desired change was only observed for some participants or some target behaviours (e.g., vocalisations increased in one out of two participants, such as in Ward, Osnes, & Partington, 2007). The response measured was categorised either in terms of observable preference for previously neutral stimuli (as in Petursdottir, Carp, Matthies, & Esch, 2011) or in terms of changes in participants' behaviour (e.g., changes in toy play, academic performance or participants' vocalisations).
4. Quality of evidence. The 14 criteria outlined by Romeiser Logan et al. (2008) were used to assess the quality of the evidence, including a description of participants and setting, independent variable, dependent variable, design and analysis. Each criterion was rated either as "yes" or "no", and each "yes" was assigned one point. Hence counting all "yes" answers provides an overall score for the study's methodological strength. Concerning their overall methodological rigour, studies scoring 11-14 points were rated as 'strong' studies scoring between seven and 11 points were considered 'moderate', and studies scoring below seven were considered 'weak'.

Intercoders' agreement

Three coders independently rated the methodological strength of 10 sample studies according to the 14 criteria questions outlined by Romeiser Logan et al. (2008). Agreement was calculated on the total of 140 answers for these ten sample studies by dividing the number of agreements by the sum of agreements and disagreements and multiplying the result by 100 to obtain the percentage of total agreements. This process resulted in an initial consensus on the 87.14% that increased to 92,14% following further discussion between the assessors.

Results

Participants' characteristics

Most studies involved a small number of participants; overall, the 33 studies included 107 participants, most of whom had a diagnosis of autism and/or ID/DD. Two studies (Holth et al., 2009; Singer-Dudek & Oblak, 2013) also included typically developing participants (two and one participants, respectively). Some studies reported the diagnosis as pervasive developmental disorder or mental retardation. While this kind of lexicon may have been acceptable historically, this no longer is the case. However, for accuracy of reporting these specific papers in the analysis reported here, the original wording was retained. Participants' ages ranged from infancy to adulthood, with the majority of studies focusing on children younger than six years of age (Figure 2).

Participants' characteristics were sufficiently detailed to allow comparison between studies. Indicators of the level of functioning, though, differed significantly between the studies. Even though age, diagnosis, gender, and school placement were reported in all of the studies, more specific information, such as communicative and verbal competencies, academic performances, and functional living skills were reported in different ways in the studies, making it very difficult to summarise these type of data and to identify potential correlations between participants' level of functioning and intervention results.

Lines of research in the study of conditioned reinforcement

The studies covered four different lines of research:

1. pairing / SSP studies (n=16),
2. discrimination /ODT studies (n=4),
3. observational conditioning studies (n=5)
4. comparison studies (n=8).

Pairing/SSP studies. Of the 16 studies (Table 1), seven focused on increasing children's vocalisations, aiming to establish a repertoire of sounds upon which selection by consequences might operate (see Cividini-Motta, Scharrer, & Ahearn, 2017 for a recent review and a comparison of pairing procedures versus echoic teaching and mand training). Of the remaining nine studies, four examined the conditioning of images, and four focused on social stimuli, such as praise statements, recorded adult's voice and staff social attention. One study examined the conditioning of tokens (Moher, Gould, Hegg, & Mahoney, 2008).

In more than half of the SSP studies an active response from the participant was required to start the pairing trial (e.g., an observing response or an arbitrary motor response, such as hand raising), adding a contingency element to the pairing procedure. Pairing studies, therefore, were categorised as applying either a contingent (RCP) or a non-contingent (also called response independent, RIP) procedure, although in some instances it was difficult to distinguish which conditioning procedures had been used (i.e., operant or classical). Among RCP studies a distinction was made between studies that resembled traditional discrete trials, where the experimenter started the pairing trial based on a pre-programmed inter-trial interval that is contingent upon an observing response (e.g. Esch, Carr, & Grow, 2009) and studies in which the participant initiated the pairing trial (e.g. Moher et al., 2008).

Results were mainly discussed in terms of increases in participants' vocal repertoire or academic and curricular skills. A minority of studies proceeded to test directly newly acquired reinforcing properties (Axe & Laprime, 2017; Jerome & Sturmey, 2014) while one of the study

evaluated the establishment of preference through an SSP procedure (Petursdottir et al., 2011).

The ten response-contingent pairing (RCP) studies in which a response was required from the participant at the beginning of the pairing trial or the paired presentation of neutral and reinforcing stimuli was contingent upon any response are identified in Table 1 with a + before the first author's surname.

Discrimination/ODT Studies. Three of the four studies summarised in Table 2 focused on social behaviour. These studies conditioned a neutral social stimulus to become a discriminative stimulus for access to reinforcement for an arbitrary response, by blocking (Isaksen & Holth, 2009) or extinguishing (Carbone et al., 2013) the arbitrary response, if emitted in the absence of the stimulus to be conditioned. The remaining study (Taylor-Santa et al., 2014) conditioned neutral visual stimuli to become discriminative and then presented the new S_D as a consequence to test their reinforcing properties. Positive results were reported as responding increased during post-test only in the S_D condition, remaining low in the S-delta condition. Therefore the procedure was judged efficacious in conditioning neutral stimuli as reinforcers through the establishment of the stimulus itself as discriminative for responding. Taylor-Santa et al. (2014), as well as Lugo, Mathews, King, Lamphere, and Damme (2017) proceeded to directly test the acquired reinforcing value of the stimulus on the participants' behaviour, while the outcome measures in Carbone et al. (2013) comprised the clinical relevance of the increase in mands with eye contact only, and Isaksen and Holth (2009) focused solely on joint attention responses (Table 2).

Observational conditioning studies. This line of research focused on the emergence of conditioned reinforcers following observation of peers receiving neutral stimuli contingent on their behaviour (Greer & Singer-Dudek, 2008). In these studies, experimental preparation was varied in terms of stimuli to be conditioned, using neutral objects like strings or disks (Greer & Singer-

Dudek, 2008), books (Singer-Dudek, Oblak, & Greer, 2011), toys (Leaf et al., 2012), or social activities (Leaf et al., 2016). Three of the studies reported results in terms of the acquisition of reinforcing properties, tested by measuring the effect of access to the conditioned item on maintenance or acquisition of behaviours. In the two remaining studies, the authors evaluated preference but not the reinforcing value of the newly conditioned stimulus, e.g., item and/or activity (Table 3).

Comparison Studies. The eight studies (Table 4) compared different protocols and verified their relative efficacy when conditioning of different stimuli. Half of the examined studies reported mixed results when comparing RIP to RCP (Dozier, Iwata, Thomason-Sassi, Worsdell, & Wilson, 2012), RIP to ODT (Isaksen & Holth, 2009; Lepper et al., 2013) and to different procedures such as echoic and mand training (Cividini-Motta et al., 2017). Two additional studies failed to identify a better procedure when comparing RCP to ODT (Rodriguez & Gutierrez, 2017) and SSP to echoic training or a control condition consisting in enriched environment (Stock, Schulze, & Mirenda, 2008). Positive results were reported when comparing RCP to RIP (Lepper & Petursdottir, 2017) in favour of RCP and when trying to identify the optimal number of pairings in SSP (Miliotis et al., 2012). Lepper et al. (2013) was the only study to report on the conditioning of vocal stimuli. Two papers (Holth et al., 2009; Rodriguez & Gutierrez, 2017) examined ODT and SSP (either RIP or RCP) in terms of their relative effectiveness in conditioning previously neutral social stimuli such as smiles, clapping, and “hurray” by measuring subsequent increases in arbitrary motor responses.

Analysis of results

The analysis took account of the main characteristics of the studies in order to highlight consistencies across lines of research and identify patterns in the findings.

Neutral Stimuli employed. Figure 4 focuses on the neutral stimuli that were employed in

the different lines of research to establish new conditioned reinforcing stimuli. Pairing/SSP studies focused mainly on speech sounds; discrimination/ ODT studies focused on social stimuli, such as nods and praise; observational conditioning studies used objects, such as books, toys, and strings, except for Leaf et al. (2016) who focused on social stimuli. Comparison studies mainly employed speech sounds, although social stimuli, such as praise (Dozier et al., 2012) and computer-administered applauses, "yay" sounds, and smiles (Holth et al., 2009) were also examined. Only one study focused on the conditioning of tokens (Moher et al., 2008).

Dependent variables. Two kinds of dependent variables were used to measure the effectiveness of the newly conditioned reinforcer: (1) preference for the conditioned stimulus and (2) effect of the conditioned stimulus on one of three kinds of target behaviour: vocals; motor responses; and curricular objectives (Figure 5).

Two studies assessed the participants' preferences after conditioning the new reinforcer, but their results offered only preliminary evidence (Leaf et al., 2012; 2016). Both of these studies had used observational methods to establish the conditioned reinforcers. Other studies measured the effects of the newly conditioned reinforcers on participants' vocal repertoire (n=12); basic motor responses, such as hand clapping or stair stepping (Dozier, Iwata, Thomason-Sassi, Worsdell, & Wilson, 2012); complex activities, such as the number of learning trials to mastery in matching-to-sample tasks (Greer & Han, 2015), or appropriate toy and computer play (Longano and Greer, 2006).

Studies that focused on curricular targets, such as matching to sample tasks (Delgado, Greer, Speckman, & Goswami, 2009) and complex repertories, such as joint attention (Isaksen & Holth, 2009) mainly used classical or operant conditioning to establish conditioned reinforcers. None of these studies offered comparisons between conditioning methods. In contrast, comparative methods were reported in five of the studies that assessed the effects of conditioned reinfocers on child-emitted speech sounds and in three of the studies that measured simple motor responses. Eleven studies tested the effects of previously neutral stimuli (e.g., praise, staff attention, objects, or tokens)

directly on an arbitrary response that were already in the learner's repertoire, such as motor responses or vocals (Figure 5).

Conditioned reinforcer effectiveness. Figure 6 reports effectiveness by lines of research. Among pairing studies, RCP ones mostly reported positive results. RIP studies were mainly directed towards increasing vocalisations in non-vocal or minimally vocal children and reported mixed or negative results, except for Jerome and Sturmey (2014) who reported positive results when focusing on the conditioning of social stimuli.

