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Associative symmetry: a divide between humans and nonhumans?

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Abstract

Anthropocentrism can bias scientific conclusions. As a case study, we challenge the 40-year-old associative symmetry dogma, supposed to cognitively set apart humans from other species. Out of 37 human studies surveyed, only 3 truly demonstrate symmetry, of which only 1 (on 5 participants) suggests that symmetry is spontaneously formed.

(49 words)

Main text

When researchers study human traits, anthropocentric biases may influence their interpretation of experimental data. In comparative studies notably, if a capacity known (or thought) to exist in humans is looked for in other species, there is a risk of submitting nonhuman results to an overcritical evaluation, when this ability is considered absent *a priori*, while being uncritical of human data, because the ability is assumed to be present. We believe such biases can generate unsubstantiated claims about human uniqueness. We explore here this possibility, taking as example an important cognitive question.

For over forty years in cognitive psychology, there is the commonly-held assumption that upon sequential exposure to two stimuli A and B (hereafter A→B), humans, but not other species, derive the unexperienced reverse relation B→A, *i.e.*, form a symmetrical association A-B after a unidirectional A→B training. This capacity can be called "derived (associative) symmetry" and most current studies acknowledge its specificity to humans, in relation with language (see Box 1).

Lionello-DeNolf has recently critically reviewed 40 studies in non-human animals [1,2], confirming that having thus learned an A→B relation, subjects show extremely limited behavioral evidence of having also formed the B→A relation. No such critical review exists for human data. In the current paper, we examine the methodology of 37 human studies on derived symmetry we are aware of (see the full list of references in Supplementary information, Table 1) and challenge the reality of such cognitive divide.

Bidirectional training

To train sequential stimulus associations, most studies of derived symmetry have used either *matching* (arbitrary Matching-To-Sample) or *pairing* procedures (see Figure 1). If associations formed during A→B exposure are symmetrical, participants subsequently tested in the reverse order should match B to A in matching procedures, or recognize B→A sequences in pairing procedures.

Our reading of the literature reveals a major flaw in 23 human studies (see Table 1), namely a partial – or even full – temporal overlap between A and B during A→B training (see Figure 1). This feature was already present in Sidman and Tailby's paper [3] and has since permeated the human literature. Let us take as example their auditory-visual trials, to illustrate that bias: in this study the As are dictated Greek letters names and the Bs are corresponding printed letters, the auditory sample A is "*repeated at 2-sec*

intervals by a continuous tape loop" and remains "*throughout the trial*" (p. 10). Since participants can repeatedly switch their attention both ways between A and B, they are potentially exposed to both A→B and B→A sequences during training. We therefore argue that *simultaneous* matching and *simultaneous* pairing are invalid tools for testing generalization performance for novel, reverse relations: at best they measure recognition performance for relations to which the participant was exposed during training. In contrast, most nonhuman studies reviewed by Lionello-DeNolf employed *sequential* (also called "delayed") matching, where A and B do not temporally overlap at all (see Figure 1). Regarding the same issue, we identified two other cases of unintended bidirectional exposure (see Supplementary information). In sum, 25 studies must be excluded, in which the reverse B→A relations may have been directly trained rather than derived. From our review, 12 studies are left which involved only *sequential* matching or pairing, *i.e.*, a truly unidirectional A→B exposure.

Instruction biases

Yet, among the remaining 12 studies, 5 included verbal instructions telling participants before training that stimuli in a trial can form a pair regardless of sequential order (hereafter, "pair-encoding" bias). For example, "*If the two stimuli previously presented go together, press the button labelled YES*" ([4], p. 5). Such indications explicitly invited participants to focus on pairing (rather than sequentiality), thereby favoring the encoding of A→B sequences as symmetrical A-B associations. The successful transfers to B→A sequences reported in these studies are thus unsurprising and do not constitute evidence for derived symmetry. No such bias exists in the nonhuman literature, because nonhumans cannot be given verbal instructions. In one additional study, the instructions directly encouraged to make a logical guess based on the previously memorized A→B sequences, suggesting a potential effect of the instructions on symmetry results (see Supplementary information). Finally, two other studies did not report the instructions given and must likewise be excluded from the potential list of valid studies (see Supplementary information). From our initial sample of 37 studies, we are thus left with 4 studies containing neither bidirectional training nor instruction biases: 1 has used sequential pairing [5], 3 have used sequential matching [6–8].

