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The use of conditioned motivating operations (CMOs) in mand training for children with autism spectrum disorder: A systematic review

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ABSTRACT
The concept of the establishing operation/motivating operation (MO) provides a useful approach for understanding motivational variables in operant conditioning. Since Michael elaborated the concept of the conditioned motivating operation (CMO), three CMO subtypes (i.e., surrogate, reflexive, transitive) have been applied in the analysis of behaviour. The aims of the current review are (a) to identify the types of CMO used in mand training, (b) to identify the stimuli functioning as CMOs in the MO manipulation procedures, and (c) to analyse the effectiveness of MO manipulation procedures in mand training. The current systematic review identifies, between 1982 and 2022, 61 studies using MO manipulation procedures to teach new mand responses to children with autism spectrum disorder. All studies used transitive CMOs in mand training. Various stimuli functioned as CMOs in a range of procedures, the most common being hiding an item from view. The evaluation of effect sizes showed that mand training using CMOs had medium to strong effects in 66% of the participants in increasing their independent mand responses. Implications for practitioners and suggestions for future research on mand training using CMOs are discussed.

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KEYWORDS
Autism spectrum disorder; conditioned motivating operation; establishing operation; discriminative stimulus; mand; verbal behaviour

Introduction

While the term *establishing operation* (EO) was first used by Keller and Schoenfeld (1950) and reflected Skinner's (1938) description of the effects of deprivation and satiation on behaviour, the revival of interest in such effects has primarily been a result of Michael's subsequent (Michael, 1982, 1993) conceptual elaboration. More recently, Laraway et al. (2003) introduced the term *motivating operation* (MO) and provided a revised definition stating that MOs alter (a) the effectiveness of reinforcers or punishers (the value-altering effect) and (b) the frequency of operant response classes related to those consequences (the behavior-altering effect). While there has been continued discussion of the nature and definition of MOs (e.g., Edwards et al., 2019; Laraway & Snycerski, 2019; Lechago, 2019; Miguel, 2019; Pilgrim, 2019), the EO/MO concept has been highly influential,

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perhaps especially in applied behaviour analysis (ABA) (e.g., Carbone, 2013; McGill, 1999), and has become part of mainstream understanding and presentation of ABA (e.g., Michael & Miguel, 2020).

MOs can be categorised as unconditioned motivating operations (UMOs) or conditioned motivating operations (CMOs) (Michael, 1993). Unlike UMOs such as deprivation of food, water, sleep and activity, CMOs acquire their motivating function as a result of a particular learning history. According to Michael (1993), there are three CMO subtypes: *surrogate*, *reflexive,* and *transitive*. A surrogate CMO (CMO-S) is a stimulus that was previously neutral prior to being paired with a UMO or other CMO, subsequently acquiring the motivational characteristics of the UMO or other CMO. A reflexive CMO (CMO-R) is a stimulus that precedes the occurrence of a worsening or improving event, its termination functioning as a reinforcement or a punishment. A transitive CMO (CMO-T) is a stimulus that establishes the effectiveness of another event as a reinforcer. Examples of CMOs are provided extensively by Langthorne and McGill (2009) and Michael and Miguel (2020).

For instance, food deprivation can be paired with a certain time on a clock (e.g., 12 pm). After the repeated pairing of food deprivation and the time on a clock, the time on a clock may function as a CMO-S, increasing the value of food as a reinforcer as well as evoking food-maintained behaviours (Langthorne & McGill, 2009). Carbone et al. (2010) examined the role of a CMO-R in escape-maintained challenging behaviour of children with autism spectrum disorder (ASD) during a discrete trial instruction. When instructional stimuli (e.g., presentation of verbal instructions, instructional materials) evoke problem behaviour, the removal of the instructional stimuli can function as a negative reinforcer. Therefore, the early phases of a demand sequence may function as CMO-Rs for challenging behaviour (Michael, 2000). In Michael's (1982) example of the slotted screw, the sight of the slotted screw can be interpreted as a CMO-T for asking for a screw driver (Michael & Miguel, 2020). CMO-Ts, in particular, have been identified as a mechanism for teaching verbal behaviour in applied settings to increase the mand repertoire of individuals with developmental disabilities (Carbone, 2013).

Skinner (1957) defined a mand as "a verbal operant in which the response is reinforced by a characteristic consequence and is therefore under the functional control of relevant conditions of deprivation or aversive stimulation" (p. 35–36). Typically developing children spontaneously emit mands from an early stage of their life, whereas children with ASD may require mand training to develop a verbal repertoire that enables them to communicate their needs (Sundberg & Michael, 2001). All mands are under the control of motivational variables and different mands specify different reinforcements (Skinner, 1957), therefore the relevant MO needs to be manipulated, or naturally developed child preferences utilised, when teaching mand skills (Michael, 1988; Shafer, 1995; Sundberg & Michael, 2001). One approach to manipulating the relevant MO has been to use a behaviour chain interruption strategy (BCIS) in which one of the items needed to complete an activity is withheld or access to the preferred item is blocked. For example, Hall and Sundberg (1987) withheld items needed to complete activities such as making instant coffee, making instant soup, and operating vending machines. The participants learned to mand for the missing items, thus gaining access to the terminal reinforcers. The BCIS procedure has been replicated frequently in studies with individuals with severe disabilities (Carter & Grunsell, 2001).

Furthermore, systematic reviews of 28 studies using a BCIS (Carnett et al., 2017), 21 studies teaching participants to ask questions (Raulston et al., 2013), and six studies using mand frame procedures (e.g., "May I have + item?") (Shea et al., 2019) have established that the manipulation of MOs is effective for teaching mand skills to children with ASD. These three systematic reviews focused on specific mand training procedures or types of mand response. In contrast, the current review incorporates mand training studies using various MO manipulation procedures to teach different mand responses to children with ASD. The current review also aims to evaluate effectiveness of mand training, through the calculation of effect sizes from the data reported in mand training studies. Despite the growing number of studies using MO manipulation procedures to teach verbal behaviours, to our knowledge, there is no systematic review focusing on the generic use of CMOs in mand training. Understanding the MO manipulation procedures used in mand training would help researchers and practitioners to design and to implement more effective training. The current review aims to address the following three questions:

(1) What types of CMO are used in mand training?
(2) Which stimuli function as CMOs in the MO manipulation procedures?
(3) Are the MO manipulation procedures effective in teaching new mand responses to children with ASD?

Method

Literature searches were conducted using electronic databases: *PsycINFO, Education Resources Information Center (ERIC)*, and *PubMed*. Since a number of studies using the BCIS procedures to teach mands did not specify the role of CMOs, a systematic methodology using two separate search strategies was adopted. The first search was conducted using a combination of the following search terms related to the MOs, mand skills, and ASD diagnosis: (*motivating operations* OR *establishing operations* OR *establishing stimulus*) AND (*mand** OR *request** OR *ask** OR *question* OR *Wh question)* AND *[(auti** OR *ASD* OR *Asperger** OR *Pervasive Developmental Disorder-Not Otherwise Specified* (*PDD-NOS)]*. The second search was conducted using a combination of the following search terms related to the BCIS procedures, mand skills, and ASD diagnosis: (*behav* chain** OR *chaining procedure* OR *chain** OR *interrupted behav* chain*) AND (*mand** OR *request** OR *ask** OR *question* OR *Wh question)* AND *(auti** OR *ASD* OR *Asperger** OR *PDD-NOS)*.

The search was restricted to full text, English language, and peer-reviewed studies published between 1982 and 2022. 1982 was used as the start point since the *establishing stimulus* (a forerunner of one type of CMO) was first described in Michael's (1982). A further manual search was conducted of *Journal of Applied Behavior Analysis (JABA)*, *The Analysis of Verbal Behavior (TAVB)*, and *European Journal of Behavior Analysis (EJOBA)* selected as the prime journals in the field of ABA regularly publishing research on verbal behaviour interventions. The reference sections of three systematic review articles (Carnett et al., 2017; Raulston et al., 2013; Shea et al., 2019) and the selected articles were manually screened to find additional articles that may have been missed in the electronic search.

Articles included in this review were required to meet all of the following criteria: (a) included a description of motivating variables manipulated, (b) provided mand training, (c) the primary dependent variable (DV) was new mand responses, (d) were empirically based, (e) included child participants up to the age of 18, (f) used a single subject research design or a group research design in which at least one participant was diagnosed with ASD, and (g) were peer-reviewed articles. Regarding criterion (f), participants who were not diagnosed with ASD were excluded from further analysis. Articles were excluded from the review if they described CMOs but were non-empirical, used a group research design in which the data were not differentiated across individuals, or included a description of motivating variables manipulated in mand training conducted within a functional communication training (FCT) intervention or behavioural skills training (BST) intended to enable parents or others to teach mands to a child with ASD.

The reason for excluding studies using a group research design in which the data were not differentiated across individuals was that we were unable to calculate participant effect sizes if individual data were not shown. The reasons for excluding mand training used in FCT studies were (a) its primary focus on reducing challenging behaviour typically involving a combination of treatments, especially including extinction. The impact of such multiple interventions and the use of extinction of existing mand equivalents (challenging behaviours) was thought to significantly complicate the mand training context, (b) FCT studies typically involve (at least in their early stages) the occurrence of pre-existing challenging behaviours, the management of which may also interfere with the mand training context, and (c) the range of other variables involved in FCT studies (especially more recent ones aiming to go beyond simple demonstrations) complicates the assessment of the effectiveness of mand training. Similarly, the reasons for excluding mand training used in BST studies were (a) its primary focus on evaluating the effectiveness of BST to implement mand training rather than the child's acquisition of new mand responses and (b) other variables such as the implementor's variable skill acquisition can affect a child's mand responses. While it may have been possible to manage these issues in respect of FCT and/or BST, their implications for the size and complexity of the review process would have required resources beyond those available to the current authors.

Literature searches were conducted in March, 2022. One-hundred-sixty-nine articles were found after excluding duplicates. Following screening of titles and abstracts, 116 articles were excluded as not meeting one or more of the inclusion criteria. After full-text review of the remaining articles, 42 were retained. The manual searches described above added 19 articles. Therefore, 61 articles were included in this review. Figure 1 summarises the search strategy and its results.