Three of the four discrimination studies reported success. Eight of the 14 RCP and ODT studies reported positive results. All five observational conditioning studies reported positive results, although two of these measured only preference shift, thus limiting the significance of their findings. Having said this, all participants were reported as having mild to moderate language delays, or, if diagnosed with autism, be fully conversational and capable of observational learning.

Comparison studies were not included in Figure 6 since they did not evaluate separate procedures but rather described which procedure was superior in the conditioning process. Table 5 presents responses measured (e.g., motor responses or child emitted speech sounds), procedures compared, and relative success reported for the comparison studies.

Reported effectiveness and stimuli to be conditioned. Figure 7 combines data reported in Figures 4 and 6: reported effectiveness together with the different stimuli conditioned in each line of research. Analysing reported effectiveness regardless of the different stimuli to be conditioned can be misleading. For this reason, results from the first two graphs are presented side by side to permit a visual analysis and to simultaneously take account of the procedures applied (e.g., lines of research), stimuli to be conditioned (e.g., social or non-social stimuli) and results obtained regarding the effectiveness in conditioning the initially neutral stimulation. As an example, of the three RCP studies focusing on the conditioning of social stimuli and voices, one reported positive results (Axe & Laprime, 2017), one negative (Petursdottir et al., 2011) and the last one reported

mixed results (Greer, Pistoljevic, Cahill, & Du, 2011). Similar inconsistencies were observed in all the lines of research except observational conditioning: all five of these studies reporting positive results, although two only investigated shift of preference and did not test reinforcing properties at all.

Stimuli to be conditioned, procedures and reported results. Table 6 summarises how the conditioning of different stimuli was addressed in different experiments. It also shows study results and identifies the procedures used in comparison studies and thereby identifies gaps in the literature and summarises research relevant to specific stimuli or experimental preparations. The inconsistency of terminology used across these studies posed a potential barrier to a thorough analysis; i.e., different terms were used to describe very similar procedures, including pairing procedure, non-contingent pairing, response independent pairing and stimulus pairing. Conversely, at times, procedures that were actually different were defined as pairing, as was the case for response-contingent and response independent stimulus-stimulus pairing procedures. Therefore, Table 6 also identifies the terminologies used in the different studies.

Quality of evidence. Tables 1 to 4 report ratings for each study against each of the 14 criteria for the quality of evidence as well as the overall rating of each study. Two studies were rated as methodologically strong; one on pairing (Jerome & Sturmey, 2014) and one on observational learning (Leaf et al., 2016). Two other studies were rated as weak (Ardoin et al., 2004; Longano & Greer, 2006), while the remaining 29 studies were rated as moderate. Ratings related to participants and independent variable (i.e., Questions 1 to 3) scored positively in all but two studies, while Question 6 (i.e., blind outcome assessor) and Questions 13 and 14 (i.e., statistical analysis) were rated negative in all studies.

Discussion

In order to organise the available evidence on the process of conditioning previously neutral stimuli to be used as reinforcers in applied contexts, a systematic review was conducted. The search identified 33 studies,16 of which pertained to research applying SSP procedures, in which, regardless of context (e.g., what the learner is doing) the neutral and reinforcing stimuli were presented repeatedly together (i.e., associated or paired). The pairing procedures described were contingent on a participant response (i.e., RCP) or non-contingent (i.e., RIP), although this distinction was not always made explicit and at times the participant response was described as “an observing prompt” (Rader et al., 2014; p.70). RIP procedures were described mainly in studies aiming to increase the vocal repertoire in minimally vocal children, while RCP, both in the form of both free-operant participant-initiated trials and discrete experimenter-initiated trials, examined conditioning of diverse stimuli. Of the six pairing studies reporting positive results, five applied RCP procedures. Three RCP studies focused on the conditioning of visual stimuli or objects, two on social stimuli and voices, while Moher et al.'s (2008) study was the only one examining the conditioning of tokens, even though tokens are said to be the most commonly used generalised conditioned reinforcer (Gillis & Pence, 2015).

Ten pairing studies reported either mixed (n= 3) or negative (n= 7; NB, five of these applied non-contingent procedures) results in conditioning speech sounds, social stimuli (Greer et al., 2011), voices (Rader et al., 2014), and visual stimuli (one RCP study; Ardoin et al., 2004).

Four ODT studies described operant discrimination training procedures in which the child was taught to emit an arbitrary response that was either easy (e.g., reaching for an edible; Lugo et al., 2017), new, or low in frequency (Taylor-Santa et al., 2014) and under the discriminative control of the previously neutral stimulus. In fact, the defining part of the ODT procedure was that the reinforced arbitrary response was emitted in the presence of a neutral (to be conditioned) stimulus that acquired discriminative properties during the training. Three of the four ODT studies reported positive results in terms of efficacy, although two of these (Carbone et al., 2013; Isaksen & Holth,

2009) focused on the clinical outcome rather than testing the reinforcing properties of the previously neutral stimulus. Stimuli to be conditioned were social in three of the studies, while they were visual in the fourth. More than half of the studies that required a response from the participant (i.e., RCP and ODT studies) reported positive results with very different populations and stimuli. These results deserve further consideration when planning new research to explore if contingent responses are necessary or, if not, what stimuli should be used and which populations would benefit.

Five studies used observational conditioning procedures, where the participant observed a consequence (e.g., delivery of neutral stimulus) of an out-of-sight response (e.g., matching-to-sample task) or they observed a peer interacting with the neutral stimulus in an engaging way while being prevented from contacting the same item. All observational conditioning studies reported positive results, either based on direct testing of newly acquired reinforcing properties (Greer & Singer-Dudek, 2008; Singer-Dudek & Oblak, 2013; Singer-Dudek et al., 2011) or on the basis that a successful shift in children's preference was evident through children's choices (Leaf et al., 2012, 2016). Four observational studies focused on the conditioning of neutral objects, such as plastic discs, strings, toothpicks, books, while in the remaining study (Leaf et al., 2016) the stimulus to be conditioned was a social activity. As "many different skills have to come together for observational learning to work" (Catania, 2007, p. 228), the basic process underlying these studies remains unclear, and the researchers recognized that "although the observational procedure was successful … numerous questions still need to be answered" (Leaf et al., 2016; p.8).

Participants in observational conditioning studies appeared to be less severely affected by social and communicative impairment than the participants of other studies. All were described as conversational partners able to participate in group teaching or attend mainstream classrooms. Clearly, participants' characteristics are relevant when examining the relative efficacy of different interventions. Commonly, as highlighted by Esch et al. (2009), participants in SSP studies were

minimally vocal, non-echoic, and their "speaker-listener repertoires have been described as largely non-functional" (p. 239). An absent listener repertoire is likely to compromise the salience of vocal stimuli and consequently constitutes an obstacle for pairing to occur. It is likely that the difference in participants' listener repertoires contributed to the inconsistency of results. Participants in observational studies tended to be described as vocal, capable of following at least one-step instructions and emitting at least one-word utterances as mands and tacts, if not fully conversational. Observational conditioning, therefore, can be described as a complex phenomenon requiring advanced verbal capabilities (Catania, 2007). The findings reported here are consistent with Normand and Knoll (2006) who concluded that "it is unclear whether the verbal repertoire of the individual influences responsiveness to the procedure" (p. 84). In fact, both Normand and Knoll (2006) and Miguel (2002) highlighted that participants with higher verbal capabilities seemed to derive the lowest benefit from the pairing procedure. This requires acknowledging not only that "systematically pairing a stimulus of weaker value with already effective reinforcers establishes the requisite history of contiguity to condition it as a reinforcer" (Esch, Carr, & Grow, 2009, p. 225) but also that although temporal contiguity is a necessary condition for the transfer of properties to occur, it may not be sufficient (Donahoe & Palmer, 2004). The present study supports the notion that it is essential to identify the necessary conditions for pairing to happen and adds participant repertoires to the list of identifiable conditions.

The present search yielded eight studies that reported the comparison of different procedures, comparing either different procedures or different protocols of the same procedure (i.e., number of pairings as in Miliotis et al., 2012). The results of these studies were inconsistent and thus conclusions cannot be drawn that drive clinical practice towards well-established procedures. Given the diversity of studies and their remarkably different approaches, no procedure can claim an absolute superiority in terms of efficacy of the conditioning procedure or methodological rigour.

Overall, there is promising evidence regarding procedures that require participants to actively respond in the pairing trial. Compared to RIP, both RCP and ODT procedures either showed better results (Dozier et al., 2012; Holth et al., 2009) or were equally effective but preferred by participants (i.e., ODT procedures; Lepper et al., 2013). These results were consistent in different sets of stimuli; social stimuli administered via computer (Holth et al., 2009), praise (Dozier et al., 2012), and speech sounds (Lepper & Petursdottir, 2017; Lepper et al., 2013). Positive results for ODT, though, were not replicated in Rodriguez and Gutierrez's study (2017), which reported "that the respondent procedure (pairing) resulted in more robust and enduring effects than the operant procedure (discriminative stimulus procedure)" (p. 159).

Measurement constituted an additional source of variability among all studies, making it even more difficult to compare results since this ranged from direct measurement of reinforcing effects in studies examining effects of conditioning on arbitrary motor responses to complex measures that are especially prone to introducing confounding variables, such as the acquisition of curricular objectives. Procedural variations across the studies made it difficult to draw any final conclusion. Taken as a whole, the literature reviewed here indicated a general superiority of procedures that required participants to emit a response (i.e., response-contingent pairing and operant discrimination training procedures) as compared to pure pairing procedures in which the presentation of neutral and reinforcing stimuli was not contingent on a response from the participant.

Limitations

This review is subject to two main limitations. First, it relies entirely the search of a single database and manual searches, and consequently, some relevant research may have been missed. Second, although two independent researchers completed the quality assessment, evaluation of

results as positive, mixed or negative derives uniquely from what the studies themselves reported and not from any other external/objective criteria.