How spontaneous is symmetry?

A comprehensive characterization of symmetry requires to know whether symmetrical associations, if detected, were formed during the initial exposure to A→B pairings, which indicates a spontaneously symmetrical encoding despite sequentiality, or instead emerged following confrontation with the new B→A relations. Performance on the first symmetry trial has particular scientific meaning in this context.

Among the 4 human studies previously retained, only 1 did provide data on individual symmetry trials [8] (overall only 3 studies out of the 37 surveyed did – see Table 1). Two of them [5,6] found up to 17% symmetry errors in the first block but did not report error distribution, which prevents to know whether symmetry was present from the very first trial, *i.e.*, was formed during training, or appeared after a few initial errors, *i.e.*, was secondarily formed. Interestingly, a third study [7] gave evidence of obvious failure to derive symmetry with bilingual pairs of words: out of 24 participants, only 3 reached mastery criterion in the first 40-trial test block while 17 failed to even reach 50% performance. Clearly, for researchers taking the existence of derived symmetry in humans as granted, this study represents a warning signal, together with frequent reports of some participants showing no evidence of symmetry, sometimes even with fully simultaneous A and B stimuli (see Column 2 in Table 1). The remaining study, on only 5 participants, did report individual trial data ([8], see their Figure 6), and correct responses observed on the first symmetry trial speak in favor of spontaneously derived symmetry.

Finally, while nonhuman studies focus on existence, in human studies derived symmetry is often merely a protocol phase towards the final object of interest, equivalence classes. Consequently, symmetry is sometimes tested in blocks of unreinforced B→A trials, repeated until criterion (e.g. up to three repetitions in [4]). Under such conditions, spontaneity is not assessed. Moreover, block repetitions combined with persisting absence of feedback might lead participants to make inferences about the experimenter's expectations, thereby turning a potentially non-symmetrical initial responding into a symmetrical one.

A cognitive divide?

In sum, out of 37 human studies examined, we show that only 4 employed an adequate methodology [5–8]. Among them, a single one, with only five participants, reported data demonstrating spontaneously derived symmetry [8], two reported symmetry that may be secondarily derived [5,6], and one reported an overall failure to derive symmetry [7]. Hence, the general agreement that the ability to spontaneously form symmetrical associations during A→B exposure distinguishes humans from other animals must be put in question. We do not mean to deny that humans ultimately can derive symmetry, but we stress that rigorous investigations are scarce, as is empirical support, and that derived symmetry might not be as prevalent as commonly thought. As of now, the alleged cognitive gap remains merely an hypothesis. We therefore call for 1) new human studies with strict A/B temporal separation, minimal verbal instructions and analysis of individual symmetry trial performance, 2) more comparative studies, using protocols as similar as possible between species, to complement rare attempts (e.g. comparison with macaques and baboons [9], or pigeons [10]).

To conclude, we take this debate as an example of how anthropocentric expectations model the interpretation of scientific data in general, and can distort comparative questions in particular. Here, studies that reported derived symmetry despite their flawed methodology can be considered false positives. Such false positives were easily accepted when derived symmetry was expected (in humans) but strictly rejected [1,2] when it was unexpected (in nonhumans). The present article provides the missing cross-checking between both literatures, thereby advocating for a rigorous equalization of criteria whenever an interspecific cognitive gap is at debate.