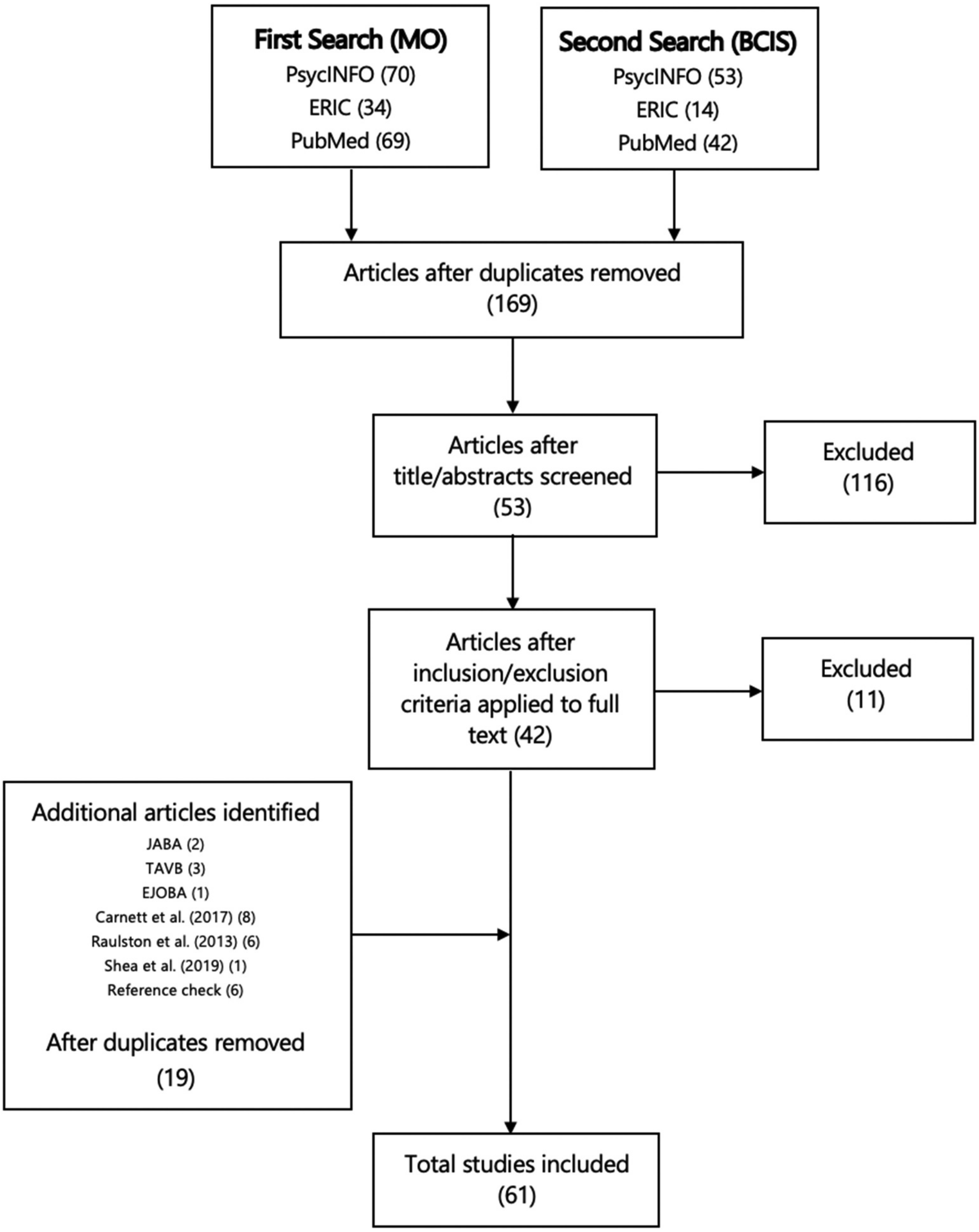

Figure 1. Search strategy and the number of articles included at each stage. MO = motivating operation; BCIS = behaviour chain interruption strategy; JABA = Journal of Applied Behavior Analysis; TAVB = The Analysis of Verbal Behavior; EJOBA = European Journal of Behavior Analysis

As all the identified articles used single subject research designs, Reichow et al. (2008)'s evaluative method was used to assess methodological quality. The tool was developed to evaluate intervention for individuals with ASD and has been compared favourably with other single-case design evaluation tools (Wendt & Miller, 2012). Based on the ratings

Table 1. Quality assessment of included studies

Study Citation	PART	IV	BSLN	DV	VIS ANAL	EXP CON	IOA	KAP	BR	FID	G/M	SV	Strength rating
1. Albert et al. (2012)	H	H	H	H	A	A	P	N	N	N	P	N	Adequate
2. Alwell et al. (1989)	H	A	H	H	H	H	P	N	N	P	P	N	Adequate
3. Betz et al. (2010)	H	H	H	H	A	H	P	N	N	P	P	N	Adequate
4. Bowen et al. (2012)	H	H	H	H	A	A	P	N	N	P	P	N	Adequate
5. Carnett et al. (2019)	H	H	H	H	A	A	P	N	N	P	P	N	Adequate
6. Carnett and Ingvarsson (2016)	H	A	A	H	H	A	P	N	N	P	P	N	Weak
7. Carnett et al. (2020)	H	H	H	H	A	A	P	N	N	P	P	N	Adequate
8. Choi et al. (2010)	H	H	H	H	A	A	P	N	N	P	P	N	Adequate
9. Drash et al. (1999)	H	H	U	H	A	A	N	N	N	N	N	N	Weak
10. Duker et al. (1994)	H	H	H	H	U	U	P	N	N	N	N	N	Weak
11. Endicott and Higbee (2007)	H	A	A	H	H	H	P	N	N	N	P	N	Adequate
12. Gordon and Shillingsburg (2019)	H	H	H	H	H	H	P	N	N	P	P	N	Strong
13. Hartman and Klatt (2005)	H	H	U	H	A	A	P	N	N	N	P	N	Weak
14. Howlett et al. (2011)	H	H	H	H	H	A	P	N	N	P	P	N	Adequate
15. Ingvarsson and Hollobaugh (2010)	H	H	H	H	H	H	P	N	N	N	P	P	Strong
16. Jessel and Ingvarsson (2021)	H	H	A	H	A	H	P	N	N	P	N	N	Adequate
17. Kahlow et al. (2019)	H	H	H	H	H	H	P	N	N	P	P	P	Strong
18. Koegel et al. (1998)	H	A	H	H	H	H	P	N	N	N	P	P	Adequate
19. Koegel et al. (2010)	H	A	H	H	H	H	P	N	N	N	P	P	Adequate
20. Landa et al. (2020)	H	H	H	H	A	H	P	N	N	N	P	N	Adequate
21. Landa et al. (2017)	H	H	H	H	A	A	P	N	N	N	P	N	Adequate
22. Lechago et al. (2010)	H	H	H	H	A	A	P	N	N	P	P	N	Adequate
23. Lechago et al. (2013)	H	H	H	H	A	A	P	N	N	P	P	N	Adequate
24. Lorah et al. (2014)	H	A	H	H	H	H	P	N	N	N	P	N	Adequate
25. Lorah et al. (2019)	H	A	H	H	H	H	P	N	N	P	P	N	Adequate
26. Lorah et al. (2020)	H	H	H	H	A	H	P	N	N	P	P	N	Adequate
27. Marion et al. (2011)	H	H	U	H	U	U	P	N	N	P	P	P	Weak
28. Marion, Martin, Yu, Buhler, and Kerr (2012)	H	H	H	H	A	A	P	N	N	P	P	P	Adequate
29. Marion, Martin, Yu, Buhler, Kerr, et al. (2012)	H	H	H	H	A	A	P	N	N	P	P	P	Adequate

(*Continued*)

Table 1. (Continued).

Study Citation	PART	IV	BSLN	DV	VIS ANAL	EXP CON	IOA	KAP	BR	FID	G/M	SV	Strength rating
30. Ostryn and Wolfe (2011a)	H	H	H	H	H	H	P	N	N	P	P	P	Strong
31. Ostryn and Wolfe (2011b)	H	H	H	H	A	A	P	N	N	P	N	N	Adequate
32. Patil et al. (2021)	H	H	A	H	A	H	P	N	N	P	P	P	Adequate
33. Pellecchia and Hineline (2007)	H	H	U	H	H	H	P	N	N	N	P	P	Weak
34. Pistoljevic and Dzanko (2017)	H	A	U	H	H	H	P	N	N	N	P	N	Weak
35. Plavnick and Vitale (2016)	H	H	H	H	A	H	P	N	N	P	P	P	Adequate
36. Pyles et al. (2021)	H	H	H	H	A	H	P	N	N	P	P	N	Adequate
37. Roberts-Pennell and Sigafoos (1999)	H	H	H	H	U	U	N	N	N	N	P	N	Weak
38. Rodriguez et al. (2017)	H	A	H	H	A	H	P	N	N	N	P	N	Adequate
39. Roy-Wsiaki et al. (2010)	H	H	U	A	U	A	P	N	N	P	P	N	Weak
40. Shih et al. (2021)	H	A	H	H	H	H	P	N	N	N	N	N	Weak
41. Shillingsburg, Bowen, and Valentino (2014)	H	H	H	H	H	A	P	N	N	P	P	N	Adequate
42. Shillingsburg, Bowen, Valantino, et al. (2014)	H	H	H	H	H	H	P	N	N	P	P	N	Strong
43. Shillingsburg et al. (2018)	H	H	H	H	H	A	P	N	N	P	P	P	Adequate
44. Shillingsburg et al. (2016)	H	H	H	H	H	H	P	N	N	P	N	N	Adequate
45. Shillingsburg et al. (2019)	H	H	H	H	H	H	P	N	N	P	N	N	Adequate
46. Shillingsburg et al. (2013)	H	H	H	H	H	H	P	N	N	N	N	N	Weak
47. Shillingsburg and Valentino (2011)	H	H	U	H	A	A	N	N	N	N	N	N	Weak
48. Shillingsburg et al. (2011)	H	H	H	H	A	A	P	N	N	N	P	N	Adequate
49. Sidener et al. (2010)	H	H	U	H	U	A	P	N	N	P	N	N	Weak
50. Sigafoos et al. (2013)	H	A	H	H	A	A	P	N	N	P	P	N	Weak
51. Sigafoos and Littlewood (1999)	H	A	H	H	A	A	P	N	N	N	N	N	Weak
52. Somers et al. (2014)	H	H	H	H	A	A	P	N	N	P	P	P	Adequate
53. Sundberg et al. (2002)	H	H	A	H	A	A	N	N	N	N	P	N	Weak
54. Sweeney-Kerwin et al. (2007)	H	A	H	H	A	A	P	N	N	N	P	N	Weak
55. Szmacinski et al. (2018)	H	H	H	H	U	A	P	N	N	P	P	P	Weak
56. Tada and Kato (2005)	H	A	U	H	U	U	P	N	N	N	P	N	Weak
57. Valentino et al. (2019)	H	H	A	H	H	H	P	N	N	P	P	N	Adequate
58. Ward and Shukla Mehta (2019)	H	H	H	H	A	A	P	N	N	P	P	P	Adequate

(*Continued*)

Table 1. (Continued).

Study Citation	PART	IV	BSLN	DV	VIS ANAL	EXP CON	IOA	KAP	BR	FID	G/M	SV	Strength rating
59. Williams et al. (2000)	H	H	H	H	A	A	P	N	N	N	P	P	Adequate
60. Williams et al. (2003)	H	H	H	H	A	A	P	N	N	N	P	N	Adequate
61. Wójcik et al. (2021)	H	H	A	H	A	H	P	N	N	P	P	P	Adequate

→ PART = participant characteristics; IV = independent variable; BSLN = baseline condition; DV = dependent variable; VIS ANAL = visual analysis; EXP CON = experimental control; IOA = interobserver agreement; KAP = kappa; BR = blind raters; FID = fidelity; G/M = generalisation or maintenance; SV = social validity; H = high; A = acceptable; U = unacceptable; P = positive; N = negative given to a range of primary and secondary quality indicators, a final rating was assigned to each article. Five studies were coded as *strong*, 37 as *adequate*, and 19 as *weak* (see Table 1). Studies assigned *weak* quality often lacked a detailed description of mand training, showed unstable baseline data, failed to collect at least three measurement points in baseline, overlapped more than 25% of data points between baseline and intervention conditions, or failed to demonstrate at least three experimental effects.

The reliability of title and abstract screening was checked by having a second person independently screen for 20% of the 169 articles (34 articles). Percentage agreement across raters was 100%. The inclusion of 19 additional articles identified through manual searches was confirmed by having a second person independently apply the inclusion and exclusion criteria for 26% of the 19 articles (five articles). The quality assessment was checked by having a second person independently apply Reichow et al. (2008)'s evaluative method for 11% of the 61 included studies (seven articles). There were no instances of disagreements between the two raters.

Data were extracted from each paper on participants' age, gender, diagnosis; intervention settings; DVs; study designs; types of mand; types of CMO; the stimuli functioning as CMOs in the MO manipulation procedures; and intervention outcomes (effect sizes). To aid identification of the type of CMOs, graphical depictions were constructed for each study in a manner similar to that used in Langthorne and McGill (2009).

To evaluate the effectiveness of mand training, quantitative data regarding independent mand responses during baseline and intervention (or post-training) phases were required. No articles presented the raw data numerically; therefore, the data were extracted from the published graphs. Articles not including baseline data were excluded from the analysis of effect sizes.

Using GetData Graph Digitizer software version 2.26 (Fedorov, 2013), graphical data were converted to numerical values, which were rounded off to the closest whole number. When mand responses were evaluated by the type of mand response (e.g., full prompt, partial prompt, independent response), the y-axis was not displayed in numerical values. Therefore, data points were coded using 0 for prompted mand responses and 1 for independent mand responses. In terms of studies assessing cumulative frequency of mand responses, extracted data were re-coded by calculating differences between pairs of consecutive sessions in order to identify the actual increase for each session. Where studies involved teaching both mands for information and correct answers to questions, these responses were combined. In a study conducted by Wójcik et al. (2021), a discrepancy was found between graphical data in that paper's figure 1 and descriptions in text. The study researchers were contacted and confirmed that responding during Play

EO+ and Academic EO+ conditions at the end of baseline should be 0% instead of 100% for participant 3. Therefore, all the responses during baseline were coded as 0.