Despite these limitations, the literature reviewed here provided some evidence to support procedures that include the learner's active response in pairing trials, such as RCP and ODT. This finding is consistent with the previously documented notion of the value of primary reinforcers to which neutral stimuli can be conditioned (Kelleher & Gollub, 1962; Lepper & Petursdottir, 2017). These elements, especially if considered together with the inconsistent results obtained through the alternative RIP procedures in the SSP studies, may be considered sufficient to shift clinical practice towards procedures that involve operant conditioning and build on the well documented multiple functions of stimuli (e.g. discriminative and reinforcing) in behavioural chains (Bullock & Hackenberg, 2015; Kelleher & Gollub, 1962).

Recommendations and conclusions

While further research is needed to identify the most efficient manner to condition neutral stimuli as reinforcers, both in terms conceptual foundations and procedural variations, the strengths and weaknesses of the studies reviewed here offer clear recommendations for future research. Given the complexity of the numerous variables involved delineating successful procedures for conditioning new reinforcers for the applied field, it is essential to firmly ground further research on a coherent conceptual analysis. Similar recommendations can also be found in the recent review on tokens published by Ivy and colleagues (Ivy et al., 2017), who pointed out that only about half (i.e., 50) of the studies they reviewed detailed the conditioning procedure. In the majority of these studies the conditioning process relied on verbal rules, despite recommendations cautioning that "substitutability of instructions and contingencies cannot always be assumed" (Hackenberg, 2018, p.399). Future researchers need to report complete procedural details together with the rationale for their use, and they must anchor these descriptions to a coherent theoretical description that is

grounded in basic research. Capitalising on these recommendations will ensure that future research reaches generalisable and parsimonious conclusions.

In the present review, differentiating clearly between operant and respondent procedures was difficult due to the remarkable variability of experimental procedures, participants' levels of functioning and pre-requisite skills, and target outcomes. This variability obscured the basic processes involved and impeded an assessment of the generality of findings. Further research is necessary to capitalise on the evidence thus far and ensure clearer results. The suggestion that "Skinner's commitment to a moment-to-moment analysis of behaviour compels a rejection of a fundamental distinction between the conditioning processes instantiated by respondent and operant procedures" (Donahoe et al., 1997, p. 198) should drive further research.

Further research is necessary also for procedures related to observational conditioning since questions remain open, both in relation to the necessary pre-requisite skills (e.g., verbal repertoires, imitative behaviour, tacting and rule-governed behaviour; Palmer, 2012; Catania, 2007)) and the mechanisms underlying observational conditioning as a special case of observational learning. Future research also should ensure detailed descriptions these issues to allow comparisons between studies and increase external validity.

In addition, in clinical practice, it is crucial to take into account also of the necessary response effort, for example, in procedures that focus on increasing vocalisations in totally non-vocal children response effort would be higher than in similar studies with minimally vocal children. Previous reviews examined the effects of different target sounds and highlighted that lack of research on the relative effectiveness of pairing novel sounds as opposed to pairing sounds that are already in the participants' repertoire. It appears that no direct comparison has been conducted yet that takes into account the baseline frequency of vocalisations (Shillingsburg et al., 2015). Furthermore, the intrinsic characteristics of the sounds to be conditioned also should be controlled in future studies.

An additional methodological issue that merits further consideration is the measurement of the newly acquired reinforcing properties following the conditioning procedures. It is essential to establish if the testing method employed is one of the variables influencing the reinforcing properties of stimuli. Future research therefore needs to rely on a “steady-state condition” (Hackenberg, 2018, p.401) when measuring reinforcing effects.

In sum, this review adds to the existing body of literature by examining and summarising the body of research regarding the conditioning of different stimuli as reinforcers including a mixture of conditioning procedures and types of stimuli. It is, to date, the only systematic literature review conducted on this topic that includes all studies published in the specified timeframe (between 2002 and 2017) and irrespectively of the nature of examined stimuli. Consequently, it adds to and updates existing literature reviews (Petursdottir & Lepper, 2015; Shillingsburg et al., 2015) that have included studies published earlier and focused solely on the conditioning of speech sounds.

Compliance with Ethical Standards:

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Table 1. Pairing studies

Study	Participant characteristics *Age/ gender/ diagnosis*	Purpose *Research question* *Stimulus to be conditioned*	Method *Study outline*	Main outcome *Results* *Response measured*	Quality of evidence
+ Ardoin et al., 2004 A method for conditioning reinforcer preference in students with moderate mental retardation	3 boys 12 years Mild to moderate mental retardation	Assess the accuracy of a pictorial choice preference assessment and examine two conditioning procedures for low preference items. Stimulus to be conditioned: VISUAL	ABA design but with only 2 data points in baseline. Neutral stimulus (NS) to be conditioned: white paper with a blue + sign on it. Conditioning was carried on through the simultaneous presentation of the NS and the picture of a highly preferred stimulus to consume upon completion of individualised tasks. The test consisted of probe sessions during which only the NS was presented as a consequence for work completion.	MIXED: NS and reinforcement presented together upon work completion resulted in an increase that was also maintained in sessions where only the NS was presented as a consequence for task completion. A failure to return to baseline in performance was registered that the authors attributed to a general learning effect derived from increased fluency in the academic tasks.	Weak
+ Axe & Laprime, 2017 The effects of contingent pairing on establishing praise as a reinforcer with children with autism	2 boys 5 and 9 years Autism	Condition praise as a reinforcer through a pairing procedure similar to the one described by Dozier et al. (2012). Stimulus to be conditioned: SOCIAL (praise)	Three consecutive experiments. In experiment 1 a reinforcer and a pairing analysis were conducted utilising an AB design. During pairing sessions praise was presented together with a known reinforcer and contingent upon a button pressing response. Aim of the second experiment was to gain experimental control in the context of a reversal design, while experiment 3 tested maintenance.	POSITIVE: praise became an effective reinforcer, but maintenance of responding measured in terms of button pressing was short-lived and reduced after a few sessions.	Moderate

Carroll & Klatt, 2008 Using stimulus-stimulus pairing and direct reinforcement to teach vocal verbal behavior to young children with autism	1 boy and 1 girl 22-23 months Autism	Two experiments: the first aimed to increase vocalisations in both participants through SSP procedure. The second examined direct reinforcement as a means to bring speech sounds under echoic control for one of the two participants. Stimulus to be conditioned: SPEECH SOUNDS	Multiple baseline design. The intervention targeted one new and one known, low in frequency, sound. The target sound was presented three times and consequently twice more while delivering the preferred item for 20 seconds. If the participant emitted the target sound, the presentation of the successive trial was delayed 20 seconds to control for adventitious reinforcement.	MIXED: for one child there was an immediate increase in the frequency of unprompted known target sound but not in the new one. No result was observed for the second child.	Moderate
+ Delgado et al., 2009 Effects of conditioning reinforcement for print stimuli on match-to-sample responding in preschoolers	2 boys and 1 girl 3-5 years Pervasive Developmental Disorder (PDD)	Demonstrate an accelerated rate of learning through the conditioning of previously neutral images as reinforcers for looking. Conditioned reinforcement for observing is considered a developmental cusp that allows for the emergence of matching to sample (MTS) responding. Stimulus to be conditioned: VISUAL	Time lagged multiple probe design across participants. Pre and post-treatment measures were: number of seconds participants looked at novel visual stimuli and ratio of learn unit to criteria for 2D MTS programs. Conditioning procedure consisted of presenting the visual stimulus for 5-second intervals and pairing it with conditioned or unconditioned reinforcers. If the participants stopped looking the interval was started over again; otherwise, the interval was immediately followed with a test trial where no reinforcement was provided for looking responses.	POSITIVE: for all three participants, the treatment phase resulted in conditioned reinforcement for observing print stimuli as measured in seconds spent observing them. A functional relationship was identified between the acquisition of conditioned reinforcement for visual stimuli and a decrease in the mean number of learn units to criteria in MTS teaching programs. For two participants, generalised matching emergence was observed.	Moderate
Esch et al., 2005	2 girls and 1 boy	Produce lasting effects supplementing the	Three experiments, the first of which is an AB multiple baseline	NEGATIVE: no increase in child emitted speech sounds	Moderate

Evaluating stimulus-stimulus pairing and direct reinforcement in the establishment of an echoic repertoire of children diagnosed with autism	6-8 years Autism	pairing procedure with an echoic training consisting of direct reinforcement of the vocal responses acquired through the pairing procedure. Stimulus to be conditioned: SPEECH SOUNDS	design across topographies with a constant series control. Procedure tested consists in the pairing of a speech sound with a reinforcing item and subsequent, direct reinforcement of echoic responding. The second study is a systematic replication of Miguel et al. (2002), while the third one examines a shaping procedure for one of the three participants.	after pairings, no increase in the subsequent echoic training, and no effect observable on the rate of production of target speech sounds in the participants. Differential reinforcement procedure led to equivocal results in the two participants: and vowel production increased only for one of them.	
+ Esch et al., 2009 Evaluation of an enhanced stimulus-stimulus pairing procedure to increase early vocalisations of children with autism	3 boys 2-5 years Autism	Evaluate procedural variations in SSP to increase stimulus salience. Stimulus to be conditioned: SPEECH SOUNDS	Non concurrent multiple baseline design combined with a reversal design. The study aims to evaluate the effects of the modified SSP procedure and reinforcement on the frequency of children's vocalisations as compared to a non-contingent reinforcement (NCR) control condition. Pairing trials were presented contingently upon an observing response.	MIXED: acceptable but moderate effect on the production of target speech sounds, suggesting a possible automatic reinforcement effect of SSP. Listener skills are suggested as a possible prerequisite for optimally benefiting from SSP procedures.	Moderate
+ Greer & Han, 2015 Establishment of conditioned reinforcement for visual observing and the emergence of	3 boys 5 years Autism	Establish 2D print stimuli as conditioned reinforcers for the observing response through direct reinforcement of prolonged observing behaviour and consequently test the	Non-concurrent multiple probe design aiming to test generalised MTS after conditioning of printed 2D stimuli as reinforcers for observing responses. Reinforcement was provided for observing 2D print pages for intervals of five seconds. Reinforcement consisted of alternating praise (conditioned	POSITIVE: after conditioning of observing responses of printed 2D stimuli, probes for MTS tasks showed a dramatic increase without direct training. Preference for looking at books during free time also increased after treatment. Preference was measured in	Moderate