(1349 words)

Box 1 : Derived symmetry and the origin of language

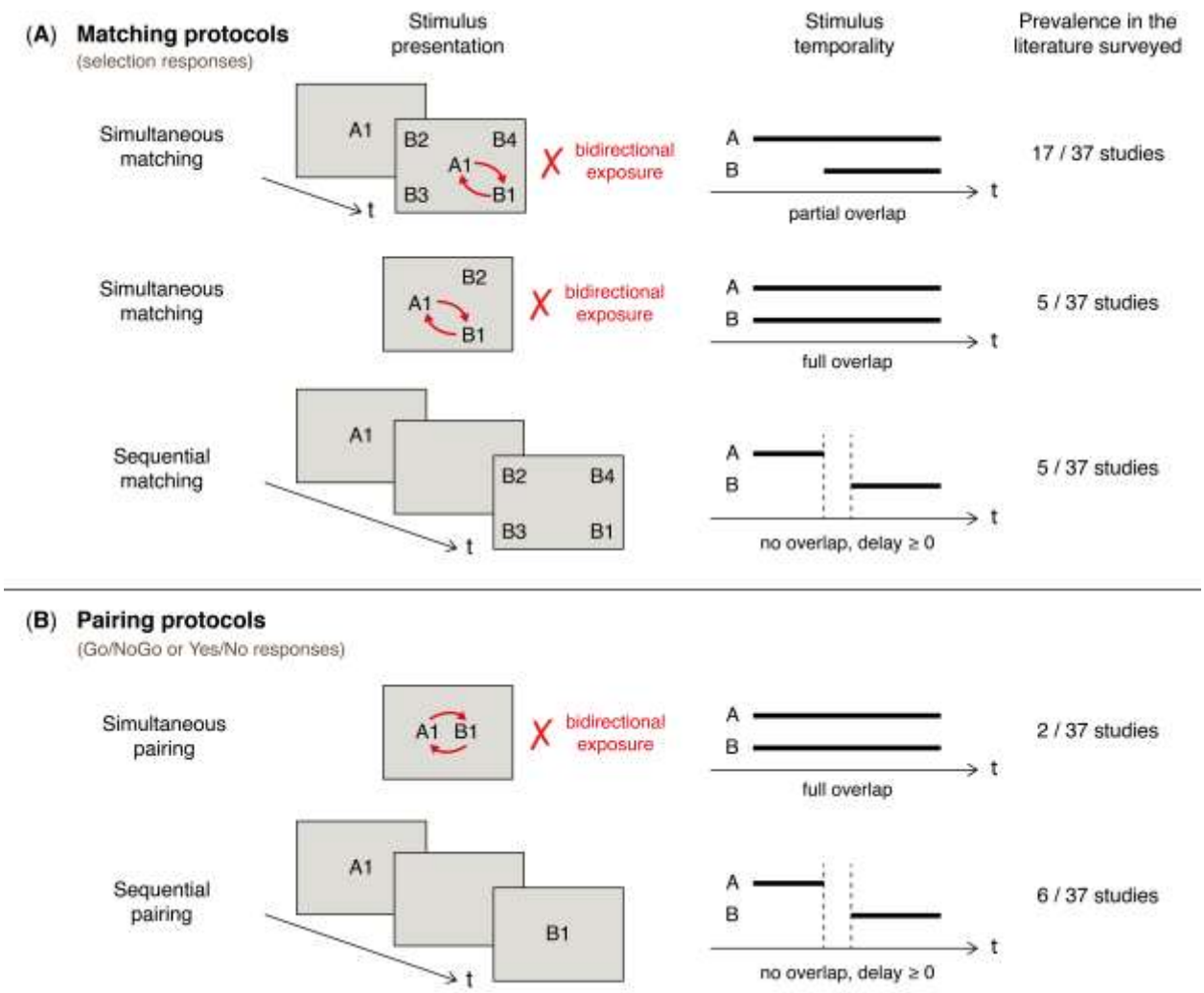
Whether humans and nonhumans spontaneously encode sequential stimulus pairs as "symmetrical" (*i.e.*, form bidirectional stimulus relations) has been actively investigated since Sidman et al.'s 1982 comparative paper [9], which reported success in human children and failure in monkeys – a failure repeatedly confirmed afterwards. In this, and a seminal paper co-authored with Tailby ([3], 2485 citations), Sidman formulated his theory of Stimulus Equivalence: stimuli satisfying three relations of symmetry, reflexivity and transitivity, become functionnaly substitutable. As equivalence mirrors the word-object bidirectional mental relations we build during language learning, the idea that non-humans do not have language because they lack derived symmetry propagated in the field of cognitive psychology.