Tau-U effect sizes (Parker et al., 2011) were calculated using an online calculator (www.singlecaseresearch.org). Tau-U is a nonparametric nonoverlap method of estimating intervention effectiveness in single-case design studies. The calculation corrects, where necessary, for a positive baseline trend. Tau-U scores were calculated by comparing individual baseline and intervention (i.e., mand training) or post-training data (where intervention data not available). In order to estimate Tau-U scores for each participant, omnibus weighted Tau-U scores were calculated for participants who engaged in several mand training trials.

Tau-U scores range from −1 ± 1, a higher percentage of nonoverlapping data between baseline and intervention phases indicating the strength of effect (Parker et al., 2011). Positive scores between 0 and .65 indicate weak effects, .66–.92 medium effects, and .93–1 strong effects (Parker & Vannest, 2009). In the current review, improvement (i.e., a positive Tau-U score) indicates an increase in correct independent mand responses.

Results

Table 2 summarises the 61 selected articles. Results are presented below in terms of participant characteristics, intervention settings, DVs, study designs, types of mand, types of CMO, the stimuli functioning as CMOs, the MO manipulation procedures, intervention outcomes assessed by effect sizes.

The 61 studies provided mand training to 158 participants with ASD. Participant ages ranged from 2.5 to 18.3 years ($M = 6.0$) and 90 participants (57%) were aged 0–5 years, 56 participants (35%) 6–10 years, 9 participants (6%) 11–15 years, and 3 participants (2%) 16–18 years. However, ages are estimated as some studies reported only approximate participant ages. One-hundred-twenty-seven participants (80%) were male and 31 participants (20%) were female. All participants had a diagnosis of ASD, autism, PDD-NOS or were described as being autistic. Fourteen participants had an additional diagnosis (e.g., intellectual disability, severe developmental disabilities, Down syndrome, language delay, foetal alcohol syndrome).

The reviewed studies conducted intervention mainly in three settings: school, clinic, or home. School or educational settings were used in 26 studies (43%) (e.g., Howlett et al., 2011; Landa et al., 2017). Clinic settings (e.g., developmental centre, university, therapy room) were used in 20 studies (33%) (e.g., Lorah et al., 2019; Shillingsburg et al., 2011). Home settings were used in seven studies (11%) (e.g., Marion, Martin, Yu, Buhler, and Kerr, 2012; Marion, Martin, Yu, Buhler, Kerr, et al., 2012; Pyles et al., 2021). Eight studies (13%) included more than one setting, either with different settings being used for each participant (e.g., Carnett et al., 2019, 2020) or to assess generalisation (e.g., Koegel et al., 1998; Patil et al., 2021). Highest use of school settings was consistent with previous

Table 2. Summary of studies using CMOs in mand training.

Study citation	Participant characteristics	Dependent variable	Study design	Type of mand	MO manipulation procedure	Type of CMO: stimulus functioning as CMO	Effect size [Tau-U, significance (2-tailed *p* value), 90% confidence intervals]
1. Albert et al. (2012)	Victor (5 years, male, autism) Nathaniel (8 years, male, autism/ seizure disorder) Carina (5 years, female, PDD/ ASD)	Type of mand response (i. e., unprompted, prompted, no response)	Concurrent multiple baseline design across activities	Mand for an missing item	Withholding an item needed to complete an activity	CMO-T: the last step before being interrupted in a behaviour chain (e.g., the sight of open bag of bread)	Victor: Tau-U = .66, $p <$ .001, 90% CI [0.36, 0.97] Nathaniel: Tau-U = .64, $p < .001$, 90% CI [0.37, 0.92] Carina: Tau-U = .72, $p <$ .001, 90% CI [0.41, 1]
2. Alwell et al. (1989)	Devon (7 years, male, autism/ severe cognitive delay)	Cumulative frequency of mand responses	Multiple baseline design across responses with multiple probes	Mand for an action (e.g., out, hug)	Interrupting ongoing sequence of events	CMO-T: the sight of a door/ the presence of an adult	Devon: Tau-U = .51, $p <$ .001, 90% CI [0.30, 0.74]

(*Continued*)

Table 2. (Continued).

Study citation	Participant characteristics	Dependent variable	Study design	Type of mand	MO manipulation procedure	Type of CMO: stimulus functioning as CMO	Effect size [Tau-U, significance (2-tailed *p* value), 90% confidence intervals]
3. Betz et al. (2010)	Trevor (5 years, male, ASD) Travis (3.5 years, male, ASD) Rachel (4.5 years, female, ASD)	Percentage of independent mand responses	Multiple baseline design across participants	Mand for information using "Where + (item name)?"	Removing a toy from the table	CMO-T: access to a toy	Trevor: Tau-U = 1, *p* = .034, 90% CI [0.23, 1] Travis: Tau-U = .76, *p* = .005, 90% CI [0.31, 1] Rachel: Tau-U = .75, *p* = .004 90% CI [0.32, 1]
4. Bowen et al. (2012)	Aubrey (3 years, female, autism) Chase (11 years, male, autism)	Cumulative frequency of correct independent mands	Adapted alternating treatments design	Mand for an item	Holding a preferred edible item up	CMO-T: the sight of a preferred edible item	Aubrey: Tau-U = .44, *p* = .071, 90% CI [0.04, 0.84] Chase: Tau-U = .75, *p* = .001, 90% CI [0.39, 1]

(*Continued*)

Table 2. (Continued).

Study citation	Participant characteristics	Dependent variable	Study design	Type of mand	MO manipulation procedure	Type of CMO: stimulus functioning as CMO	Effect size [Tau-U, significance (2-tailed *p* value), 90% confidence intervals]
5. Carnett et al. (2019)	Ryan (10 years, male, ASD) Franny (13 years, female, ASD/ Down syndrome) Seth (5 years, male, ASD)	Type of mand response (i. e., independent, gesture, verbal, partial, full prompt)	Concurrent probe multiple baseline design across participants	Mand for an action	Locking a screen and blocking access to a video game or a music video	CMO-T: the sight of a locked screen	Ryan: Tau-U = .75, $p <$ .001, 90% CI [0.43, 1] Franny: Tau-U = .53, $p =$ .004, 90% CI [0.23, 0.84] Seth: Tau-U = .47, $p =$ .007, 90% CI [0.18, 0.76]
6. Carnett and Ingvarsson (2016)	Ryan (11 years, male, autism)	Frequency of the participant said "I do not know, please tell me". or gave the correct answer to the question	Multiple baseline design across stimulus sets	Mand for information	Presenting an unknown question	CMO-T: an unknown question	Ryan: Tau-U = .88, $p <$ .001, 90% CI [0.56, 1]
7. Carnett et al. (2020)	Ryan (10 years, male, ASD) Franny (13 years, female, ASD/ Down syndrome) Seth (5 years, male, ASD)	Type of mand response (i. e., independent, gesture, verbal, partial, full prompt)	1. concurrent multiple baseline design across participants 2. concurrent probe/ multiple baseline design across behaviour chains embedded in a multiple baseline across participants	Mand for information using "Where [item name]?"	1. withholding an item needed for an activity 2. presenting a vocal statement ("I don't know".)	1. CMO-T: the last step before being interrupted in a behaviour chain (e.g., the sight of a board game) 2. CMO-T: the presence of the first communication partner	Ryan: Tau-U = .72, $p =$ .045, 90% CI [0.13, 1] Franny: Tau-U = .29, $p =$ .083, 90% CI [0.01, 0.56] Seth: Tau-U = .40, $p <$ .001, 90% CI [0.21, 0.60]

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Table 2. (Continued).

Study citation	Participant characteristics	Dependent variable	Study design	Type of mand	MO manipulation procedure	Type of CMO: stimulus functioning as CMO	Effect size [Tau-U, significance (2-tailed *p* value), 90% confidence intervals]
8. Choi et al. (2010)	Dan (7 years, male, autism/ severe developmental disabilities) Rob (8 years, male, autism/ severe developmental disabilities/ seizure) Jay (6.5 years, male, autism/ developmental disabilities)	Percentage of correct requesting, rejecting, and re-requesting responses	Multiple probe design across participants	Mand for the removal of a wrong item using "No."	Offering a wrong item when a missing item is requested	CMO-T: the sight of the necessary items for an activity, except a missing item	Dan: Tau-U = .80, p = .043, 90% CI [0.15, 1] Rob: Tau-U = .82, p = .019, 90% CI [0.25, 1] Jay: Tau-U = .59, p = .032, 90% CI [0.14, 1]
9. Drash et al. (1999)	Subject 1 (2.67 years, male, autism) Subject 2 (2.5 years, male, autism) Subject 3 (3.5 years, male, pervasive developmental disorder with autistic symptoms)	1. percentage of mands 2. percentage of correct echoic response 3. percentage of error responses 4. percentage of no responses/ inappropriate behaviour 5. percentage of tact responses	B design	Mand for an item	Presenting a preferred toy or food stimulus out of reach	CMO-T: the sight of an item	Not applicable (no formal baseline sessions were conducted)

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Table 2. (Continued).

Study citation	Participant characteristics	Dependent variable	Study design	Type of mand	MO manipulation procedure	Type of CMO: stimulus functioning as CMO	Effect size [Tau-U, significance (2-tailed *p* value), 90% confidence intervals]
10. Duker et al. (1994)	Rene (14 years, male, autistic)	Frequency of spontaneous mands	Reversal design	Mand for an item or an activity	Providing one quarter/halves of the item needed for an activity (e.g., puzzles) or withholding an ongoing activity (e.g., music)	CMO-T: the sight of an insufficient amount of item needed for an activity/a brief access to an activity	Rene Tau-U = .18, p = .497, 90% CI [−0.25, 0.61]
11. Endicott and Higbee (2007)	Stewart (4 years, male, ASD) Braden (4 years, male, ASD) Gavin (3 years, male, ASD) Dillon (5 years, male, ASD)	1. percentage of correct mands using "Where?" 2. percentage of correct mands using "Who?"	Multiple baseline across participants	1. mand for information regarding location of the item 2. mand for information regarding which adult has the item	1. hiding the item in a box, on a shelf, or in the participant's backpack 2. when the participant asked "Where (item)?", presenting a vocal statement	1. CMO-T: access to a preferred item 2. CMO-T: a vocal statement, "I gave it to somebody."	Stewart: Tau-U = .92, p = .003, 90% CI [0.42, 1] Braden: Tau-U = .88, p < .001, 90% CI [0.54, 1] Gavin: Tau-U = .86, p = .011, 90% CI [0.30, 1] Dillon: Tau-U = 1, p = .011, 90% CI [0.36, 1]

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Table 2. (Continued).

Study citation	Participant characteristics	Dependent variable	Study design	Type of mand	MO manipulation procedure	Type of CMO: stimulus functioning as CMO	Effect size [Tau-U, significance (2-tailed *p* value), 90% confidence intervals]
12. Gordon and Shillingsburg (2019)	Adam (17 years, male, autism) Patrick (13 years, male, autism)	1. percentage of correct mands for information 2. percentage of correct intraverbal responses	Concurrent multiple baseline across participants	Mand for information	Presenting a question about a social partner that is not known nor observable	CMO-T: an unknown question (e.g., "What is Mary's favorite holiday?")	Adam: Tau-U = .80, p = .033, 90% CI [0.18, 1] Patrick: Tau-U = .75, p = .029, 90% CI [0.19, 1]
13. Hartman and Klatt (2005)	Sean (2.5 years, male, autism) Billy (2.5 years, male, autism)	Cumulative frequency of correct independent mands	A-B design	Mand for an item	1. restricting access to toys for more than 23hrs 2. restrictingaccess to toys for more than 23hrs/hiding a toy under the table	1. CMO-T: the sight of a toy 2. CMO-T: the sight of a toy	Not applicable (baseline data is not graphically displayed)
14. Howlett et al. (2011)	Nick (3.67 years, male, autism/ expressive language delay)	Percentage of correct mands	Multiple probe design across participants	Mand for information using "Where's [object]?"	Hiding a toy from view	CMO-T: the sight of an empty toy container	Nick: Tau-U = .83, p = .015, 90% CI [0.27, 1]

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Table 2. (Continued).