generalised visual identity matching		acquisition of generalised MTS. Stimulus to be conditioned: VISUAL	reinforcement) and edibles (non-conditioned reinforcement).	terms of the number of 5-second intervals spent observing books.	
+ Greer et al., 2011 Effects of conditioning voices as reinforcers for listener responses on rate of learning, awareness, and preferences for listening to stories in preschoolers with autism	2 boys 1 girl 4-5 years Autism	Evaluate changes before and after voice conditioning protocol (VCP) in: rate of acquisition of listener instructional objectives, frequency of observing responses to voices and adults' presence, listening to stories activity selection during free play. Stimulus to be conditioned: SOCIAL (recorded voices)	Delayed non concurrent pre and post intervention multiple probe design. Intervention consists of the VCP aiming to the acquisition of conditioned reinforcement for listening to recorded voices. During training sessions, known preferred items (edibles) were delivered contingently on pressing the button that resulted in recorded voices of familiar adults reading a story. Efficacy was measured via preference probes.	MIXED: VCP appears to affect participants' repertoires in different ways. All participants demonstrated a significant decrease in learn units required to master listener objectives while observing responses and listening to stories increased for two participants. Decrease in stereotypy while listening to stories was observed in two participants.	Moderate
Jerome & Sturmey, 2014 The effects of pairing non-preferred staff with preferred stimuli on increasing the reinforcing value of non-preferred staff attention	3 adult males 42-56 years Mild to moderate Intellectual Disability	Two studies, the second of which is relevant to the conditioning procedure since it explores the applicability of pairing procedures to staff attention. Stimulus to be conditioned: SOCIAL (staff attention)	Experimental design: alternating treatment design embedded in a multiple baseline across participants design to demonstrate experimental control. After evaluation of staff preference, non-preferred staff attention was conditioned through repeated pairings with the delivery of preferred stimuli.	POSITIVE: SSP procedure was effective in changing the value of previously non-preferred staff. After the conditioning procedure staff attention became an effective reinforcer as shown in terms of task engagement measured through progressive ratio and in terms of the rate of approach to previously non-preferred staff members.	Strong
+ Longano & Greer, 2006	Experiment 1 1 boy	Evaluate the applicability of SSP	Multiple baseline across behaviours. In the first	POSITIVE: experiment one shows an increase in	Weak

The effects of a stimulus-stimulus pairing procedure on the acquisition of conditioned reinforcement on observing and manipulating stimuli by young children with autism	5 years Autism Experiment 2 2 boys 6-7 years Autism	procedure to independent and seatwork. Stimulus to be conditioned: VISUAL	experiment, appropriate toy play, play at the computer and looking at books were the behaviours observed. In the second experiment, the behaviour of interest was independent work. During SSP trials, students were asked to complete the intervals without stereotypy or passivity. During the pairing interval, the experimenter delivered vocal praise two or three times per interval while during the successive test interval no pairing was conducted.	appropriate play in all the behaviours measured, as well as a decrease in stereotypy and passivity in varying degrees. In experiment two, a significant increase in independent work was observed. The authors claim these results support the notion that SSP procedure was effective in increasing appropriate behaviours and decreasing stereotypy.	
Miguel et al., 2002 The effects of a stimulus – stimulus pairing procedure on the vocal behavior of children diagnosed with autism	3 boys 3-5 years Autism	Evaluate effects of SSP procedure on the vocal utterances of three boys with limited vocal repertoire. Stimulus to be conditioned: SPEECH SOUNDS	Multiple baseline design across vocal behaviours. Target sounds were the two lowest frequency syllable utterances as measured in free operant observation. Pairing sessions consisted of 20 SSP trials defined as five consecutive presentations of the target sound with preferred food delivery on the third one.	MIXED: Increase in child emitted speech sounds observed in two participants, only one of whom showed a significant increase in both sounds.	Moderate
+ Moher et al., 2008 Non generalised and generalised conditioned reinforcers:	3 boys 2 girls 9-21 years Autism or PDD in four	Establishing and validating the use of tokens. First and second of four experiments focused on procedures for conditioning tokens and satiation effects.	The first experiment studied the conditioning procedure through an AB design in which two tokens were used for each participant. In stage one, the token and the preferred edible were delivered concurrently, in stage two the	POSITIVE: Conditioned tokens functioned as reinforcers on a hand raising response and mirrored the reinforcing effectiveness of the edible they were paired with. Novel and	Moderate

establishment and validation	participants, mental retardation, ADHD and bipolar disorder for one participant.	The third and fourth experiment studied satiation and generalised tokens respectively. Stimulus to be conditioned: TOKEN	token was exchanged for the backup item. No conditioning procedure was necessary for one participant, who was simply verbally informed of the token exchange rule.	unconditioned tokens, however, did not function as reinforcers for hand-raising responses for any student.	
Normand & Knoll, 2006 The effects of a stimulus – stimulus pairing procedure on the unprompted vocalisation of a young child diagnosed with autism	1 boy 3 years Autism	Test the effects of SSP procedure on the spontaneous vocalisations. Stimulus to be conditioned: SPEECH SOUNDS	Multiple baseline design across two target phonemes. Conditions were: baseline, control, SSP. A follow-up condition is added to test for the duration of effects, reported in the literature as short-lived.	NEGATIVE: No increase in the vocal production of target sounds was observed, neither in the control nor in the pairing or follow-up conditions.	Moderate
+ Petursdottir et al., 2011 Analysing stimulus-stimulus pairing effects on preferences for speech sounds	3 boys 3,5 and 4 years Autism	Identify variables influencing the success of SSP in establishing a preference for specific auditory stimuli. Stimulus to be conditioned: SOCIAL (speech syllables adult female voice).	Reversal design in which target and control sounds were presented alternately, in the context of a multiple baseline design across participants. An observing response was required before stimulus presentation.	NEGATIVE: the concurrent operant procedure failed to establish a reliable preference for speech sound as measured via button pressing frequency despite several procedural variations.	Moderate
+ Rader et al., 2014 Stimulus-stimulus pairing	2 boys 1 girl 4-7 years	Systematic replication of SSP study by Esch et al. (2009).	Multiple baseline across participants. Treatment consisted of presenting three repetitions of the target sound together with high preference items. Sounds	MIXED: a substantial increase only in target vocalisations was shown in two children, demonstrating	Moderate

of vocalisations: A systematic replication	Autism	Stimulus to be conditioned: SPEECH SOUNDS	were presented in motherese, interspersed with non-target sounds. An observing response was required.	that exposure alone was not responsible for the increase.	
Ward, Osnes, & Partington, 2007 The effects of a delay of non-contingent reinforcement during a pairing procedure in the development of stimulus control of automatically reinforced vocalisation.	2 girls 3 years Developmental and language delays	Evaluate the efficacy of a procedure that included both automatic and socially mediated reinforcement in the development of vocal repertoire. Stimulus to be conditioned: SPEECH SOUNDS	Multiple probes across sounds. Treatment consisted of a multi-component package: the pairing of target sound with a variety of reinforcers, reinforcement of vocal play and reinforcement of occasional echoic responses.	MIXED: Important increase in speech sounds production and echoic behaviour for one participants and significant gain in echoic control of one sound for the other.	Moderate

+ Studies in which a response was required by the participant to start the pairing trial

Table 2. Discrimination studies

Study	Participant characteristics *Age/ gender/ diagnosis*	Purpose *Research question* *Stimulus to be conditioned*	Method *Study outline*	Main outcome *Results* *Response measured*	Quality of evidence
Carbone et al., 2013 Teaching eye contact to children with autism: A conceptual analysis and single case study	1 boy 3 years Autism	Extend the analysis of development of social skills to the teaching of eye contact as a language pragmatic skill. Stimulus to be conditioned: SOCIAL (eye contact)	AB design: at baseline manding accompanied by eye contact was infrequent. Treatment consisted of extinction for mands without eye contact and differential reinforcement for mands with eye contact.	POSITIVE: Listener face and eye contact became a conditioned reinforcer for looking and orienting toward the listener in the context of a chain of behaviours in manding. Reinforcing properties of eye contact were not directly tested.	Moderate
Isaksen & Holth, 2009 An operant approach to teaching joint attention skills to children with autism	2 boys 2 girls 3.5-5.5 years Autism	Develop a behavioural training protocol to establish responding to joint attention (JA) bids, engaging in turn-taking activities and initiating JA. Stimulus to be conditioned: SOCIAL (nods and smiles)	Multiple baseline design across children. Training consisted in 3 phases: teach the child to respond to JA bids through prompt and prompt fading, establishing nods and smiles as S_D for the availability of preferred items and teaching turn-taking and switch between responding and initiating JA behaviours.	POSITIVE: Post-intervention and follow up measures show an increase in both respondent and initiating JA behaviours as measured on the Early Social Communication Scale (ESCS-m).	Moderate
Lugo et al., 2017 Operant discrimination training to establish praise as a reinforcer	3 girls 1 boy 2-3 years	Evaluate operant discrimination training as a teaching procedure to condition praise statements as reinforcers.	Non-concurrent multiple baseline design to evaluate the effects of operant discrimination training on the conditioning of unfamiliar praise statement as reinforcers. Replication of Holth et al. (2009) and Taylor-Santa et al. (2014).	MIXED: All participants demonstrated a reinforcing effect on arbitrary touching a card response, although these effects were short-lived since responding decreased to zero	Moderate

	Autism Spectrum Disorder	Stimulus to be conditioned: SOCIAL (praise statement)		levels in one or two sessions after training	
Taylor-Santa et al., 2014 A discrimination training procedure to establish conditioned reinforcers for children with autism	2 boys 1 girl 6 years Autism	Identify the optimal method for establishing conditioned reinforcement and test in the applied setting a procedure in which stimuli trained as discriminative were then presented as consequence. Stimulus to be conditioned: VISUAL	Multiple probe design across stimulus/ response to evaluate the effects of discrimination training procedure on responding. During discrimination training, S_D and S-delta were established. The same stimuli were then tested for their acquired reinforcing properties during post-training.	POSITIVE: Same pattern of responding in all three participants: responding increased during post-test only in the S_D condition, remaining low in the S-delta condition. Previously neutral stimuli were tested in their newly acquired reinforcing properties. Responses measured comprised basic switches operations.	Moderate