This is visible in several recent publications, for example: "*we argue that [derived symmetry] is likely to be a cognitive bias unique to humans and that it is a key prerequisite for language learning*" ([11], p.7) or "*together with the abundant evidence that nonhuman animals have difficulties in processing bidirectional associations, [our findings] suggest a clear discontinuity between human and nonhuman behavior, which might be a building block for [...] language development*" ([12], p.4). Here, we call for reconsideration of this dominant view, due to overall poor demonstrations of derived symmetry in humans.

(200 words)

Figure 1. Classical training protocols for studies of derived symmetry.
Training is done with A→B sequences, testing with B→A. In Matching procedures (top panel), participants select among several possibilities the second stimulus correctly associated with the first one. In Pairing procedures (bottom panel), participants make a binary response, Yes/No or Go/NoGo, depending on whether the two stimuli presented are correctly associated. Two further studies described in Supplementary used alternative protocols. Stimuli are generally visual and displayed on screens or cards, but are sometimes auditory. We argue that temporal overlap between A and B invalidates methodology, as it enables bidirectional exposure (red arrows) to both A→B and B→A during training.

(99 words)



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Supplementary information

In this article we have reviewed a total of 37 human studies. Due to space limitation, we mentioned only representative examples in the paper's main body, and provide the full list of references in Table 1 below. Column 1 lists all human studies on derived symmetry we surveyed. Column 2 indicates how many participants were reported with positive symmetry results. Column 3 indicates the type of training protocol used, with reference to Figure 1. Columns 4 and 5 present information on the two criteria we adopted to accept or reject these studies on methodological grounds: 1) were participants potentially exposed to both A→B and B→A sequences during training? 2) did verbal instructions given to participants bias their encoding or their responses towards symmetry? Column 6 indicates the number of symmetry test trials included in the average performance reported in these studies.

Bidirectional training.

The paper's main body mentions two cases of unintended bidirectional exposure, using procedures different from the ones depicted in Figure 1. In the first study [12], involving EEG measurements in 5-month-old human infants, the training protocol combined a too short between-pair interval and a non-randomized presentation of pairs, hence each A was followed *and* preceded repeatedly by its B associate at the same temporal distance. This resulted effectively in a regular alternation of A→B and B→A sequences during training, that is, a bidirectional exposure instead of well-separated A→B sequences. This bias is called "contiguity of A→B sequences" in Table 1 – see [13] for a detailed criticism of this paper, and [14] (p.395) for an example of the same bias identified in the conditioning literature. In the second study [15], the A and B stimuli were not arbitrarily related, but instead were both sides of a computerized playing card. This task representation minimizes sequentiality encoding, because card sides, by nature, have no inherent sequential ordering. The authors commented on this possible configural bias when they suggested that their "*subjects could have considered [A and B] as different aspects of the same stimulus*" (p.46). In our opinion their Experiment 3 failed to address this concern, as their new A and B (a folder and its content) were still facets of a same virtual object. This bias is called "2-faceted object" in Table 1.

Instruction biases.

We identified two different biases in the verbal instructions given to participants. The most common one is when participants are explicitly instructed to pay attention to pairing ("pair encoding" bias, see main text and Table 1). Another one is when participants are informed

that in symmetry trials, there will always be a correct response to be inferred from the training phase. This latter bias was found in study [16] involving a matching procedure: participants were told "*based on what you have learned so far, you can get all of the tasks correct*" (p.182), referring to trials without feedback, *i.e.*, symmetry test trials. When participants of this study were presented with B as first stimulus, their only possible logical guess involved finding back which A had preceded this B during training. Without this piece of information, they might have been unable to decide which stimulus to choose. This experiment thus does not establish that the previously formed A-B association was symmetrical. This bias is called "always-one-correct" in Table 1. Note that two additional studies listed in Table 1 ([17,18]) were excluded from the list of valid studies, because they did not report the instructions given to the participants.