Study citation	Participant characteristics	Dependent variable	Study design	Type of mand	MO manipulation procedure	Type of CMO: stimulus functioning as CMO	Effect size [Tau-U, significance (2-tailed p value), 90% confidence intervals]
15. Ingvarsson and Hollobaugh (2010)	Chris (10 years, male, autism) Neil (7 years, male, autism) Matt (6 years, male, autism) Jim (4 years, male, autism)	Frequency of the correct answer to the question or the participants said "I do not know, please tell me."	Multiple baseline across stimulus sets, embeded in multiple baseline across participants	Mand for information using "I do not know, please tell me."	Presenting a question answered incorrectly (personal information, general knowledge, academic skills)	CMO-T: an unknown question	Chris: Tau-U = .95, p = .009, 90% CI [0.35, 1] Neil: Tau-U = 1, $p < .001$, 90% CI [0.57, 1] Matt: Tau-U = .90, $p <$ .001, 90% CI [0.52, 1] Jim: Tau-U = .97, $p <$ .001, 90% CI [0.57, 1]
16. Jessel and Ingvarsson (2021)	Pat (7 years, male, ASD) Sam (3 years, male, ASD)	Cumulative frequency of mands	Phase1: Nonconcurrent multiple baseline design across participants Phase 3: Concurrent multiple baseline design across items	Phase 1: mand for information using "Where is the [item]? (known item) Phase 3: mand for information using "What am I missing?" (unknown item)	Withholding an item needed for a task	CMO-T: the last step before being interrupted in a behaviour chain (e.g., the sight of an item matched)	Pat: Tau-U = .72, $p <$ .001, 90% CI [0.41, 1] Sam: Tau-U = .86, $p <$ .001, 90% CI [0.64, 1]

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Table 2. (Continued).

Study citation	Participant characteristics	Dependent variable	Study design	Type of mand	MO manipulation procedure	Type of CMO: stimulus functioning as CMO	Effect size [Tau-U, significance (2-tailed *p* value), 90% confidence intervals]
17. Kahlow et al. (2019)	Boris (7.08 years, male, ASD) Earl (17.33 years, male, ASD) Kitty (8.92 years, female, ASD)	1. percentage of trials with the mand "When?" 2. percentage of trials with the mand "Where?"	Nonconcurrent multiple baseline design across participants	1. mand for information using "When?" 2. mand for information using "Where?"	1. presenting an unavailability statement ("Not right now.") 2. hiding an item	1. CMO-T: the sight of a preferred item 2. CMO-T: the sight of an empty drawer	Boris: Tau-U = .75, p = .066, 90% CI [0.08, 1] Earl: Tau-U = .88, p = .001, 90% CI [0.44, 1] Kitty: Tau-U = .75, p = .002, 90% CI [0.35, 1] *only "When" trials were evaluated due to "Where?" was previously acquired
18. Koegel et al. (1998)	Child1 (3.92 years, male, autism) Child2 (5.42 years, male, autism) Child3 (3.75 years, female, autism)	1. frequency of spontaneous targeted mands 2. number of stimulus items the child labeled correctly	Multiple baseline design across children	Mand for information using "What's that?"	Hiding a preferred item in an opaque bag	CMO-T: the sight of an opaque bag	Child1: Tau-U = 1, p = .014, 90% CI [0.33, 1] Child2: Tau-U = 1, p = .002, 90% CI [0.48, 1] Child3: Tau-U = 1, p < .001, 90% CI [0.57, 1]

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Table 2. (Continued).

Study citation	Participant characteristics	Dependent variable	Study design	Type of mand	MO manipulation procedure	Type of CMO: stimulus functioning as CMO	Effect size [Tau-U, significance (2-tailed *p* value), 90% confidence intervals]
19. Koegel et al. (2010)	Child1 (3.33 years, male, autism) Child2 (4.67 years, male, autism) Child3 (3.17 years, male, autism)	1. frequency of unprompted mands using "Where?" 2. frequency of prepositions/ ordinal markers the child correctly produced	Multiple baseline design across children	Mand for information using "Where?"	Hiding a preferred item	CMO-T: access to a preferred item	Child1: Tau-U = 1, $p <$ .001, 90% CI [0.51, 1] Child2: Tau-U = 1, $p <$ .001, 90% CI [0.54, 1] Child3: Tau-U = 1, $p <$ .001, 90% CI [0.60, 1]
20. Landa et al. (2020)	Neal (7 years, male, ASD) Kiley (5 years, female, ASD) Rachel (5 years, female, ASD) Cage (7 years, male, ASD)	Percentage of trials with correct mands	Adapted alternating treatments design (treatment) Multiple probe design–(generalisation) Nonconcurrent multiple baseline design (replication)	Mand for social information (e.g., "What kind of ice cream do you like?")	Presenting a social question for which the answer could not be observed	CMO-T: a social question (e.g., "What kind of ice cream does Sarah like?")	Neal: Tau-U = .53, $p =$ .078, 90% CI [0.04, 1] Kiley: Tau-U = .28, $p =$ .426, 90% CI [−0.30, 0.86] Rachel: Tau-U = .77, $p =$ .006, 90% CI [0.31, 1] Cage: Tau-U = .42, $p =$ .188, 90% CI [−0.10, 0.94]

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Table 2. (Continued).

Study citation	Participant characteristics	Dependent variable	Study design	Type of mand	MO manipulation procedure	Type of CMO: stimulus functioning as CMO	Effect size [Tau-U, significance (2-tailed *p* value), 90% confidence intervals]
21. Landa et al. (2017)	Haley (6 years, female, autism) Brian (7 years, male, autism) Daisy (6 years, female, autism)	Percentage of trials with mands for information during EO-present and EO-absent conditions	Alternating treatments design/multiple baseline design across participants	Mand for information using "When?" or "When can I have [item]?"	Presenting an unavailability statement (e.g., "Not right now.")	CMO-T: the sight of a preferred item	Haley: Tau-U = .90, p = .023, 90% CI [0.25, 1] Brian: Tau-U = .67, p = .121, 90% CI [−0.04, 1] Daisy: Tau-U = .73, p = .008, 90% CI [0.28, 1]
22. Lechago et al. (2010)	John (4.5 years, male, autism) Matt (4.5 years, male, autism) Anthony (7 years, male, autism)	Cumulative frequency of correct mands	Nonconcurrent multiple baseline design across participants	Mand for information using "Where is [item]?" and "Who has [item]?"	Where trials: withholding an item needed to complete an activity Who trials: presenting a vocal statement	CMO-T (Where): the last step before being interrupted in a behaviour chain (e.g., the sight of an open bin) CMO-T (Who): a vocal statement, "One of your teachers has it."	John: Tau-U = 1, p = .021, 90% CI [0.29, 1] Matt: Tau-U = 1, p = .011, 90% CI [0.36, 1] Anthony: Tau-U = 1, p = .002, 90% CI [0.47, 1]

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Table 2. (Continued).

Study citation	Participant characteristics	Dependent variable	Study design	Type of mand	MO manipulation procedure	Type of CMO: stimulus functioning as CMO	Effect size [Tau-U, significance (2-tailed *p* value), 90% confidence intervals]
23. Lechago et al. (2013)	Greg (7.58 years, male, autism) Raymond (7.58 years, male, autism) Jake (5.75 years, male, autism)	Cumulative frequency of correct mands and completion of behaviour chains	Concurrent multiple probe design across behaviour chains	Mand for information using "How do I?" and "How many?"	Presenting a preferred activity that cannot be completed independently	CMO-T: the sight of a preferred activity	Greg: Tau-U = .58, p = .002, 90% CI [0.28, 0.89] Raymond: Tau-U = .80, p = .003, 90% CI [0.36, 1] Jake: Tau-U = .73, $p <$ .001, 90% CI [0.39, 1]
24. Lorah et al. (2014)	Jayson (4 years, male, ASD) Aaron (4 years, male, ASD) Sean (5 years, male, ASD)	1. percentage of independent mands 2. percentage of independent listener responses 3. trials to criterion for both speaker and listener responses	Multiple baseline design across participants	Mand for a missing item from the peer	Withholding 1–3 pieces needed to complete a puzzle	CMO-T: a completion of a puzzle with the exception of 1–3 pieces	Jayson: Tau-U = 1, p = .034, 90% CI [0.23, 1] Aaron: Tau-U = 1, p = .034, 90% CI [0.23, 1] Sean: Tau-U = 1, p = .011, 90% CI [0.36, 1]

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Table 2. (Continued).

Study citation	Participant characteristics	Dependent variable	Study design	Type of mand	MO manipulation procedure	Type of CMO: stimulus functioning as CMO	Effect size [Tau-U, significance (2-tailed *p* value), 90% confidence intervals]
25. Lorah et al. (2019)	Sally (3.9 years, female, autism) Nate (3.6 years, male, autism) Linda (4.2 years, female, autism)	Percentage of independent and prompted mands	Multiple baseline across participants	Mand for a missing item from the peer	Withholding the final piece needed to complete a puzzle	CMO-T: a completion of a puzzle with the exception of the final piece	Sally: Tau-U = 1, p = .034, 90% CI [0.23, 1] Nate: Tau-U = 1, p = .009, 90% CI [0.37, 1] Linda: Tau-U = .92, p = .008, 90% CI [0.35, 1]
26. Lorah et al. (2020)	Walter (3.25 years, male, ASD) Jane (4.33 years, female, ASD) Jax (4.5 years, male, ASD)	Percentage of independent mands	Multiple baseline across participants	Mand for a missing item from the peer	Withholding an item needed for arts and crafts	CMO-T: the sight of an art activity	Walter: Tau-U = .50, p = .205, 90% CI [−0.15, 1] Jane: Tau-U = .58, p = .011, 90% CI [0.20, 0.95] Jax: Tau-U = 1, p = .002, 90% CI [0.48, 1]

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Table 2. (Continued).

Study citation	Participant characteristics	Dependent variable	Study design	Type of mand	MO manipulation procedure	Type of CMO: stimulus functioning as CMO	Effect size [Tau-U, significance (2-tailed *p* value), 90% confidence intervals]
27. Marion et al. (2011)	Zach (4 years, male, ASD) Kevin (5.58 years, male, ASD) Luke (8.42 years, male, autism)	Percentage of correct mands	Modified multiple baseline design across four CMEOs	Mand for information using "What is it?"	1. hiding an item 2. withholding an item needed to complete an activity 3. providing an insufficient amount of item 4. hiding an item behind back, peeking around a door, "Oooh"	1. CMO-T: the sight of an item 2. CMO-T: the completion of an activity with the exception of a missing item 3. CMO-T: the presence of items needed to begin an activity *mand training was conducted in 1, 2, 3	Zach: Tau-U = .25, p = .497, 90% CI [−0.36, 0.86] Kevin: Tau-U = .76, p = .068, 90% CI [0.08, 1] Luke: Tau-U = .71, p = .032, 90% CI [0.17, 1]
28. Marion, Martin, Yu, Buhler, and Kerr (2012)	Zack (5 years, male, ASD) Chris (3.83 years, male, PDD-NOS) Connor (5 years, male, ASD)	Percentage of correct mands	Modified multiple baseline design across participants	Mand for information using "Where?"	1. hiding a preferred toy 2. withholding an item needed to complete an activity 3. providing an insufficient amount of item 4. giving a locked box or moving an item from a box to another container	CMO-T: the sight of a preferred toy *mand training was conducted in 1	Zack: Tau-U = .64, p = .298, 90% CI [−0.37, 1] Chris: Tau-U = 1, p = .064, 90% CI [0.11, 1] Connor: Tau-U = .63, p = .192, 90% CI [−0.16, 1]

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Table 2. (Continued).