Table 3. Observational conditioning studies

Citation *Author/ title/ yr.*	Participant characteristics *Age/ gender/ diagnosis*	Purpose *Research question*	Method *Study outline*	Main outcome *Results* *Response measured*	Quality of evidence
Greer & Singer-Dudek, 2008 The emergence of conditioned reinforcement from observation	5 boys 1 girl 3 to 5 years Mild to moderate language delays and behaviour disorders	Evaluate if observation of a peer receiving disks or strings as consequences of performance could condition these previously neutral stimuli as reinforcers. Stimulus to be conditioned: OBJECTS (string/ disk)	Multiple baseline across participants. Pre-intervention assessment demonstrated absent reinforcing properties of the objects to be conditioned. Observational conditioning consisted of having the target child observe the confederate peer receive the token or the string as a consequence of correct responding, while observation of the performance and attempting to reach for the object were prevented. After two sessions in which the target child asked or tried to reach for the object, the post-intervention test was run.	POSITIVE: All children either mastered or significantly improved their performance in both acquisition and maintenance tasks during the post-intervention condition, when disks/strings were delivered as reinforcers after the observational conditioning.	Moderate
Singer-Dudek & Oblak, 2013 Peer presence and the emergence of conditioned reinforcement from observation.	2 boys Developmental delays 1 girl Typically developing 3-5 years	Evaluate the acquisition of reinforcing values for previously neutral items after an observational treatment. Stimulus to be conditioned: OBJECTS (strings and toothpicks)	Delayed multiple baseline design across participants combined with a reversal design. Pre-intervention assessed the non-reinforcing effect of the items to be conditioned as compared to an effective reinforcer (food). Treatment was in two phases: no peer present and peer present. The peer's response was out of the participant sight, and participants could only see the delivery of the object, with no additional stimulus (e.g., praise).	POSITIVE: Non-reinforcing items can become reinforcers for MTS tasks after an observational treatment. Reinforcing properties were acquired only when the peer was present during the observational conditioning phase.	Moderate

Singer-Dudek et al., 2011 Establishing books as conditioned reinforcers for preschool children as a function of an observational conditioning	2 female 1 male 4 years Mild language and developmental delays	Evaluate the feasibility and efficacy of a procedure based solely upon observational learning in conditioning stimuli as reinforcers. Stimulus to be conditioned: OBJECTS (books)	Delayed multiple baseline design across participants that consisted of measuring participants' responses before and after observational conditioning of books as reinforcers. During the intervention, participants were exposed to peers performing a task (non-observed) and receiving/ observing books, for which peers already had a preference. Simultaneously participants were asked to perform the same task at the same time while receiving no consequence for completion.	POSITIVE: For all participants, books, previously neutral, acquired reinforcing properties. Reinforcing effects were observed on maintenance and acquisition tasks. Time spent looking at books during free time also increased after treatment.	Moderate
Leaf et al., 2012 Observational effects on the preferences of children with autism	First experiment: 3 boys 5-6 years Autism Second experiment: 2 out of the three original study participants.	Modify preferences for toys through an observational procedure. Stimulus to be conditioned: OBJECTS (toys)	Two experiments: the first to alter children's preferences for toys, the second to test for maintenance and replicate results with different items. Conditioning procedure consisted of observation of a preferred adult playing with non-preferred toys in exciting ways. ABABA and ABACA design and a multiple baseline design were utilised, ABA and multiple baseline across participants in the second experiment.	POSITIVE: In the first experiment, all three children switched their preference for toys after the intervention, results replicated with a different set of materials. Reinforcing properties were not tested.	Moderate
Leaf et al., 2016 Changing preference from tangible to social activities through	2 boys 1 girl 5 years Autism	Test the feasibility of an observational procedure to shift preferences from tangible items to initially non-	Reversal design: preference for tangible items, social activities, and control items were measured by calculating the percentage of trials in which the participant selected the item. During baseline, all three participants selected the item that was preferred at the	POSITIVE: All three participants demonstrated a change in their preferences after the observational procedure, and started to select the social	Strong

an observation procedure	preferred social activities. Stimulus to be conditioned: SOCIAL (activities)	previous preference assessment but after observing five trials during which a peer confederate chose and experienced a social game all of them shifted their preference to the social activity.	activity as a reinforcer after engaging in a simple task.

Table 4. Comparison studies

Citation *Author/ title/ yr.*	Participant characteristics *Age/ gender/ diagnosis*	Purpose *Research question*	Method *Study outline*	Main outcome *Results* *Response measured*	Quality of evidence
Cividini-Motta et al., 2017 An assessment of three procedures to teach echoic responding	5 males 1 female 7-17 years Autism	Evaluate a protocol to assess the most effective teaching procedure for increasing participants' vocalisations and echoic responding. Stimulus to be conditioned: SPEECH SOUNDS	Within subjects alternating treatment design comparing the effects of three treatment conditions. Vocal imitation training, stimulus-stimulus pairing (SSP-RIP) and mand model were compared.	MIXED: assessment protocol identified effective teaching procedures in five out of six children, but in terms of evaluating conditioning procedures, no single procedure was superior, and there was considerable variability in their efficacy.	Moderate
Dozier et al., 2012 A comparison of two pairing procedures to establish praise as a reinforcer	12 adults 17-56 years Mild to severe mental retardation associated with other diagnoses for some participants	Evaluate if the pairing of neutral stimuli such as praise with primary reinforcers such as food would be more effective in establishing praise alone as a reinforcer in a contingent or in a non-contingent preparation Stimulus to be conditioned: SOCIAL (praise).	ABC, reversal or multiple baseline designs were applied depending on subjects. In experiment 1, praise statements were presented and immediately followed by a preferred edible. In experiment 2, praise statements and food were presented contingently on a simple motor response. Procedures compared: RIP vs RCP.	MIXED: Experiment 1 results demonstrated that RIP was ineffective in conditioning praise statement as reinforcers for simple target behaviours in three participants. Experiment 2 results demonstrated that praise acquired reinforcing properties in four participants through RCP. Effects of praise on simple motor responses measured newly acquired reinforcing efficacy.	Moderate
Holth et al., 2009 An operant analysis of joint attention skill and the establishment of	8 males 2-12 years 4 Autism 2 Down Syndrome	Compare SSP with ODT in the establishment of two different visual or auditory neutral stimuli as reinforcers.	Single-subject design with pre-test and post-test. Four phases starting with a pre-test to identify potential reinforcers. ODT was run for one stimulus and SSP for the	MIXED: Five children clearly emitted more responses after the ODT procedure than after the SSP procedure, for one child no difference was found, while one child emitted more responses after SSP than after ODT. Responses	Moderate

conditioned social reinforcers	2 Typically developing (1 did not complete the study)	Stimulus to be conditioned: SOCIAL (computer-administered applause/ yay sound/ smiles).	other. Sequence effect was controlled. Procedures compared: ODT vs. SSP.	tested were basic motor responses such as moving an object or hand clapping.	
Lepper et al., 2013 Effects of an operant discrimination training on the vocalisations of nonverbal children with autism	3 boys 2-3-4 years Autism	Evaluate the feasibility of ODT (Holth et al., 2009) to increase vocal production while comparing it to SSP. Stimulus to be conditioned: SPEECH SOUNDS.	Alternating treatment design to compare ODT, SSP and control conditions. In each condition, target and non-target speech sounds were measured. Procedures compared: ODT vs SSP	MIXED: ODT increased two participants' target vocalisations only, showing similar results to SSP condition, but ODT was preferred over SSP by all participants.	Moderate
Lepper & Petursdottir, 2017 Effects of response-contingent stimulus pairing on vocalisation of non-verbal children with autism	3 boys 4-5-6 years Autism	Compare the effects of RCP and RIP on the development of new vocalisations. Stimulus to be conditioned: SPEECH SOUNDS.	Two experiments, the first of which focused on comparing RIP and RCP to condition new language sounds as reinforcers through a multielement design with target sounds randomly assigned to each procedure. Procedures compared: RCP vs. RIP	POSITIVE: RCP was superior to RIP. RCP proved to be more effective in developing new vocalisations in all participants. A subsequent treatment also proved effective in maintaining gains and increasing the durability of RCP.	Moderate
Miliotis et al., 2012 An evaluation of the number of presentations of target sounds during stimulus	1 girl 1 boy 6-8 years Autism	Identify optimal number of repetitions in SSP trials. Stimulus to be conditioned: SPEECH SOUNDS.	Alternating treatment design comparing different NUMBER OF PRESENTATIONS in SSP trials.	POSITIVE: the enhanced SSP procedure (Esch et al., 2009) showed the best results when one sound presentation was associated with the delivery of the preferred items. An attending response was required.	Moderate

stimulus pairing trials					
Rodriguez & Gutierrez, 2017 A comparison of two procedures to condition social stimuli to function as reinforcers for children with autism	6 males 18-36 months Autism	Compare procedure based on operant and respondent paradigms to increase the value of social stimuli. Stimulus to be conditioned: SOCIAL (smiles, yay sounds, clapping)	Multiple baseline design with an embedded multiple treatment with reversal design. The respondent pairing trials were presented contingently on a simple motor response. Procedures compared: RCP vs ODT	NEGATIVE: Both conditioning procedures proved to have limited and overall not durable effects on basic motor response rates. RCP was found to have clear conditioning effects for two out of the six participants. ODT proved effective for two participants but with unstable data.	Moderate
Stock et al., 2008 A comparison of stimulus-stimulus pairing, standard echoic training and control procedures on the vocal behavior of children with autism	2 females 1 male 2-4 years Autism	Compare echoic and SSP procedures to increase vocal production in three preschoolers, early learner with autism. Stimulus to be conditioned: SPEECH SOUNDS.	Alternating treatment design to compare the effects of SSP, standard echoic training and control condition. Procedures compared: SSP vs ECHOIC vs CONTROL (enriched environment)	NEGATIVE: Results showed an immediate but short-lived effect in vocal production for only one participant out of the three. In the echoic condition, children emitted many avoidance behaviours. This study failed to demonstrate any superiority of SSP on control or standard echoic training conditions.	Moderate