Table 1. List of human studies investigating derived symmetry and surveyed in this article. Red cells indicate methodological invalidity, 'n/a' indicates information unavailable in the articles.

Reference	Number of participants showing derived symmetry	Protocol	Bidirectional training bias	Instruction bias	Number of symmetry trials in average performance
Lazar 1977, [19]	2 / 3	Simultaneous matching	**full A/B overlap**	no bias identified "*Your task is to touch one of the sets and then touch the other with your index finger*" p.384	24
Sidman & Tailby 1982, [3]	6 / 8	Simultaneous matching	**partial A/B overlap**	no bias identified "The experimenter provided nonverbal instruction by pressing windows appropriately for several hue-hue trials" p.11	30
Sidman et al. 1982, [9]	4 / 6	Simultaneous matching	**partial A/B overlap**	no bias identified "The experimenter provided non-vocal instructions by pressing the keys appropriately for several trials" p.34	24

Fields et al. 1990, [20]	7 / 7	Simultaneous matching	**partial A/B overlap**	**Pair encoding** "*Your task is to discover which words go together*" p. 347	28 to 44
Wulfert et al. 1991, Exp. 1, [21]	9 / 10	Simultaneous matching	**partial A/B overlap**	no bias identified "*You will choose either the left or the right symbol*" p.491	10
Fields et al. 1992, [22]	7 /14	Simultaneous matching	**partial A/B overlap**	n/a	16
Bentall et al. 1993, Exp. 1, Group 2, [17]	6 / 6	Simultaneous matching	**full A/B overlap**	n/a	9
Fields et al. 1995, [23]	3 / 12	Simultaneous matching	**partial A/B overlap**	**Pair encoding** "*Your task is to discover which words go together*" p. 131	16
Leader et al. 1996, [24]	8 / 10	Sequential pairing (training) + Simultaneous matching (test)	**partial A/B overlap in test**	no bias identified "*You must choose one of the three nonsense syllables at the bottom*" p.690	60
Smeets et al. 1997, Exp. 1, [25]	6 / 10	Sequential pairing (training) + Simultaneous matching (test)	**partial A/B overlap in test**	no bias identified "*You must choose one of the three nonsense syllables at the bottom*" p.290	8, 16 or 60
Brady & McLean 2000, [26]	4 / 4	Simultaneous matching	**full A/B overlap**	no bias identified "*Find this*" p.205	30

Carr et al. 2000, [27]	4 / 5	Simultaneous matching	**partial A/B overlap**	n/a	10
Leader et al. 2000, [28]	12 / 15	Sequential pairing (training) + Simultaneous matching (test)	**full A/B overlap in test**	no bias identified *"If you see this, point to that*" p. 66, then "the experimenter silently presented the matching card" p.66	16
Rosales-Ruiz et al 2000, [29]	9 / 25	Simultaneous matching	**full A/B overlap**	no bias identified "*Now answer the following 12 problems*" p.179	individual trials reported
Barnes-Holmes et al 2001, [30]	3 / 16	Simultaneous matching	**partial A/B overlap**	no bias identified "*When I wave/clap at you, I want you to pick (A1) or (A2)" p.294* / "[During test] the experimenter remained silent" p.294	8
Barnes-Holmes et al 2001, [31]	4 / 16	Simultaneous matching	**partial A/B overlap**	no bias identified "*When I wave/clap at you, I want you to pick (A1) or (A2)*" p.594 / "[During test] the experimenter remained silent" p.595	8
Debert et al. 2007, [32]	6 / 6	Simultaneous pairing with Go/NoGo	**full A/B overlap**	no bias identified "*Your task is to click […] when you think correct symbols are shown, and not to click when incorrect ones are shown*" p. 91	144
Gómez et al 2007, [33]	2 / 4	Simultaneous matching	**partial A/B overlap**	no bias identified "*When I wave/clap at you, I want you to pick (A1) or (A2)*" p.281 / "[During test] the experimenter remained silent" p.282	8