Study citation	Participant characteristics	Dependent variable	Study design	Type of mand	MO manipulation procedure	Type of CMO: stimulus functioning as CMO	Effect size [Tau-U, significance (2-tailed p value), 90% confidence intervals]
29. Marion, Martin, Yu, Buhler, Kerr, et al. (2012)	Zack (male, ASD) Connor (male, ASD) Kevin (male, ASD) *all participants ranged in age from 5 to 6 years	Percentage of correct mands	Modified multiple baseline design across participants	Mand for information using "Which?"	Where trials: 1. hiding a toy in one of the container 2. withholding an item needed to complete an activity 3. providing an insufficient amount of item 4. giving a locked box Which trials: after the participant manded "Where?" providing a general description	CMO-T: a vocal statement (e. g., "In the box".) *mand training was conducted using Where trial 1	Zack: Tau-U = .40, p = .558, 90% CI [−0.72, 1] Connor: Tau-U = .45, p = .324, 90% CI [−0.30, 1] Kevin: Tau-U = 1, p = .083, 90% CI [0.05, 1]
30. Ostryn and Wolfe (2011a)	Rex (4 years, male, PDD-NOS) Carrie (3 years, female, ASD) Amy (4 years, female, autism)	Percentage of unprompted pictorial communication (later changed to full spoken response)	Multiple baseline design across three participants	Mand for information using "What's that?"	Hiding a toy in a bag or a box	CMO-T: the sight of an item that could not be identified (hidden in a bag or a box)	Rex: Tau-U = 1, p = .014, 90% CI [0.33, 1] Carrie: Tau-U = 1, p = .006, 90% CI [0.40, 1] Amy: Tau-U = .83, p = .023, 90% CI [0.23, 1]

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Table 2. (Continued).

Study citation	Participant characteristics	Dependent variable	Study design	Type of mand	MO manipulation procedure	Type of CMO: stimulus functioning as CMO	Effect size [Tau-U, significance (2-tailed p value), 90% confidence intervals]
31. Ostryn and Wolfe (2011b)	Rita (4.92 years, female, ASD) Joann (4.17 years, female, ASD) Henry (4.17 years, male, ASD)	1. percentage of correct independent utterance of "What's that?" 2. percentage of correct independent utterance of "Where is it?"	Multiple baseline design across participants	Mand for information using "What's that?"/"Where is it?"	1. hiding a toy in a bag 2. hiding a toy in a container	1. CMO-T: the sight of an item that could not be identified (hidden in a bag) 2. CMO-T: the sight of an empty container	Rita: Tau-U = 1, p = .027, 90% CI [0.26, 1] Joann: Tau-U = 1, p = .019, 90% CI [0.30, 1] Henry: Tau-U = .77, p = .007, 90% CI [0.31, 1]
32. Patil et al. (2021)	Gianna (9.92 years, female, ASD) Brandon (18.33 years, male, ASD) Ken (8.08 years, male, ASD)	Percentage of independent correct responses	Concurrent multiple-baseline design across three scenario types	Mand for information using "Why?"	Presenting an unavailability statement (e.g., "You can't have it.")/showing a video of someone engaging in an emotional response/ walking with the participant to a different room, hallway, or outside	CMO-T: the sight of a preferred item/the observation of an emotional response/the sight of a different room, hallway, or outside	Gianna: Tau-U = 1, p < .001, 90% CI [0.63, 1] Brandon: Tau-U = .91, p < .001, 90% CI [0.52, 1] Ken: Tau-U = .93, p < .001, 90% CI [0.55, 1]

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Table 2. (Continued).

Study citation	Participant characteristics	Dependent variable	Study design	Type of mand	MO manipulation procedure	Type of CMO: stimulus functioning as CMO	Effect size [Tau-U, significance (2-tailed *p* value), 90% confidence intervals]
33. Pellecchia and Hineline (2007)	Rachel (4 years, female, autism) Bobby (5 years, male, autism) Nate (4 years, male, autism)	Percentages of unprompted mands	Multiple baseline across participants	Mand for an item	Placing a preferred item out of reach/ blocking access to an item	CMO-T: the sight of a preferred item	Rachel: Tau-U = .76, p = .037, 90% CI [0.16, 1] Bobby: Tau-U = 1, p = .009, 90% CI [0.37, 1] Nate: Tau-U = 1, p = .013, 90% CI [0.34, 1]
34. Pistoljevic and Dzanko (2017)	A (5.38 years, male, ASD) B (5.66 years, male, ASD) C (5 years, male, ASD)	1. frequency of vocal verbal operants emitted during the non-instructional settings 2. frequency of target mands	Non-concurrent multiple baseline across subjects design	Mand for item/ action (e.g., “Give me ______ please.”, “Open_____ please.”)	15 EO (e.g., withholding an item needed to complete an activity/ blocking access to an item/activity)	CMO-T: the sight of a desired item or activity	A: Tau-U = 1, p = .317, 90% CI [−0.65, 1] B: Tau-U = 1, p = .221, 90% CI [−0.34, 1] C: Tau-U = 1, p = .180, 90% CI [−0.23, 1]

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Table 2. (Continued).

Study citation	Participant characteristics	Dependent variable	Study design	Type of mand	MO manipulation procedure	Type of CMO: stimulus functioning as CMO	Effect size [Tau-U, significance (2-tailed *p* value), 90% confidence intervals]
35. Plavnick and Vitale (2016)	Trish (2.92 years, female, autistic) Paula (2.92 years, female, autistic) Corey (3.42 years, male, autistic) Marcus (3.5 years, male, ASD)	Cumulative frequency of acquired and mastered mands	Adapted alternating treatment design	Mand for an item	Placing a preferred item on a high shelf/withholding one part of an activity that required two parts	CMO-T: the sight of a preferred item/the presence of one part of an activity	Trish: Tau-U = .34, p = .108, 90% CI [−0.01, 0.69] Paula: Tau-U =.32, p = .102, 90% CI [0.00, 0.65] Corey: Tau-U = .38, p = .109, 90% CI [−0.01, 0.76] Marcus: Tau-U = .54, p = .009, 90% CI [0.20, 0.88]
36. Pyles et al. (2021)	Ivan (5 years, male, ASD) Tony (6 years, male, ASD)	1. percentage of correct responses asking "why" questions 2. asking follow-up questions, retrieving missing items, and behaviour excesses	Multiple baseline across participants	Mand for information using "Why?"	Presenting an unavailability statement ("I can't give it to you.")	CMO-T: the sight of a preferred item	Ivan: Tau-U = .60, p = .051, 90% CI [0.09, 1] Tony: Tau-U = .67, p = .121, 90% CI [−0.04, 1]
37. Roberts-Pennell and Sigafoos (1999)	Adam (3 years, male, autism/ intellectual disability)	Percentage of correct mands for "More."	Multiple baseline across subjects	Mand for an activity using "More."	Interrupting an ongoing play (e.g., turning off the keyboard)	CMO-T: the presence of an item	Adam: Tau-U = .50, p = .015, 90% CI [0.16, 0.84]

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Table 2. (Continued).

Study citation	Participant characteristics	Dependent variable	Study design	Type of mand	MO manipulation procedure	Type of CMO: stimulus functioning as CMO	Effect size [Tau-U, significance (2-tailed *p* value), 90% confidence intervals]
38. Rodriguez et al. (2017)	Wilson (8 years, male, PDD-NOS) Cooper (4 years, male, autistic disorder) Sylvie (6 years, female, autistic disorder)	Percentage of trials with correct responses during incapable trials (Try + "Help.") and capable trials (Try + No "Help.")	Concurrent multiple probe design across sets for all participants except Wilson (nonconcurrent multiple baseline design across sets)	Mand for help	Providing a task a child cannot complete independently/ providing less items needed for an activity/ placing an item out of reach	CMO-T: an incapable task/the presence of items for an activity/the sight of an item	Wilson: Tau-U = .50, p = .027, 90% CI [0.13, 0.87] Cooper: Tau-U = .77, $p <$ .001, 90% CI [0.47, 1] Sylvie: Tau-U = .61, $p <$ .001, 90% CI [0.32, 0.89]
39. Roy-Wsiaki et al. (2010)	Child (5 years, male, autism)	Percentage of correct independent mand responses	Modified multiple baseline design across settings	Mand for information using "What?"	1. hiding an item 2. withholding an item needed to complete an activity 3. providing an insufficient amount of item 4. hiding an item	1. CMO-T: the sight of an item 2. CMO-T: a completion of an activity with the exception of the missing item 3. CMO-T: the presence of items needed to begin an activity *mand training was conducted in 1, 2, 3	Child: Tau-U = .46, p = .161, 90% CI [−0.08, 1]

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Table 2. (Continued).

Study citation	Participant characteristics	Dependent variable	Study design	Type of mand	MO manipulation procedure	Type of CMO: stimulus functioning as CMO	Effect size [Tau-U, significance (2-tailed p value), 90% confidence intervals]
40. Shih et al. (2021)	Wang (10 years, male, ASD) Lin (12 years, male, ASD) Chen (9 years, male, ASD)	Frequency of spontaneous requests	Multiple-probe baseline design across participants	Mand for help	1. terminating a mouse cursor operation 2. terminating a video	1. CMO-T: access to a computer game 2. CMO-T: the sight of a cartoon video	Wang: Tau-U = .97, $p <$ .001, 90% CI [0.45, 1] Lin: Tau-U = 1, $p < .001$, 90% CI [0.58, 1] Chen: Tau-U = 1, $p < .001$, 90% CI [0.64, 1]
41. Shillingsburg, Bowen, and Valentino (2014)	Josh (7 years, male, autism) Doug (3 years, male, autism)	Cumulative frequency of independent mands across EO-present and EO-absent conditions	Alternating treatment design/ nonconcurrent multiple-baseline design across participants	Mand for information using "How?" /"How do I do it?"	Providing a preferred activity that cannot be completed independently	CMO-T: an unknown task	Josh: Tau-U = .36, $p =$ .300, 90% CI [−0.21, 0.93] Doug: Tau-U = .20, $p =$ .178, 90% CI [−0.05, 0.45]

(*Continued*)

Table 2. (Continued).

Study citation	Participant characteristics	Dependent variable	Study design	Type of mand	MO manipulation procedure	Type of CMO: stimulus functioning as CMO	Effect size [Tau-U, significance (2-tailed *p* value), 90% confidence intervals]
42. Shillingsburg, Bowen, Valantino, et al. (2014)	Ian (12.33 years, male, autism) Jeb (8 years, male, autism) Jen (6.08 years, male, partial fetal alcohol syndrome/ PDD-NOS)	Cumulative frequency of correct independent mands for information during EO and AO conditions	Adapted alternating treatments design/ nonconcurrent multiple baseline design across participants	Mands for information using "Which?" and "Who?"	Which: presenting a vocal statement Who: presenting a vocal statement	CMO-T (Which): a vocal statement (e. g., "You can have a Skittle. It's under one of these cups.") CMO-T (Who): a vocal statement (e. g., "One of your therapists has your chip.")	Ian: Tau-U = .66, p = .011, 90% CI [0.23, 1] Jeb: Tau-U = .77, p = .003, 90% CI [0.35, 1] Jen: Tau-U = .79, $p <$ .001, 90% CI [0.47, 1]
43. Shillingsburg et al. (2018)	Cooper (6 years, male, ASD) Gerald (6 years, male, ASD)	Cumulative frequency of social questions and correct intraverbals across conditions	Adapted alternating treatment design	Mand for social information (e. g., "What do you like to eat?")	Asking a question about others	CMO-T: a question about others (e.g., "What does Sarah like to eat?")	Cooper: Tau-U = .35, p = .311, 90% CI [−0.22, 0.91] Gerald: Tau-U = .44, p = .097, 90% CI [0.00, 0.89]

(*Continued*)

Table 2. (Continued).