Table 5. Summary of comparison studies

Stimulus to be conditioned	SOCIAL STIMULI			SPEECH SOUNDS				
Response measured	MOTOR RESPONSE			CHILD EMITTED SPEECH SOUNDS				
Short reference/ conditioning procedure	Dozier et al., 2012	Holth et al., 2009	Rodriguez & Gutierrez, 2017	Cividini-Motta et al., 2017	Lepper et al., 2013	Lepper & Petursdottir, 2017	Miliotis et al., 2012	Stock et al., 2008
RIP	-	-	N/A	+ 1 of 6 participants *Named SSP*	+	-	N/A	- *Named SSP*
RCP	+ *Named response stimulus pairing*	N/A	+ *Named respondent procedure*	N/A	N/A	+	3vs1 pairing	N/A
ODT	N/A	+	-	N/A	+ *Preferred*	N/A	N/A	N/A
Other condition (e.g., echoic or control)	N/A	N/A	N/A	+	-	N/A	N/A	-

RCP: Response-contingent pairing SSP: Stimulus-stimulus pairing RIP: Response independent pairing ODT: Operant discrimination training N/A: Not-Applicable + : the procedure was deemed effective by the authors - : the procedure was deemed ineffective by the authors

Table 6. Procedures used across studies and reported results

Stimulus to be conditioned / Experimental preparation	Speech sounds	Social and voices	Visual and Objects	Token
SSP: Stimulus-stimulus pairing Also called traditional procedure (Lugo et al., 2017) or response independent pairing (RIP) in Lepper and Petursdottir (2017). Procedural variations in terms of stimuli characteristics and number of presentations. In RIP the pairings are time-based and do not depend on any behaviour of the subject. Pairings can be simultaneous, delayed or trace, mirroring basic literature on respondent conditioning.	Carroll & Klatt, 2008 (mixed results) Cividini-Motta et al., 2017 (CMPR) Esch et al., 2005 (-) Lepper et al., 2013 (CMPR) Lepper & Petursdottir, 2017 CMPR Miguel et al., 2002 (mixed results) Normand & Knoll, 2006 Neg. Stock et al., 2008 (CMPR) Ward et al., 2007 (mixed results)	Dozier et al., 2012 (CMPR) Holth et al., 2009 (CMPR) Jerome & Sturmey, 2014 (+).		
RCP: Response contingent pairing Also called response stimulus pairing (Dozier et al., 2012) and respondent pairing procedure (Rodriguez & Gutierrez, 2017). A response is either required from the participant to start the pairing trial or a prompt is provided for the participant to emit some sort of observing response before the pairing trial starts.	Esch et al., 2009 (mixed results) Miliotis et al., 2012 (CMPR) Lepper & Petursdottir, 2017 (CMPR) Rader et al., 2014 (mixed results)	Dozier et al., 2012 (CMPR) Axe & Laprime, 2017 (+) Greer et al., 2011 (mixed results) Rodriguez & Gutierrez, 2017 (CMPR) Petursdottir et al., 2011 (-)	Ardoin et al., 2004 (+) Delgado et al., 2009 (+) Greer & Han, 2015 (+) Longano & Greer, 2006 (+)	Moher et al., 2008 (+).
ODT: Operant discrimination training Also called discriminative stimulus procedure (Rodriguez & Gutierrez, 2017). The neutral stimulus becomes an S_D for a	Lepper et al., 2013 (CMPR)	Carbone et al., 2013 (+) Holth et al., 2009 CMPR Isaksen & Holth, 2009 (+)	Taylor-Santa et al., 2014 (+).	

reinforced response and can then be tested as a reinforcer.		Lugo et al., 2017 (mixed results) Rodriguez & Gutierrez, 2017 (CMPR)		
Observational Conditioning Observation of participant's confederate or familiar adult receiving neutral stimuli as a consequence for brief non-observed tasks shifts subsequent participants' preference		Leaf et al., 2016 (+)	Greer & Singer-Dudek, 2008 Pos. Leaf et al., 2012 (+) Singer-Dudek & Oblak, 2013 (+) Singer-Dudek et al., 2011 (+)	
Total number of studies	12	11	9	1

-: negative results +: positive results CMPR: Comparison study

Table 7. Quality of evidence ratings

Quality of evidence ratings in pairing studies

Brief citation	Q. of E.	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Total
Ardoin et al. 2004	Weak	1	0	1	0	0	0	0	0	0	1	1	1	0	0	5
Axe & Laprime 2017	Moderate	1	1	1	1	1	0	1	1	1	0	1	1	0	0	10
Carroll & Klatt 2008	Moderate	1	1	1	1	1	0	1	1	0	0	1	1	0	0	9
Delgado et al. 2009	Moderate	1	1	1	1	1	0	0	1	0	1	0	1	0	0	8
Esch et al. 2005	Moderate	1	1	1	1	1	0	1	1	0	0	1	1	0	0	9
Esch et al. 2009	Moderate	1	1	1	1	1	0	1	1	0	1	1	1	0	0	10
Greer & Han 2015	Moderate	1	1	1	1	1	0	0	1	0	0	0	1	0	0	7
Greer et al. 2011	Moderate	1	1	1	1	1	0	0	1	0	1	0	1	0	0	8
Jerome & Sturmey 2014	Strong	1	1	1	1	1	0	1	1	1	1	1	1	0	0	11
Longano & Greer 2006	Weak	1	1	1	1	0	0	0	1	0	0	0	1	0	0	6
Miguel et al. 2002	Moderate	1	1	1	1	1	0	1	1	1	0	1	1	0	0	10
Moher et al. 2008	Moderate	1	1	1	1	1	0	1	0	0	1	1	1	0	0	9
Normand & Knoll 2006	Moderate	1	1	1	1	1	0	1	1	1	0	1	1	0	0	10
Petursdottir et al. 2011	Moderate	1	1	1	1	1	0	0	0	0	1	1	1	0	0	8
Rader et al. 2014	Moderate	1	1	1	1	1	0	1	1	0	0	1	1	0	0	9
Ward et al. 2007	Moderate	1	1	1	1	1	0	1	1	0	0	0	1	0	0	8

Quality of evidence ratings in discrimination studies

Carbone et al. 2013	**Moderate**	**1**	**1**	**1**	**1**	**1**	**0**	**0**	**1**	**1**	**0**	**1**	**1**	**0**	**0**	**9**
Isaksen & Holth 2009	Moderate	1	1	1	1	1	0	1	0	0	1	1	1	0	0	9
Lugo et al. 2017	Moderate	1	1	1	1	1	0	1	1	0	1	1	1	0	0	10
Taylor-Santa et al. 2014	Moderate	1	1	1	1	1	0	1	1	0	1	1	1	0	0	10

Quality of evidence ratings in observational conditioning studies

Greer & Singer- Dudek 2008	**Moderate**	**1**	**1**	**1**	**1**	**1**	**0**	**0**	**0**	**0**	**1**	**0**	**1**	**0**	**0**	**7**
Singer- Dudek & Oblak 2013	Moderate	1	1	1	1	1	0	0	1	0	1	0	1	0	0	8
Singer- Dudek et al. 2011	Moderate	1	1	1	1	1	0	1	1	1	1	1	1	0	0	10

Leaf et al. 2012	Moderate	1	1	1	1	1	0	1	1	0	1	1	1	0	0	10
Leaf et al. 2016	Strong	1	1	1	1	1	0	1	1	1	1	1	1	0	0	11

Quality of evidence ratings in comparison studies

Cividini-Motta et al. 2017	**Moderate**	**1**	**1**	**1**	**1**	**1**	**0**	**1**	**1**	**0**	**0**	**1**	**1**	**0**	**0**	**9**
Dozier et al. 2012	Moderate	1	1	1	1	1	0	1	1	0	1	1	1	0	0	10
Holth et al. 2009	Moderate	1	1	1	1	1	0	1	0	0	1	1	1	0	0	9
Lepper et al. 2013	Moderate	1	1	1	1	1	0	0	1	0	1	1	1	0	0	9
Lepper & Petursdottir 2017	Moderate	1	1	1	1	1	0	1	1	0	1	1	1	0	0	10
Miliotis et al. 2012	Moderate	1	1	1	1	1	0	1	1	1	0	0	1	0	0	9
Rodriguez & Gutierrez 2017	Moderate	0	1	1	1	1	0	1	1	1	0	1	1	0	0	9
Stock et al. 2008	Moderate	1	1	1	1	1	0	0	1	1	0	0	0	0	0	8