Schlund et al. 2008, [34]	20 / 20	Simultaneous matching	**partial A/B overlap**	**pair encoding** ”Subjects were instructed that the sample stimulus was 'related' to one of the two comparisons” p.2	n/a
Ogawa et al. 2010, [35]	15 / 15	Simultaneous matching	**partial A/B overlap**	**pair encoding** ”The subjects were asked to choose the comparison figure they thought was related to the sample figure” p.2122	25
Rosales et al 2011, [36]	0 / 4	Simultaneous matching	**partial A/B overlap**	no bias identified “The experimenter present[ed] one stimulus with the instruction *‘What is it?’ ” p.68*	8
Grisante et al. 2013, [37]	14 / 14	Simultaneous pairing with Go/NoGo	**full A/B overlap**	no bias identified *“Your task is to click on this area when the symbols you believe to be correct are displayed and to not to click when the symbols are incorrect*” p.67	96
Navarro & Wasserman 2020, [10]	12 / 12	Simultaneous matching	**partial A/B overlap**	no bias identified *“One of the buttons will be correct for each specific stimulus; the other one will be incorrect. You have to learn to choose the correct one” p.8-9*	4 to 5
Palmer et al. 2021, Exp. 1, [38]	10 / 10	Simultaneous matching	**partial A/B overlap**	n/a	18
Gerolin & Matute 1999, [15]	10 / 10	Second-item prediction	**2-faceted object**	no bias identified *”You will be able to bet on the card before you turn it over. If this particular figure is on the back of the card, you will win*” p.43	individual trials reported
Kabdebon & Dehaene-	group-level only	Sequential pairing	**contiguity of A→B sequences**	none	42

Lambertz 2019, [12]					
Bentall et al. 1993, Exp. 2, Group 2, [17]	6 / 6	Sequential matching	none	n/a	18
Fields et al. 1997, [39]	14 / 17	Sequential pairing with Yes/No	none	**pair encoding** "*discover whether the words go together*" p. 665 "*select the BOTTOM word that goes with the TOP word*" p.671	32
Bentall et al 1999, [18]	20 / 20	Sequential matching	none	n/a	16 or 96
Arntzen et al 2007, [16]	20 / 20	Sequential matching	none	**always-one-correct** "*based on what you have learned so far, you can get all of the tasks correct*" p.182	18
Fields et al. 2021, [4]	11 / 11	Sequential pairing with Yes/No	none	**pair encoding** "*if the two stimuli go together, press the button labelled YES*" p.5	12
Hanson & Miguel 2021, [40]	16 / 16	Sequential pairing with Go/NoGo	none	**pair encoding** "*if you think the first and second word go together, touch the white box*" p.5	24
Howland et al. 2021, [41]	23 / 24	Sequential pairing with Go/NoGo	none	**pair encoding** "*continue touching images that go together*" p.4	16
Zhelezoglo et al. 2021, [42]	8 / 8	Sequential pairing with Go/NoGo	none	**pair encoding** "*touch the white box if the sound goes with the image*" p.5	16

Vaidya & Smith 2006, [7]	3 / 24	Sequential matching	none	no bias identified "All participants were instructed to respond by touching the screen. No other task relevant instructions were presented" p.10	40
Arntzen & Haugland 2012, [8]	5 / 5	Sequential matching	none	no bias identified "*you are supposed to choose one of these. [...] Do your best to get all of them correct*" p.248	individual trials reported
Velasco & Tomanari 2014, [6]	4 / 4	Sequential matching	none	no bias identified "*your task is to select one of those images*" p.5	48
Lantaya et al. 2018, [5]	32 / 32	Sequential pairing with Go/NoGo	none	no bias identified "*if you think that second symbol is correct, touch it*" p.5	24
Imai et al 2021, [11]	23 / 33	Sequential pairing with habituation switch	*not enough details provided*[1]	none	6

[1] This recent comparative study was the only one using the habituation switch paradigm, to compare looking times between familiar and unfamiliar pairs of stimuli in both 8-month-old human infants and adult chimpanzees. Unfortunately, too few details are provided on the timing of pair presentation to verify absence of the "contiguity of A→B sequences" bias identified in [12], a study which presented stimuli in a comparable manner.

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