Study citation	Participant characteristics	Dependent variable	Study design	Type of mand	MO manipulation procedure	Type of CMO: stimulus functioning as CMO	Effect size [Tau-U, significance (2-tailed *p* value), 90% confidence intervals]
44. Shillingsburg et al. (2016)	Sarah (6.08 years, female, autism) Zack (6 years, male, autism) Danny (3.58 years, male, autism) Brian (6.17 years, male, autism)	Phase1: cumulative frequency of "Who?" responses during EO and AO conditions Phase2: cumulative frequency of correct independent re-statements of the initial mand for the item	Phase1: adapted alternating treatments design embedded within a nonconcurrent multiple baseline design across the participants Phase2: multiple baseline design across the participants	Mand for information using "Who?"/ "Who has it?"/ "Who has (the name of the item)?"	Presenting a vocal statement	CMO-T: a vocal statement (e.g., "Someone in the room has your toy.")	Sarah: Tau-U = .67, p = .004, 90% CI [0.29, 1] Zack: Tau-U = .53, p = .034, 90% CI [0.12, 0.93] Danny: Tau-U = .72, p=.007, 90% CI [0.28, 1] Brian: Tau-U = .57, p = .116, 90% CI [−0.03, 1]
45. Shillingsburg et al. (2019)	Justin (6 years, male, ASD) Emma (7 years, female, ASD) Bruce (3 years, male, ASD)	Cumulative frequency of mands	Nonconcurrent multiple baseline across participants	Mand for information using "Which cup?" or "Who has it?"	Which: presenting a vocal statement Who: presenting a vocal statement	CMO-T (Which): a vocal statement (e.g., "It's under one of the cups.") CMO-T (Who): a vocal statement (e.g., "One of your teachers has it.")	Justin: Tau-U = .83, p < .001, 90% CI [0.49, 1] Emma: Tau-U = .60, p = .027, 90% CI [0.16, 1] Bruce: Tau-U = .86, p < .001, 90% CI [0.45, 1]

(*Continued*)

Table 2. (Continued).

Study citation	Participant characteristics	Dependent variable	Study design	Type of mand	MO manipulation procedure	Type of CMO: stimulus functioning as CMO	Effect size [Tau-U, significance (2-tailed *p* value), 90% confidence intervals]
46. Shillingsburg et al. (2013)	Tommy (4 years, male, autism) Josh (3 years, male, autism) Abby (4 years, female, autism) Jenny (5 years, female, PDD-NOS/partial fetal alcohol syndrome) Julian (8 years, male, autism)	Cumulative frequency of correct independent mands	Adapted alternating treatments design/ nonconcurrent multiple baseline design across participants	Mand for the removal of an obstruction (i.e., "Move please." or "Excuse me.")	Placing an object to obstruct a child's view	CMO-T: the sight of the TV or a computer screen	Tommy: Tau-U = .50, p = .163, 90% CI [−0.09, 1] Josh: Tau-U = .90, p = .023, 90% CI [0.25, 1] Abby: Tau-U = .60, p = .015, 90% CI [0.19, 1] Jenny: Tau-U = .70, p = .001, 90% CI [0.35, 1] Julian: Tau-U = .79, p < .001, 90% CI [0.43, 1]
47. Shillingsburg and Valentino (2011)	Samuel (7.67 years, male, autism)	Cumulative frequency of independent mands	Multiple baseline design across "How" scenarios	Mand for information using "How?" "How do I do it?"	Interrupting an ongoing activity or response	CMO-T: the sight of an item or an activity	Samuel: Tau-U = .44, p = .204, 90% CI [−0.13, 1]

(*Continued*)

Table 2. (Continued).

Study citation	Participant characteristics	Dependent variable	Study design	Type of mand	MO manipulation procedure	Type of CMO: stimulus functioning as CMO	Effect size [Tau-U, significance (2-tailed *p* value), 90% confidence intervals]
48. Shillingsburg et al. (2011)	John (7.75 years, male, cerebral palsy/autism) Cameron (11.92 years, male, autism)	Percentage of the appropriate form of the mand	Multiple probe across ''Wh'' questions design	Mand for information using using "Who" "Which?" "When?" "Where?"	Who/Which: presenting a vocal statement When: presenting an unavailability statement Where: hiding an item from view	CMO-T (Who/Which): a vocal statement (e.g., "Someone took your mouse"./"One of my hands has a surprise for you".) CMO-T (When): an availability statement ("We are going to play trains, but not right now".) CMO-T (Where): the sight of a box without a snack	John: Tau-U = .79, $p <$ .001, 90% CI [0.55, 1] Cameron: Tau-U = .78, $p <$ .001, 90% CI [0.58, 0.99]
49. Sidener et al. (2010)	Ezra (4 years, male, autism)	Number of sessions to criterion	Adapted alternating treatments design	Mand for an item	Hiding a toy in an opaque bag	CMO-T: the sight of an item in an opaque bag	Not applicable (baseline data is not graphically displayed)
50. Sigafoos et al. (2013)	Sean (5 years, male, autism) Marco (4 years, male, autism)	Cumulative frequency of each response (i.e., reaching, hitting, and correct iPad-based requesting)	Multiple baseline across participants design	Mand for continuation of an activity	Interrupting an ongoing play	CMO-T: access to a toy	Sean: Tau-U = .88, $p <$ .001, 90% CI [0.51, 1] Marco: Tau-U = .71, $p <$ .001, 90% CI [0.39, 1]

(*Continued*)

Table 2. (Continued).

Study citation	Participant characteristics	Dependent variable	Study design	Type of mand	MO manipulation procedure	Type of CMO: stimulus functioning as CMO	Effect size [Tau-U, significance (2-tailed *p* value), 90% confidence intervals]
51. Sigafoos and Littlewood (1999)	Kurt (4.67 years, male, autism)	Percentage of correct mand response	A-B design	Mand for continuation of an activity	Interrupting an ongoing play or behaviour	CMO-T: access to a playground equipment	Kurt: Tau-U = .38, p = .313, 90% CI [−0.24, 1]
52. Somers et al. (2014)	Vernon (male, autism) Rob (male, autism) *8 and 9 years	Percentage of correct mand response during Item Present trials, I Want trials, and Where trials	Concurrent multiple baseline across participants	Mand for information using "Where's (item)?"	Where trials: hiding a toy	CMO-T (Where): the sight of an empty container *mand for an item is previously mastered	Vernon: Tau-U = .22, p = .480, 90% CI [−0.30, 0.74] Rob: Tau-U = .20, p = .439, 90% CI [−0.23, 0.63]
53. Sundberg et al. (2002)	Kevin (5 years, male, autism) Billy (6 years, male, autism) Joey (8 years, male, autism)	Experiment 1: percentage of correct mands Experiment 2: correct and incorrect mands	Multiple baseline across settings/a multielement design	1. Mand for information using "Where?" 2. Mand for information using "Where?" "Who?"	1. hiding an item in one of the other two containers 2. presenting a vocal statement	1. CMO-T: the sight of an empty container 2. CMO-T: a vocal statement, "I gave it to a teacher".	Kevin: Tau-U = .72, p = .008, 90% CI [0.27, 1] Billy: Tau-U = .58, p = .032, 90% CI [0.14, 1] Joey: Tau-U = 1, p = .009, 90% CI [0.37, 1]

(*Continued*)

Table 2. (Continued).

Study citation	Participant characteristics	Dependent variable	Study design	Type of mand	MO manipulation procedure	Type of CMO: stimulus functioning as CMO	Effect size [Tau-U, significance (2-tailed *p* value), 90% confidence intervals]
54. Sweeney-Kerwin et al. (2007)	Martin (3 years, male, autism) Jeff (7 years, male, autism)	Frequency of MO-controlled mands	Multiple baseline design across behaviors	Mand for an item	Hiding a preferred edible item from sight	CMO-T: access to a small amount of an item	Martin: Tau-U = .71, $p <$ .001, 90% CI [0.55, 0.87] Jeff: Tau-U = .59, $p <$ .001, 90% CI [0.35, 0.84]
55. Szmacinski et al. (2018)	Bobby (8 years, male, ASD) Carl (7 years, male, ASD)	Cumulative frequency of correct mands	Multiple probe design across stimuli	Mand for an item	Providing a broken item	CMO-T: the sight of a broken item (e.g., a marble is flattened, a straw is split)	Bobby: Tau-U = .11, $p =$ .601, 90% CI [−0.23, 0.45] Carl: Tau-U = .11, $p =$ .534, 90% CI [−0.18, 0.40]
56. Tada and Kato (2005)	Taro (4.83 years, male, ASD/ intellectual disability)	Percentage of on-task behaviour/percentage of occurrences of mand topographies	Multiple baseline design across activities	Mand for an item	Withholding an item needed for an activity	CMO-T: the sight of a pen case	Not applicable (no baseline data)
57. Valentino et al. (2019)	Kipp (6.08 years, male, autism) Dexter (6 years, male, autism) Neil (5.67 years, male, autism)	Percentage of manding for information using "Why?" during EO-present trials and not asking a question that included "Why?" during EO-absent trials	Multielement design/ nonconcurrent multiple baseline design across participants	Mand for information using "Why?"	Putting an object on an experimenter's body/Doing a wheelbarrow across the floor or other activity	CMO-T: the sight of an object placed in an odd location/the sight of the experimenter's peculiar behaviour	Kipp: Tau-U = 1, $p =$ .029, 90% CI [0.25, 1] Dexter: Tau-U = .92, $p <$ .001, 90% CI [0.50, 1] Neil: Tau-U = 1, $p <$ .001, 90% CI [0.55, 1]

(*Continued*)

Table 2. (Continued).

Study citation	Participant characteristics	Dependent variable	Study design	Type of mand	MO manipulation procedure	Type of CMO: stimulus functioning as CMO	Effect size [Tau-U, significance (2-tailed *p* value), 90% confidence intervals]
58. Ward and Shukla Mehta (2019)	Praveen (7 years, male, ASD) Angel (6 years, male, ASD) Daneesha (5 years, female, ASD) Vanessa (5 years, female, ASD)	Frequency of occurrence of a motivating operation controlled mand and multiply controlled mand	Concurrent multiple baseline design across participants	Mand for an item	Hiding a preferred item from sight	CMO-T: access to a preferred item	Praveen: Tau-U = .86, p = .002, 90% CI [0.40, 1] Angel: Tau-U = .90, $p <$ .001, 90% CI [0.59, 1] Daneesha: Tau-U = .57, $p < .001$, 90% CI [0.32, 0.83] Vanessa: Tau-U = .71, $p <$ .001, 90% CI [0.43, 1]
59. Williams et al. (2000)	Ana (4 years, female, autism) Betty (4 years, female, autism)	Frequency of mands	Multiple baseline design across the three response forms	Mand for information using 1. "What's that?" 2. "Can I see it?" 3. "Can I have it?"	1. presenting a comment about an object in a box 2. restricting access to the box 3. restricting access to an object in the box	1. CMO-T: a comment about an object in a box 2. CMO-T: the sight of the box with an object inside 3. CMO-T: the sight of an object in the box	Ana: Tau-U = .69, $p <$ .001, 90% CI [0.39, 1] Betty: Tau-U = .55, p = .002, 90% CI [0.26, 0.84]

(*Continued*)

Table 2. (Continued).

Study citation	Participant characteristics	Dependent variable	Study design	Type of mand	MO manipulation procedure	Type of CMO: stimulus functioning as CMO	Effect size [Tau-U, significance (2-tailed *p* value), 90% confidence intervals]
60. Williams et al. (2003)	Jim (2.75 years, male, autism) Erik (4.42 years, male, autism) Dario (9.33 years, male, autism)	Frequency of mands	Multiple baseline design across the three response forms	Mand for information using 1. "What's in the box?" or"What's that?" 2. "Can I see it?" 3. "Can I have it?"	1. presenting a comment about the object 2. restricting access to the box 3. restricting access to an object in the box	1. CMO-T: a comment about an object in a box 2. CMO-T: the sight of the box with an object inside 3. CMO-T: the sight of an object in the box	Jim: Tau-U = 1, $p < .001$, 90% CI [0.69, 1] Erik: Tau-U = .91, $p < .001$, 90% CI [0.61, 1] Dario: Tau-U = 1, $p < .001$, 90% CI [0.77, 1]
61. Wójcik et al. (2021)	Participant 1 (6.25 years, male, ASD) Participant 2 (6 years, male, ASD) Participant 3 (4.25 years, male, ASD)	Percentage of correct responses	Nonconcurrent multiple-baseline design across participants	Mand for a missing item	Withholding an item needed for a task	CMO-T: the sight of an activity schedule and materials	Participant 1: Tau-U = .26, $p = .118$, 90% CI [−0.01, 0.53] Participant 2: Tau-U = .29, $p = .086$, 90% CI [0.01, 0.58] Participant 3: Tau-U = .53, $p < .001$, 90% CI [0.31, 0.76]

systematic reviews (Carnett et al., 2017; Raulston et al., 2013; Shea et al., 2019). The small number of studies conducted in home settings may reflect the exclusion of mand training conducted within BST studies. More studies should focus on designing mand training in home or community environments to promote generalisation.