1: "yes" response to question *0: "no" response to question*

Figure

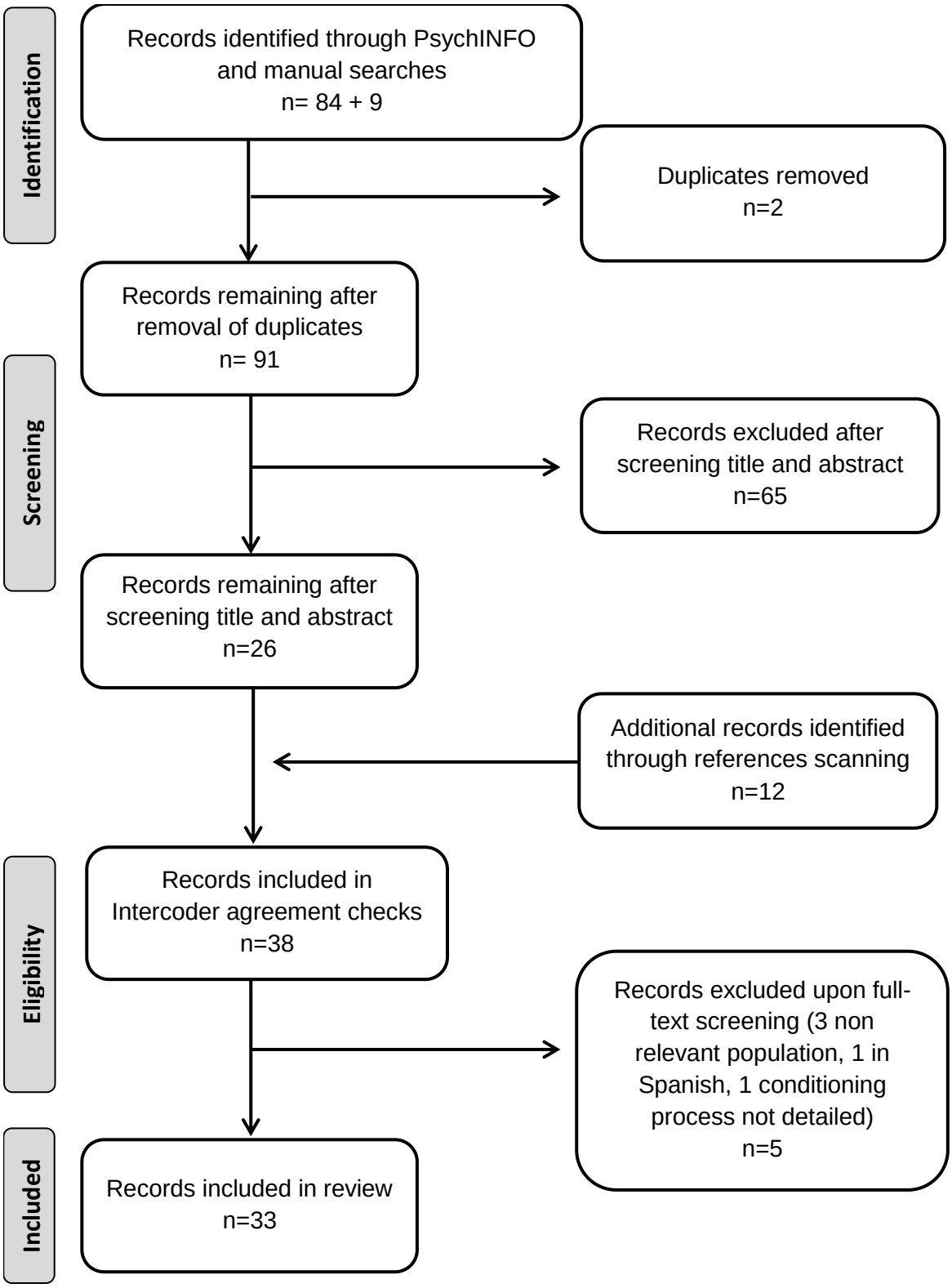

Figure 1. Flowchart depicting inclusion process

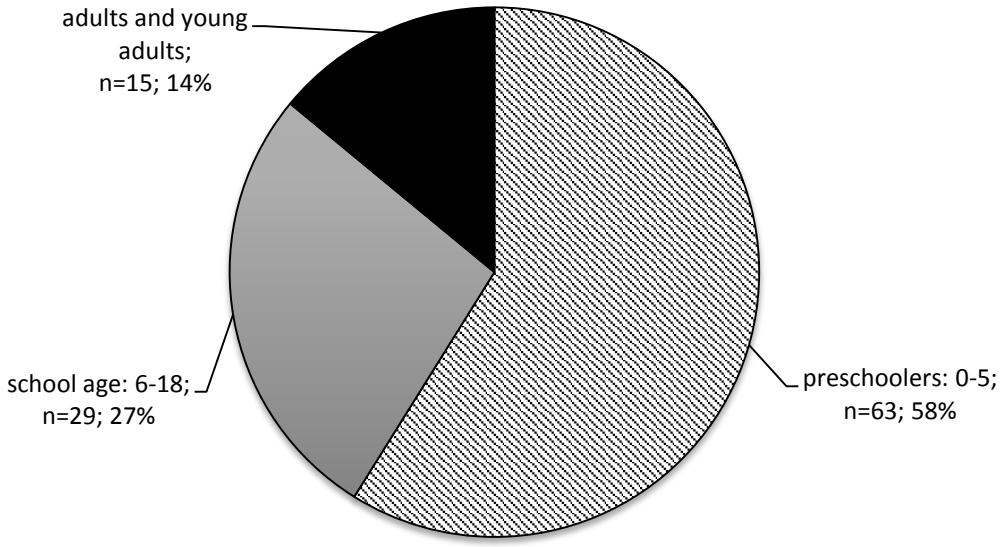

Figure 2. Summary of participants' age

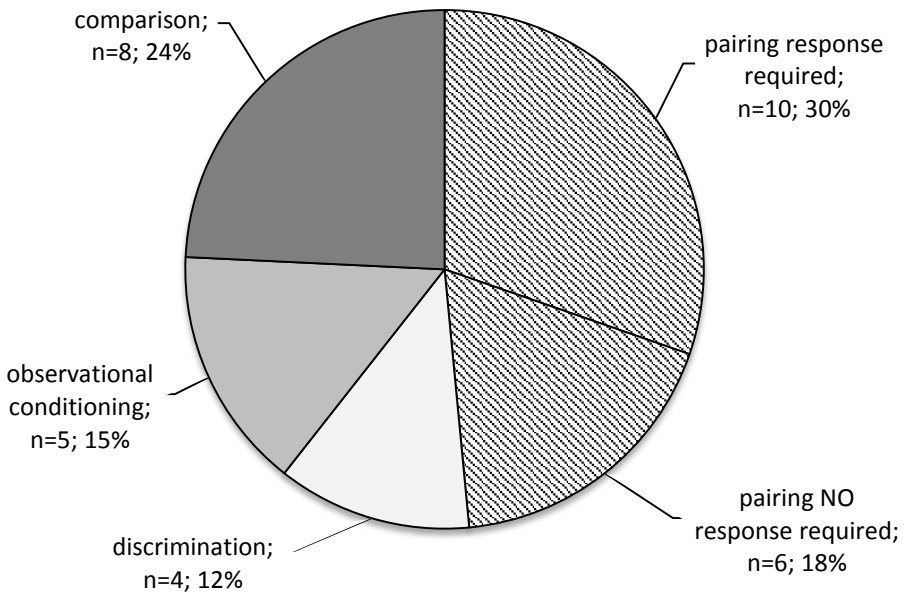

Figure 3. Lines of research

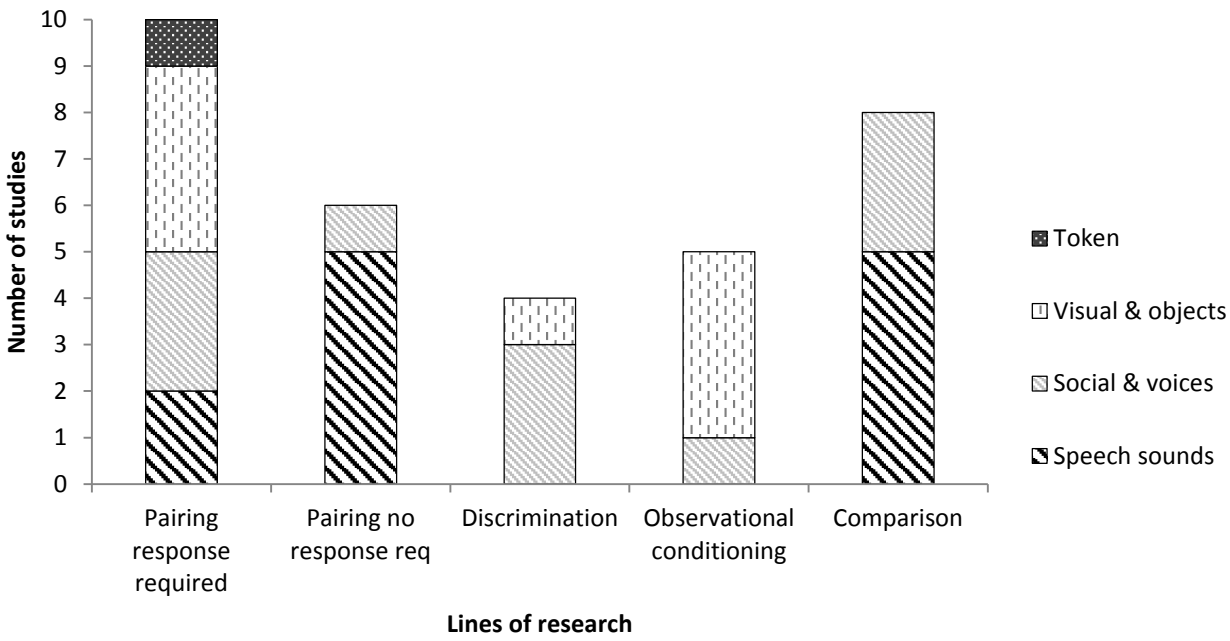

Figure 4. Stimuli to be conditioned across lines of research

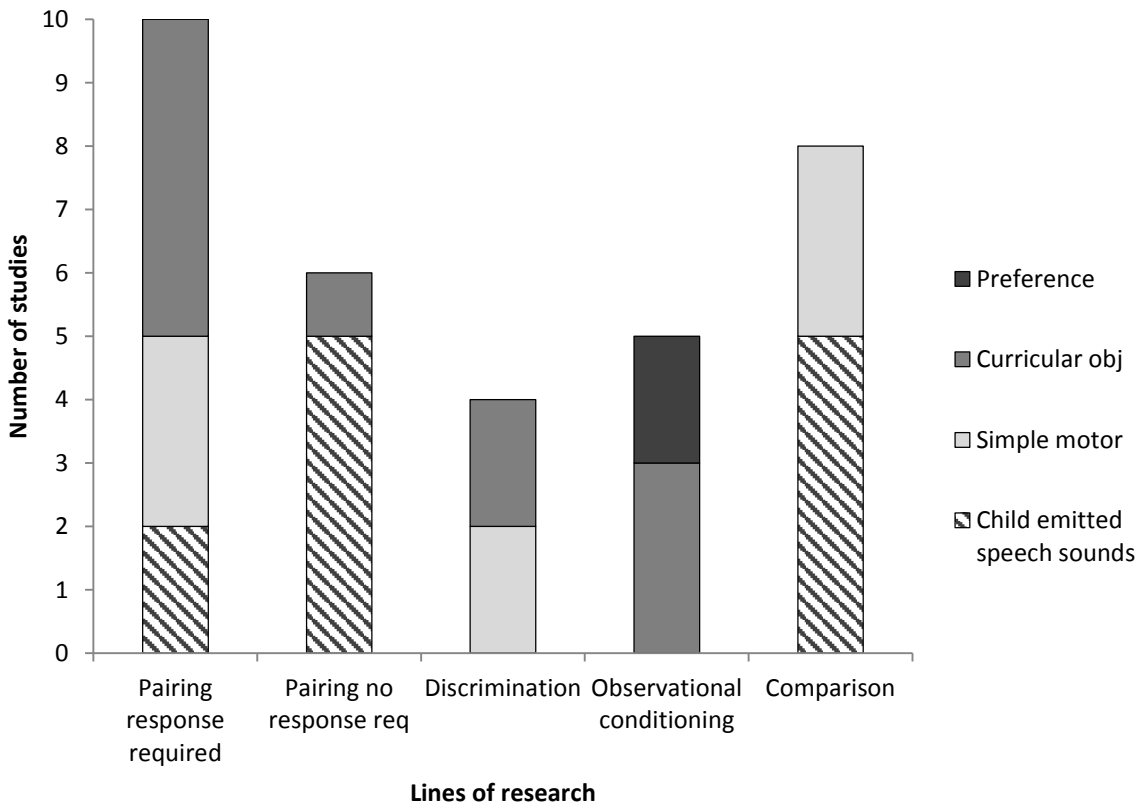

Figure 5. Dependent variable measures across lines of research

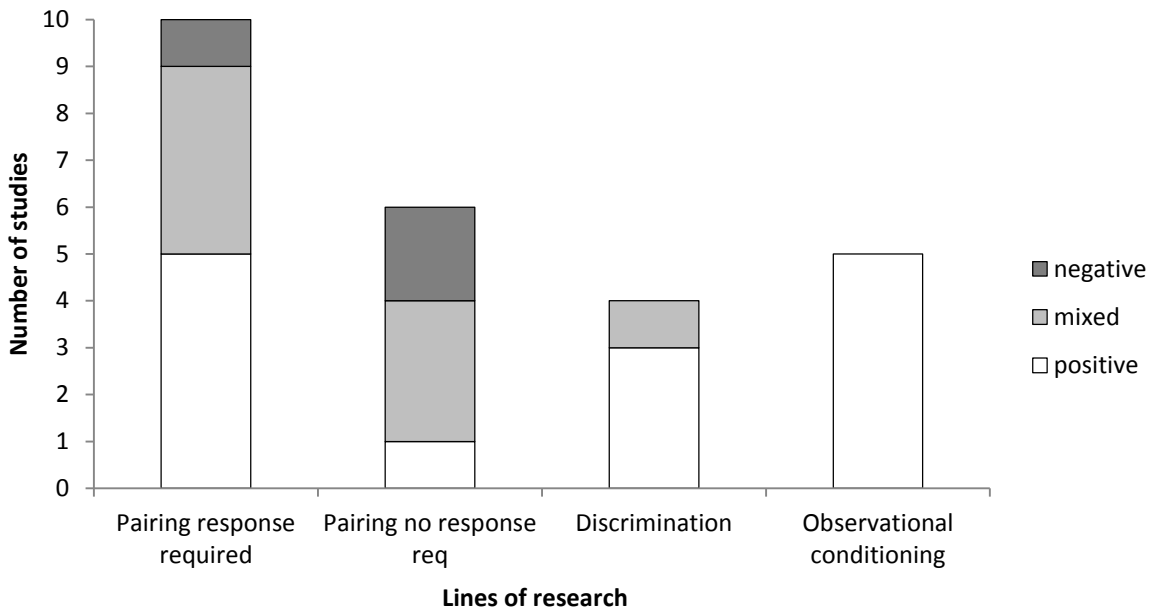

Figure 6. Reported effectiveness across lines of research: Pairing with and without response, discrimination and observational conditioning

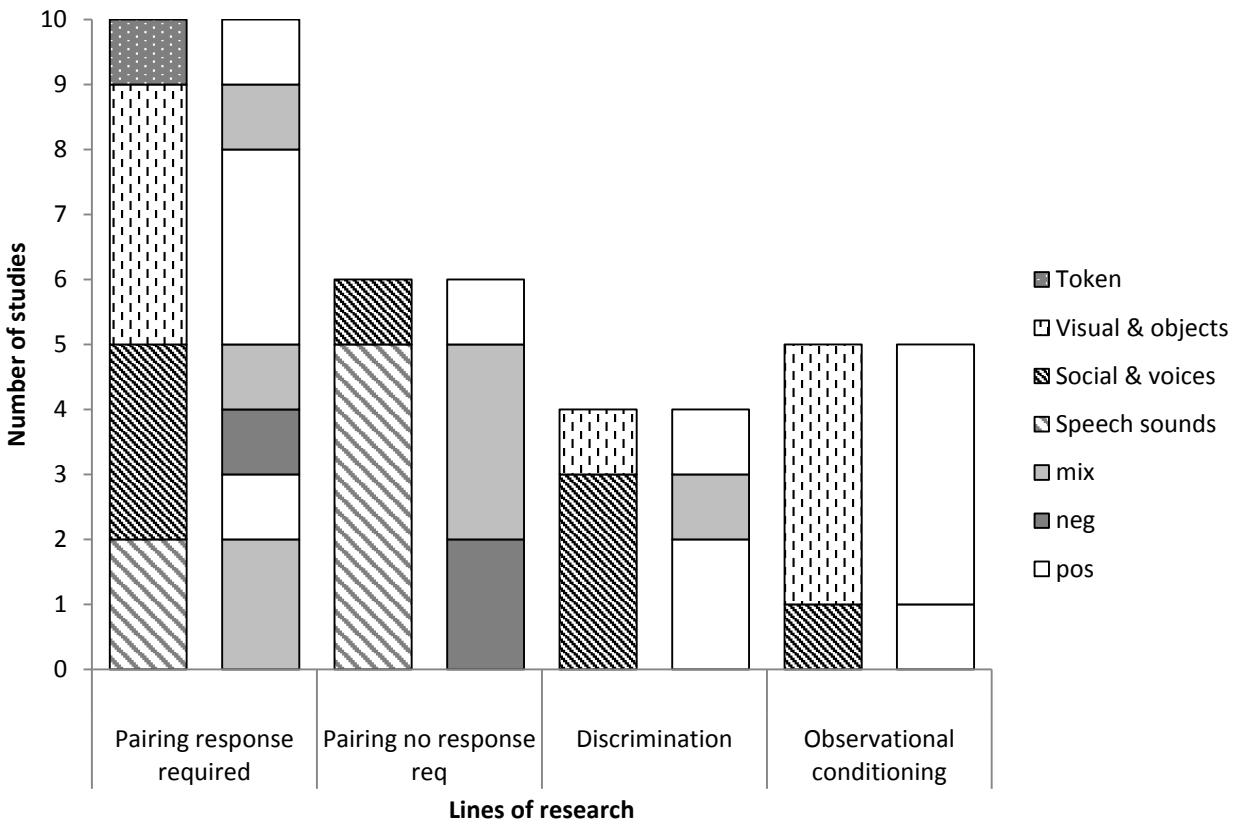

Figure 7. Reported effectiveness per stimuli to be conditioned across lines of research

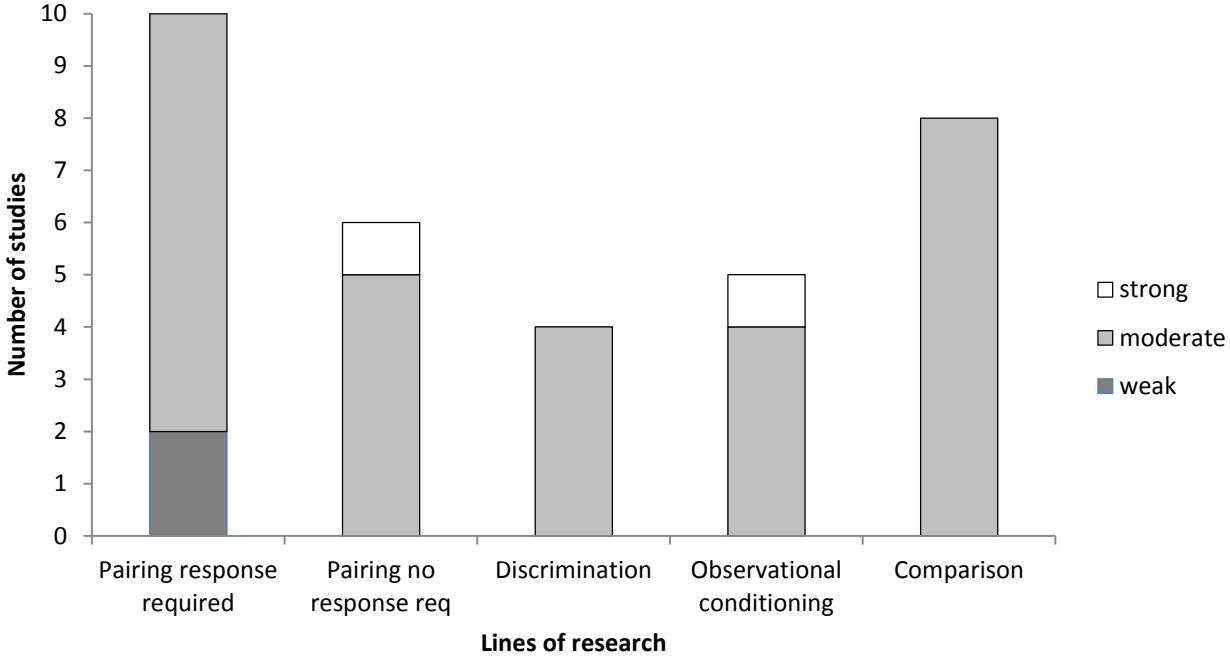

Figure 8. Quality of evidence across lines of research

Compliance with Ethical Standards:

Funding: No funding was received for this study.

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.

Conflict of interest

Authors have no conflict of interest to declare.