Percentage of correct mand responses was the primary DV in 30 studies (49%) (e.g., Kahlow et al., 2019; Marion et al., 2011). Cumulative frequency of correct mand responses was used in 16 studies (26%) (e.g., Lechago et al., 2013; Shillingsburg, Bowen, & Valentino, 2014). The frequency of correct mand responses was used in 11 studies (18%) (e.g., Koegel et al., 1998; Williams et al., 2000). The type of mand response (e.g., full prompt, partial prompt, independent response) was used in three studies (5%) (Albert et al., 2012; Carnett et al., 2019, 2020). The number of sessions to criterion was used in one study (2%) (Sidener et al., 2010).

Twenty-three studies (38%) used multiple baseline designs across participants (e.g., Betz et al., 2010; Endicott & Higbee, 2007), five studies (8%) used multiple baseline designs across settings (e.g., Marion et al., 2011; Roy-Wsiaki et al., 2010), and five studies (8%) used multiple baseline designs across behaviours (e.g., Albert et al., 2012; Sweeney-Kerwin et al., 2007). Both multiple baseline design across participants and multiple baseline design across setting were used in one study (2%) (Jessel & Ingvarsson, 2021). Ten studies (16%) used a variation of multiple baseline designs such as multiple probe designs (e.g., Choi et al., 2010; Howlett et al., 2011) and multiple baseline across stimulus sets embedded in multiple baseline across participants (Ingvarsson & Hollobaugh, 2010). Alternating treatment designs were used in five studies (8%) (e.g., Bowen et al., 2012; Plavnick & Vitale, 2016). Both multiple baseline design and alternating treatment designs were used in eight studies (13%) (e.g., Shillingsburg et al., 2013; Valentino et al., 2019). Two studies (3%) used an A-B design (Hartman & Klatt, 2005; Sigafoos & Littlewood, 1999). One study (2%) used a reversal design (Duker et al., 1994) and one (2%) a B design (Drash et al., 1999).

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Mands for information were taught in 31 studies (51%) (e.g., Landa et al., 2017; Ostryn & Wolfe, 2011b), mands for items in 15 studies (25%) (e.g., Albert et al., 2012; Lorah et al., 2019). Six studies (10%) included two different mand types: mands for items and information (Jessel & Ingvarsson, 2021; Somers et al., 2014); mands for information and permission (Williams et al., 2000, 2003); mands for items and activities (Duker et al., 1994); mands for items and action (Pistoljevic & Dzanko, 2017). Other types taught included mands for activities (5%) (e.g., Sigafoos & Littlewood, 1999; Sigafoos et al., 2013), action (3%) (Alwell et al., 1989; Carnett et al., 2019), help (3%) (Rodriguez et al., 2017; Shih et al., 2021), rejection or removal of an item (3%) (Choi et al., 2010; Shillingsburg et al., 2013).

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All studies used CMO-Ts in mand training. For example, using the diagrammatic format from Langthorne and McGill (2009), mand training conducted by Albert et al. (2012) with one of their participants is depicted in Figure 2. A behaviour chain such as making toast is interrupted by withholding an item (i.e., a toaster) needed to complete the chain. The initial stimulus change (S1: the sight of open bag of bread) would normally function as an S^D for R1 (putting bread in toaster), but, in the absence of the toaster, it functions as a CMO-T instead and the value of a second stimulus change (S2: access to the toaster) is momentarily increased. This CMO-T evokes a second response (R2) that has been effective in accessing the missing item in the past. Through mand training, Victor (one of Albert et al'.s participants) learned R2 (asking for the toaster) so that he was then in position to complete the behaviour chain and eat the toast.

One study (Hartman & Klatt, 2005) also used another type of MO manipulation procedure that did not fit as clearly with the above description. In their study, one toy from each of a number of preference categories (high to low) was placed in either a 23-hr deprivation condition or a 5-min presession exposure condition prior to mand training. During mand training, one of the participants learned to mand in fewer sessions when toy access had been restricted. While still employing a CMO-T relation, the effectiveness of the CMO-T in evoking manding appears here to have been influenced by toy deprivation/preference in a manner analogous to a UMO relation in which deprivation of the stimulus enhances its reinforcing value (see Figure 3), albeit this is clearly not in this case an unlearned phenomenon. Similar relationships involving deprivation or satiation of other conditioned reinforcers (such as social attention) have been noted by Michael and Miguel (2020) though the type of CMO involved in such relations remains unspecified.

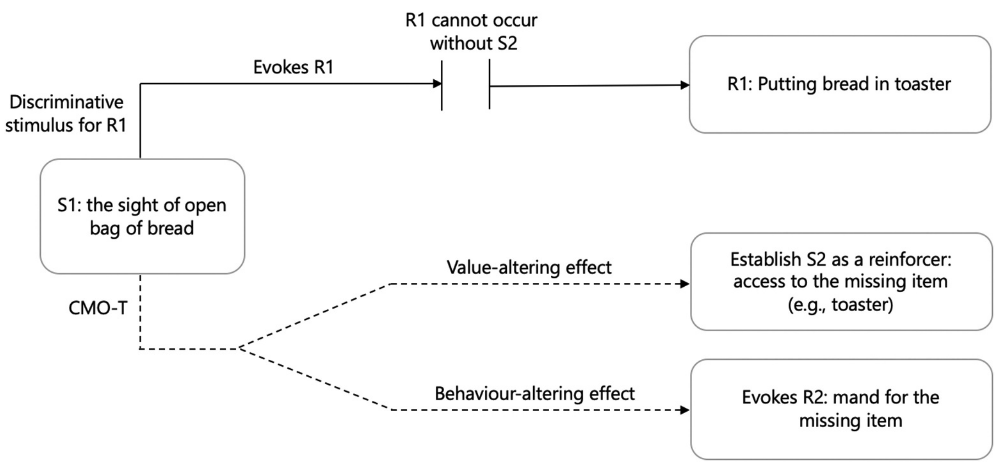

Figure 2. Example of CMO-T role in mand training. Adapted from Albert et al. (2012). S1 = the initial stimulus change; S2 = a second stimulus change; R1 = the initial response; R2 = a second response; CMO-T = transitive conditioned motivating operation

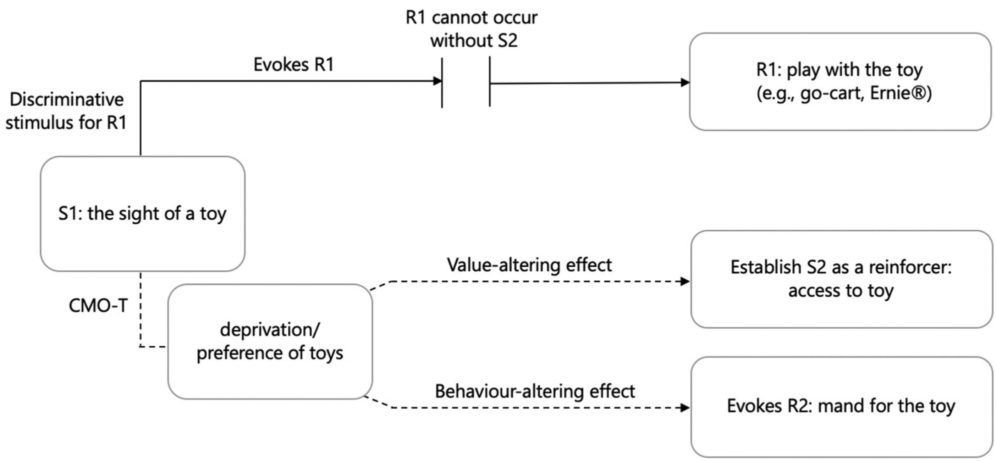

Figure 3. Representation of mand training conducted by Hartman and Klatt (2005). Adapted from Hartman and Klatt (2005). S1 = the initial stimulus change; S2 = a second stimulus change; R1 = the initial response; R2 = a second response; CMO-T = transitive conditioned motivating operation

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Table 3 provides a summary of the procedures used and their frequency. The most commonly used MO manipulation procedure was hiding an item from sight. Stimulus change, such as the sight of an empty container (Howlett et al., 2011), increased the value of information regarding location of the item. Vocal statements or instructions such as "Someone in the room has your toy." or "One of your teachers has it." were also often used in the reviewed studies (e.g., Shillingsburg et al., 2016, 2019) and functioned as

Table 3. MO manipulation procedures used in mand training.

MO manipulation procedure used in mand training	Number of studies	Percentage (number of studies/61)	Study number (see Table 1)
Hiding an item	19	31.1%	3, 11, 13, 14, 17, 18, 19, 27, 28, 29, 30, 31, 39, 48, 49, 52, 53, 54, 58
Presenting a vocal statement or an instruction	14	23.0%	7, 11, 17, 21, 22, 32, 36, 42, 44, 45, 48, 53, 59, 60
Withholding an item needed for an activity	13	21.3%	1, 7, 16, 22, 24, 25, 26, 27, 34, 35, 39, 56, 61
Presenting an unknown task or question	8	13.1%	23, 38, 41 (task) 6, 12, 15, 20, 43 (question)
Interrupting an ongoing activity	8	13.1%	2, 5, 10, 37, 40, 47, 50, 51
Placing an item out of reach or blocking access	8	13.1%	4, 9, 33, 34, 35, 38, 59, 60
Providing insufficient amount of item needed for an activity	4	6.6%	10, 27, 38, 39
Manipulating an item or behaviour	3	4.9%	32, 55, 57
Placing an item to obstruct the child's view	1	1.6%	46
Offering a wrong item	1	1.6%	8
Withholding access to toys for more than 23hrs	1	1.6%	13

→ MO = motivating operation

CMO-Ts for manding for information. Unavailability statements (e.g., “Not right now”.) also evoked mands for information. In studies using BCIS procedures, the last step before being interrupted in a behaviour chain functioned as a CMO-T for manding for the missing item needed to complete an activity. Providing tasks that children cannot complete independently evoked mand responses such as “How?” (e.g., Lechago et al., 2013) or “Help.” (Rodriguez et al., 2017). Similar to unknown tasks, unknown questions functioned as CMO-Ts for manding for information such as “I do not know, please tell me.” (Carnett & Ingvarsson, 2016; Ingvarsson & Hollobaugh, 2010). Ongoing activities and responses were interrupted in various ways: turning a keyboard off when playing (Roberts-Pennell & Sigafoos, 1999), holding the preferred item up when the child reached for the item (Bowen et al., 2012), placing an object to restrict the child’s view when watching a movie (Shillingsburg et al., 2013), or providing only one quarter/half of the item needed for an activity (Duker et al., 1994). In addition, the sight of unusual events (Patil et al., 2021), a broken item (Szmacinski et al., 2018), and an experimenter’s peculiar behaviour (Valentino et al., 2019) functioned as CMO-Ts and evoked mands for the item or information using “Why?”.

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Effect sizes (Tau-U scores) were individually calculated for 151 participants from 57 studies. To evaluate the effectiveness of mand training, independent mand responses during baseline and intervention (or post-training) phases were compared. Seven participants from four studies (Drash et al., 1999; Hartman & Klatt, 2005; Sidener et al., 2010; Tada & Kato, 2005) were excluded from the calculation due to being unable to extract their graphical baseline data from the published articles nor obtain raw data from the

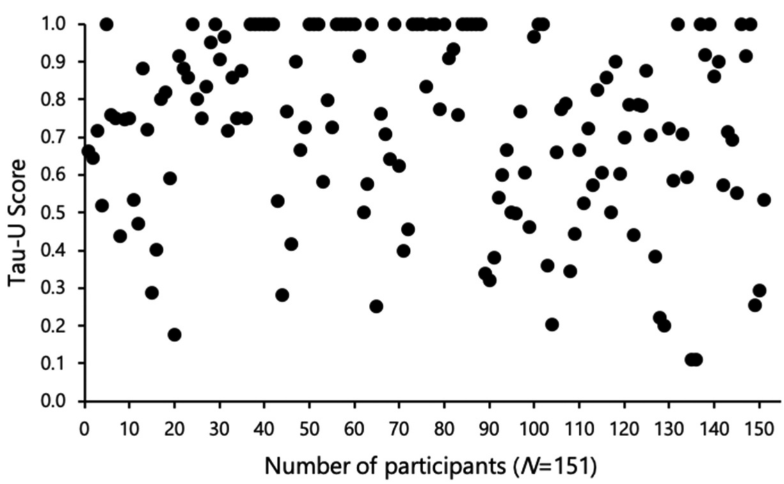

Figure 4. Tau-U effect sizes for participants in mand training. Each dot represents the effect size for one participant. Participant number 1 is the first participant of study 1 (i.e., Victor) shown in Table 2. Tau-U scores ranged from 0 to 1. Four studies (Jessel & Ingvarsson, 2021; Lechago et al., 2010, 2013; Pistoljevic & Dzanko, 2017) did not include graphical data during mand training, therefore a baseline was compared with a post-training phase.

Table 4. Number of participants and effect sizes for each MO manipulation procedure

MO manipulation procedure	Number of participants with weak effect size	Percenage of weak effect size	Number of participants with medium effect size	Percentage of medium effect size	Number of participants with strong effect size	Percentage of strong effect size	Mean (SD) effect size
Hiding an item from view	11	24%	20	43%	15	33%	0.78 (0.22)
Presenting a vocal statement or an instruction	8	20%	24	59%	9	22%	0.78 (0.17)
Withholding an item needed for an activity	14	41%	8	24%	12	26%	0.70 (0.27)
Presenting an unknown task or question	10	48%	8	38%	3	14%	0.65 (0.24)
Interrupting an ongoing activity	6	50%	3	25%	3	25%	0.68 (0.22)
Placing an item out of reach or blocking access	8	40%	5	25%	7	20%	0.73 (0.25)
Providing insufficient amount of item needed for an activity	5	63%	3	38%	0	0%	0.53 (0.21)
Manipulating an item or behaviour	2	25%	2	25%	4	50%	0.75 (0.37)
Placing an item to obstruct the child's view	2	40%	3	60%	0	0%	0.70 (0.14)
Offering a wrong item	1	33%	2	67%	0	0%	0.74 (0.10)
All procedures	67	35%	78	41%	47	24%	0.72 (0.24)

→ MO = motivating operation; SD = standard deviation
When more than one MO manipulation procedures was applied, participants were included for both categories

researchers. Figure 4 shows the range of Tau-U scores across participants. Mand training had strong effects in 41 participants (27%), medium effects in 59 participants (39%), and weak effects in 51 participants (34%). Regarding the association between the methodological quality of studies and effect sizes, the five studies categorised as having a strong quality had medium to strong effects on the acquisition of mand responses, whereas studies categorised as having a weak quality included participants with all ranges from weak to strong effect sizes.

Table 4 shows variations in effect sizes between different procedures. "Hiding an item from view" and "Presenting a vocal statement or an instruction" had the highest mean effect sizes of .78 while that for "Providing insufficient amount of item needed for an activity" had the lowest at .53. Interpretation of these differences is problematic; however, both because there is partial overlap of participants across procedures and because some procedures have been used for far larger numbers of participants.

Discussion

The aims of the review were to identify the types of CMO used in mand training for children with ASD, stimuli functioning as CMOs in the MO manipulation procedures, and the effects of MO manipulation procedures on the acquisition of new mand responses. A total of 61 studies using MO manipulation procedures to teach mands to children with ASD were identified and summarised. All studies used CMO-Ts in mand training and various stimuli functioned as CMOs, the most commonly used MO manipulation procedure being hiding an item from view to evoke mands for the hidden item or information regarding location of the item. One study (Hartman & Klatt, 2005) used an additional MO manipulation procedure involving variations in prior access to and preference for the hidden items. Overall, the included studies reported positive outcomes with effect sizes showing that mand training using CMOs had medium to strong effects in 66% of the participants in increasing their independent mand responses. The results of this review suggest that MO manipulation procedures used in mand training are empirically supported and effective for teaching mand skills to children with ASD.

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All the reviewed studies used CMO-Ts in mand training. A stimulus classified as a CMO-T in each study increased the value of another stimulus as a type of reinforcer. The second stimulus could not be obtained until the correct mand response had occurred. While this finding is consistent with previous research that suggested the role of CMO-Ts in mand training (e.g., Carbone, 2013; Carnett et al., 2017; Langthorne & McGill, 2009) it is, arguably, rather trivial and will be unsurprising to researchers and practitioners in this field. However, it may prompt consideration of the possible role of other CMO subtypes in mand training. For example, might it be possible to pair a neutral stimulus with a CMO-T so that the former becomes a CMO-S? Such a procedure could aim at the development of a CMO-S that can act as a generalised substitute for more specific CMO-Ts, helping to develop more generalised manding skills in children with ASD. For instance, in a study conducted by Endicott and Higbee (2007), participants were taken out of the instructional cubicle after they were allowed to briefly access the preferred items. While the participants were out of the cubicle, the preferred items were hidden. Conceivably, if the experimenter said, “Let’s take a break now.” when the participants were taken out of the cubicle, this instruction may become a CMO-S through pairing with the hiding of the item.

Similarly, we could consider the role of CMO-Rs in mand training. Imagine a “warning” stimulus occurring prior to an interruption. In a study conducted by Sigafoos and Littlewood (1999), the participant wiggled and struggled to continue when ongoing play was interrupted. Through repeated mand training, the sight of the experimenter may function as a “warning” stimulus prior to the ongoing activity being interrupted. The learner might then learn to mand to prevent the interruption which would be a potentially advanced social skill – picking up when things are deteriorating and intervening to prevent the deterioration. Further empirical and conceptual research might usefully explore the role of such CMOs in mand training as well as the more general application of the deprivation/preference procedures used by Hartman and Klatt (2005).

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Identifying stimuli functioning as CMOs in the MO manipulation procedures required careful examination of the research. Various stimuli functioned as CMOs and the most commonly used procedure to manipulate MOs was hiding a needed item from sight. Many children with ASD experience difficulties in spontaneously manding for items that are not visible (Sundberg & Michael, 2001), therefore this MO manipulation procedure would be useful to teach them to mand for the hidden item or information regarding location of the item. Another way to teach children to mand for items not in their view was withholding an item needed to complete an activity. In order to implement the procedure successfully, it is essential to evaluate whether children have familiarised themselves with all the steps required in a behaviour chain prior to mand training as well as analysing the value of the terminal reinforcers to ensure that the relevant MOs are in effect (Carnett et al., 2017; Lechago et al., 2013). Interestingly, three studies (Lorah et al., 2014, 2019, 2020) applied the missing item procedure to teach peer manding by allowing only the child's peer access to the missing item. Using such peer mand scenarios could improve not only mand skills of the child but also social skills of the peer, because the peer is required to willingly provide the item upon request in order to reinforce the appropriate mand behaviour of the child (Lorah et al., 2014). In natural settings, it might be more difficult to control a peer's response, therefore mand training should include scenarios in which reinforcers are delivered in a delayed manner (e.g., the peer provides the item after they played with it) or on an intermittent reinforcement schedule (e.g., the peer sometimes rejects the request) to mimic naturally occurring contingencies.

Among the MO manipulation procedures identified in the review, interruption of ongoing activities or withholding preferred items out of reach could strongly enhance the value of the ongoing activities or the preferred items, thus providing children with opportunities to mand for continuation of the activities or access to the items. Such MO manipulation procedures can be relatively easily implemented as they do not require a specific history of conditioning, however it is important to consider two factors when using these procedures: firstly, a child must have a strong motivation even after the interruption occurred; secondly, there is a possible occurrence of challenging behaviour when such MOs are manipulated (Sigafoos & Littlewood, 1999). During mand training, a child is more likely to engage in any behaviour–including challenging behaviour–that has produced the relevant reinforcer in the past (Sundberg, 1993). Children may try to escape from the interruption (Sigafoos & Littlewood, 1999), which would result in discontinuation of mand training. Presenting the interruptions or obstructions might momentarily function as extinction or punishment (Shillingsburg et al., 2013), thus correct mand responses might be maintained by negative reinforcement (i.e., escape from interruption) as well as by positive reinforcement (i.e., continuation of play) (see Sigafoos & Littlewood, 1999, p. 428). Therefore, on some occasions, the MO manipulations involved in mand training can be regarded as being aversive, which may evoke challenging behaviour in the same way as it may be evoked by extinction or punishment contingencies. Researchers and practitioners should carefully design and implement the MO manipulation procedures in mand training to enhance the acquisition of new mand responses and to avoid inadvertently establishing contingencies of aversive control.

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In this review, effect sizes were calculated using the data extracted from published graphs. Mand training using CMOs had medium to strong effects in 66% of the participants in increasing their independent mand responses. Previous systematic reviews on mand training (Carnett et al., 2017; Raulston et al., 2013; Shea et al., 2019) did not calculate effect sizes, therefore the current review provided additional findings. Among the 61 reviewed studies, only one study calculated the percentage of non-overlapping data for each participant (Lorah et al., 2020). Calculating effect sizes as part of research studies would be beneficial in evaluating outcomes and supporting the methodological robustness of the intervention. Furthermore, reviewed studies used different methods to measure independent mand responses (e.g., percentage of responses, frequency of responses, cumulative frequency of responses, type of response). By obtaining effect sizes, researchers can compare studies using different methods to measure the DVs. Future studies should evaluate effect sizes to analyse the improvements achieved by each participant.

We identified that all studies categorised as methodologically strong had medium to strong effects on participants' acquisition of mand responses. Although two MO manipulation procedures (hiding an item from view, presenting a vocal statement or an instruction) were found to be the most effective, it should be noted that the small number of participants for some procedures reduces confidence in the genuineness of the differences between procedures. Considering the importance of teaching a verbal behaviour in the form of mand (Shafer, 1995; Skinner, 1957), it is crucial for practitioners to identify the most appropriate MO manipulation procedures that promote each child's mand repertoire effectively.

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In this review, a systematic methodology using two separate search strategies was adopted in order to include studies using BCIS procedures that did not specify the role of CMOs in mand training. However, 19 additional articles were added from a manual search using three journals (*JABA*, *TAVB, EJOBA*), the reference sections of three systematic review articles (Carnett et al., 2017; Raulston et al., 2013; Shea et al., 2019), and the reference sections of the selected 61 articles. There is a possibility that some relevant articles are still missing from this review. In addition, a systematic review including mand training conducted within the context of FCT and BST studies will be needed to analyse the use of CMOs in mand training comprehensively. The included studies used different terminologies referring to the manipulation of MOs such as *conditioned MOs/EOs*, *contrived MOs/EOs*, *manipulating MOs/EOs, an interrupted behaviour chain procedure, or incidental teaching*. Considering the variety of terms describing functionally the same MO manipulation, it seems important that researchers take a conceptually systematic approach to the description of the conduct of mand training (Baer et al., 1968), which helps the reader to understand the nature of the MO manipulations involved in training procedures. This might also help to ensure that all relevant studies are identified in searches for future reviews.

Assurance of the reliability of the current review might have been enhanced if inter-coder agreement was assessed for all the included studies, rather than a sample, with respect to the application of the inclusion criteria, quality assessment, and identification of stimuli functioning as CMOs. When evaluating effect sizes, the data were extracted from published graphs. The accuracy of the effect sizes could have been increased if the original raw data were obtained from the researchers. The current review focused on the acquisition of new mand responses. Although the majority of the studies included generalisation and/or maintenance phases, these phases were not included for effect size evaluation due to the time required for graphical data extraction. MO manipulation procedures can be used to promote maintenance or generalisation of acquired mand skills and the level of MOs may affect these processes (Fragale et al., 2012; O'Reilly et al., 2012). Further analysis on how to incorporate motivating variables in maintenance and/or generalisation phases would help to identify effective mand training in various natural environments over time.

Evaluation of possible publication bias in the mand training literature was beyond the scope of the current study. It remains possible that the percentage of medium/strong effects reported here is exaggerated because of a failure to publish studies in which mand training produced small or no effects. Future reviews might build on the preliminary guidance provided by Dowdy et al. (2022) for the use of relevant meta-analytic techniques to explore this issue in research using single-case experimental design.

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Availability of data and material (data transparency)

The data that support the findings of this review are available upon request.

Code availability (software application or custom code)

All software used is publicly available.

Ethical approval

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

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